8-2014

Management of silverleaf whitefly, Bemisia argentifolii bellows and perring (Hemiptera: Aleyrodidae), using non-crop companion plants in organically-managed cantaloupe systems in South Texas

Ruth Renee Colyer
University of Texas-Pan American

Recommended Citation

Colyer, Ruth Renee, "Management of silverleaf whitefly, Bemisia argentifolii bellows and perring (Hemiptera: Aleyrodidae), using non-crop companion plants in organically-managed cantaloupe systems in South Texas" (2014). *Theses and Dissertations - UTB/UTPA*. 959.
https://scholarworks.utrgv.edu/leg_etd/959

MANAGEMENT OF SILVERLEAF WHITEFLY, *Bemisia argentifolii* BELLOWS AND PERRING (HEMIPTERA: ALEYRODIDAE), USING NON-CROP COMPANION PLANTS IN ORGANICALLY-MANAGED CANTALOUPE SYSTEMS IN SOUTH TEXAS

A Thesis

by

RUTH RENEE COLYER

Submitted to the Graduate School of
The University of Texas-Pan American
In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2014

Major Subject: Biology

MANAGEMENT OF SILVERLEAF WHITEFLY, *Bemisia argentifolii* BELLOWS AND PERRING (HEMIPTERA: ALEYRODIDAE), USING NON-CROP COMPANION PLANTS IN ORGANICALLY-MANAGED CANTALOUPE SYSTEMS IN SOUTH TEXAS

A Thesis
by
RUTH RENEE COLYER

COMMITTEE MEMBERS

Dr. Kenneth Rod Summy
Chair of Committee

Dr. Mohamed Farooqui
Committee Member

Dr. Andrew McDonald
Committee Member

August 2014

ABSTRACT

Colyer, Ruth Renee., Management of Silverleaf Whitefly, *Bemisia argentifolii* Bellows and Perring (Hemiptera: Aleyrodidae), Using Non-crop Companion Plants in Organically-Managed Cantaloupe Systems in South Texas. Master of Science (MS), August, 2014, 65 pp., 10 tables, 13 illustrations, references, 68 titles.

Field trials in three separate phases of research were carried out from March, 2010, to August, 2012, to determine the effects of inter-cropping cantaloupe (*Cucumis melo* var. *inodorus*) with select non-crop companion plants in an effort to develop organic production strategies for melons in South Texas without the use of pesticides. A research program was designed and initiated to assess the effects of the companion plants and their ability to: 1) attract insect pollinators, and 2) repel or suppress pest species without affecting beneficial natural enemy complexes. The hypotheses were: 1) that organically-managed cantaloupe systems grown with non-crop companion plants would support a greater level of agro-biodiversity to avoid reliance on agro-chemical interventions, and 2) that the yellow French marigolds foster an environmentally safe, effective, natural, and economical means of pest repellency relative to agrochemical intervention. Results from all three phases conclusively demonstrated whitely repellency by yellow French marigold.

DEDICATION

This thesis is dedicated with love to my parents, Raymond and Gloria, and my children, Maegan, Joshua, and Casey.

Philippians 4:13

ACKNOWLEDGEMENTS

Sincerest appreciation and gratitude is extended to my thesis advisory committee members at The University of Texas-Pan American: Dr. Kenneth Rod Summy, Department of Biology, Chairman of Advisory Committee, and Drs. Mohamed Farooqui and Andrew McDonald, also of the Department of Biology. Without the guidance and support of these members, this project would never have materialized.

Sincere appreciation is additionally extended to the following for their material and professional contributions to this project: Drs. John Goolsby and Alex Racelis, Ann Vacek and Crystal Salinas, USDA/ARS Subtropical Research Laboratory at Weslaco and Mission Moore Air Base Quarantine Lab.

I never truly realized how much was accomplished in this project until I wrote this paper. I understand now why during our meetings Drs. Summy and McDonald never agreed on proposed experimental designs, the variables to be studied in and within those designs, and the respective statistics involved; why my parents wondered why I ever wanted to become a scientist, despite their belief in the pursuit of dreams; and why my children wanted a new mother after all the work was done! This project was complex and labor-intensive and would have never happened had it not been for the support and sacrifices made of my committee members, family, friends and beloved children, Maegan, Joshua, and Casey.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Man's preoccupations with an adequate supply of food and the pests that interfere with the production of that food have been of fundamental importance since earliest times. In this project, native and exotic non-crop companion plants were intercropped with organically-grown cantaloupe (*Cucumis melo* var. *inodorus*) in an effort to study the interactions between companion plants, target melon pests, and the overall effects of each on organically-managed cantaloupe production in South Texas.

Organic farming systems are the wave of the future (Lammerts van Bueren *et al.,* 2002). Because of the long-term detrimental effects of pesticides on the environment, wildlife, pet health, and human health, avoidance of pesticide use is the eventual goal for future farming systems in the United States (Lammerts van Bueren *et al.,* 2002). Organic gardeners are, therefore, prohibited from using readily available synthetic insecticides (inorganic fertilizers and chemical inputs) to control crop arthropod pests and reduce economic losses as a result of pest infestations. Direct and indirect exposures to pesticides are particularly hazardous to human health and are oftentimes fatal. More specifically, use of pesticides does not solve pest problems (Cox, 2006) and may exacerbate emergence of secondary pest outbreaks (Pimentel and Levitan, 1986; Leigh, Roach, and Watson, 1996). For these reasons, organically-managed cantaloupe production was the only option for this project.

The concept of "organic" is based on the premise that insect problems are commonly manifested on weaker plants. One of the logical goals of organic farming, therefore, is to strive for stronger plants. According to the principals of organic farming, stronger plants are achieved through agro-ecosystem manipulation, which begins with organic soil fertility management to increase agro-biodiversity (Lammerts van Bueren *et al.,* 2002). Agro-ecosystem manipulation additionally takes into account the concept of organic naturalness, which revolves around the non-chemical, agro-ecological, and integrity approaches (Lammerts Van Bueren *et al*., 2004; Ammann, 2008), as well as the principals of crop rotation (Leigh, Roach, and Watson, 1996; Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009) and varietal selection (Murphy *et al.*, 2007). This project began with organic soil fertility management and complied throughout with principals of biological control (Collier and Van Steenwyk, 2004; Macfadyen *et al*., 2009), cultural control, mechanical control, and organic naturalness to ensure consistent organically-managed cantaloupe production.

Target melon pests in South Texas include various ant species, melon aphids (*Aphis gossypii)*, and whiteflies *(Bemisia argentifolii* B biotype). According to the Crop Profile for Cantaloupes and Honeydew Melons in Texas (2009), whiteflies are the most damaging cantaloupe pest, with an estimated 75% yield loss from uncontrolled whitefly infestations. Currently, melon growers in affected areas of Texas, namely South Texas, rely upon conventional farming practices to keep whitefly populations below the threshold level required to permit profitable cantaloupe production. The problem is that such grower management practices involve chemical inputs of more than a dozen different synthetic pesticides during any given growing season (Leigh, Roach, and Watson, 1996; Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). It is reported in the literature, however, that whiteflies are resistant to pesticides (Leigh, Roach, and Watson, 1996; Jones *et al.*, 2008; USDA/ARS, 2008). Aside from their natural resistance to pesticides, the distribution of whitefly within the plant canopy on the underside of the leaves in conjunction with their high reproductive potential (adult whiteflies mate within one to two days of emergence from the egg) attribute to the ineffectiveness of controlling the pest with conventional spray application methods (Leigh, Roach, and Watson, 1996).

In the studies defined in this application, cost-effective exotic and native non-crop companion plants that were intercropped with organically-managed melon plants were selected based on their ability to attract insect pollinators, which are critical for melon production, and/or to repel or suppress ants, aphids, and whiteflies without affecting natural enemy complexes (Kuepper and Dodson, 2001). The hypotheses were: 1) that organically-managed cantaloupe systems grown with non-crop companion plants would support a greater level of agro-biodiversity to avoid reliance on agro-chemical interventions, and 2) that one specific non-crop companion plant, the yellow French marigold, would foster an environmentally safe, effective, natural, and economical means of pest repellency relative to agrochemical intervention.

Ant, aphid, and nymph and adult whitefly densities were analyzed and compared between garden plots consisting of melon plants and the companion plants. The chosen non-crop companion plants included zinnias (*Zinnia elegans*) and dill *(Anethum graveolens),* which have been reported to attract pollinators, such as bees, wasps, and syrphid flies (Kuepper and Dodson, 2001). It is reported that dill additionally repels aphids (Kuepper and Dodson, 2001). French marigolds *(Tagetes patula)* are known to repel whiteflies (Nivsarkar *et al.,* 2001; Trinklein, 2010), and native Texas sage *(Leucophyllum frutescens)* is said to repel ants (Kuepper and Dodson, 2001).

This project occurred in three phases following a preliminary study began in June of 2010 and ended abruptly in August, 2010, as a result of flooding from Hurricane Alex and Tropical Depression 2. Replication of this study was scheduled for the following summer growing season, however, it was not successful as a result of the worst drought in Texas history, the drought of 2011. The Phase I Block Study commenced in March, 2012, and continued until June, 2012. The Phase II Olfactometry Study began shortly after the Phase I study in June of 2012 and ended in early July of 2012. The Phase III Pot Study began in August, 2012. During Phases I and III, integrated pest management methodologies - biological, cultural, conservation, allelopathic, and mechanical control strategies - were employed to sustain organically-managed cantaloupe systems (Way and van Emden, 2000) in an effort to support a greater level of agro-biodiversity to 1) avoid reliance on agro-chemical interventions and 2) increase natural enemy complexes to control target pest infestations.

During Phase III, emphasis was placed on the effectiveness of bright yellow French marigolds to repel whiteflies. Marigolds synthesize a phototoxic allelochemical called ά-terthienyl that functions as a broad-spectrum biocide (Nivsarkar *et al.,* 2001; Trinklein, 2010). This peculiar biocide adversely affects target organisms, including plant enemies, e.g. disease-causing plant pathogens, parasitic nematodes, herbivorous insects, and competing plant species. Unlike pesticides, target organisms do not develop resistance to allelochemicals (Narwal *et al.,* 2005), the implication being that whiteflies would not develop resistance to ά-terthienyl, the phototoxic allelochemical found in French marigolds. The expectation of the Phase III experiment was, therefore, to observe continuous whitefly repellency by French marigolds.

The specific aims of the studies explained in this application were geared towards the development of organic production strategies for cantaloupes in South Texas without reliance upon agro-chemical interventions. The research goals set forth for this project included:

1) Studying the interactions between companion plants and select insect arthropods and the overall effects of each on cantaloupe production in South Texas.

2) Incorporation of integrated pest management methodologies for the development of organic production strategies of melons in South Texas without agro-chemical intervention.

3) Assessing the ability of select cost-effective exotic and native non-crop companion plants to sustain organically-managed cantaloupe systems by effectively attracting insect pollinators and repelling or suppressing insect pests (whiteflies, aphids, and ants) without affecting beneficial natural enemy complexes.

CHAPTER II

REVIEW OF LITERATURE

Significance of Organic Farming Systems

Organic farming systems are the wave of the future (Lammerts van Bueren *et al.,* 2002). An organic farming system is defined as a philosophy of a natural sustainable farming system characterized by avoidance of agro-chemical intervention and reliance of agro-ecosystem biodiversity (Lammerts van Bueren *et al.,* 2002) to suppress, reduce, or control insect pests and increase product yield, quality, and stability. In general, organically-managed systems depend upon a greater level of agro-biodiversity and the activities of sufficient numbers of naturally occurring predators, parasitoids, and pathogens. Organic gardeners are prohibited from using readily available synthetic insecticides to control crop arthropod pests and reduce economic losses resulting from pest infestations.

The concept of “organic” is based on the premise that insect problems are commonly manifested on weaker plants. One of the logical goals of an organic farming system, therefore, is to manipulate an agro-ecosystem in ways that will result in the production of stronger plants. In an organic farming system, agro-ecosystem manipulation begins with organic soil fertility management (Lammerts van Bueren *et al.,* 2002). Adequately prepared soil facilitates growth of strong, healthy plants which will be more resistant to damage from insect pest infestations.

Organic agriculture takes into account the concept of organic naturalness. Recognized by the world umbrella organization for organic agriculture, IFOAM (International Federation of Organic Agriculture Movements), the concept of organic naturalness revolves around the non-chemical, agro-ecological, and integrity approaches (Lammerts Van Bueren *et al*., 2004; Ammann, 2008). The non-chemical approach implies that no chemicals (inorganic fertilizers and chemical pesticides) and no transgenic modifications (GMOs) are to be used in an organic farming system (Lammerts Van Bueren *et al*., 2004). The agro-ecological approach maintains that organic farmers respond to the conditions of a sound ecosystem through biodiversity and perform agricultural activities that integrate with nature (Lammerts Van Bueren *et al*., 2004; Ammann, 2008). The integrity approach takes into consideration that all living organisms are whole, are complete, have species-specific characteristics, and are in balance with a species-specific environment because all living organisms have more than just extrinsic value to mankind (Lammerts Van Bueren *et al*., 2004; Ammann, 2008). In general, organic agriculture does not rely on agro-chemical intervention because such intervention violates the integrity approach. Compliance with all three approaches in the concept of organic naturalness was adhered to for the duration of this project.

Ramifications of Pesticide Use

The simplicity of pesticide use is in the literal meaning of the term "pesticide" – *"pest-killer"*. A pesticide is, therefore, something that kills "pests", and a "pest" is anything that a human says is "unwelcome" regardless of taxonomic lines (EPA, 1999). Because of the inherent diversity in human perception, the term additionally does not mean the same from one person to another, much less from one locality to another. The legal definition of "pesticide", according to the Federal Insecticide, Fungicide, and Rodenticide Act 1947 (FIFRA), is “any substance or mixture of substances intended for pesticidal purpose…”(EPA, 1999). FIFRA states that “an organism is declared a pest under circumstances that make it deleterious to man or the environment” (EPA, 1999). Pesticides are intentionally designed to be toxic to target pests, e.g. weeds, rodents, bacteria, insects, and fungi, but can be toxic to unintended targets as well.

Most pesticides generally leave a persistent residue (NCAP, 2010), a build-up of which is detrimental to the global environment, wildlife, pet health, and human health. It has long been known that direct and indirect exposures to pesticides are particularly hazardous to human health and are oftentimes fatal. Approximately 30 commonly used pesticides are associated with reproductive and birth defects, kidney, liver and lung damage, nerve and nervous system damage, genetic defects, and cancer (Cox, 2006). Chemical build-up from excess pesticide use remains in human body tissues and vital organs, and children are more susceptible to toxic effects of pesticides (Alliance for Healthy Homes Website; Zahm and Ward, 1998). There is a higher incidence of leukemia, brain cancer, and birth defects in children repeatedly exposed to pesticides (Zahm and Ward, 1998).

During the 1980’s, an estimated 350 million kg of agricultural pesticides were used annually in the United States (Pimentel and Levitan, 1986). According to a pesticides usage report published by the Environmental Protection Agency (EPA) in 2011, agricultural pesticide use was down, from 948 million pounds in 2000 to 877 million pounds in 2007. Approximately 33 million pounds of organophosphates, which are neurotoxins that are still detected in the bodies of most Americans (CDC's The Fourth National Report on Human Exposure to Environmental Chemicals, 2009), are currently being used. The most popular herbicide on the planet, glyphosate (Samsel and Seneff, 2013), the active ingredient found in Monsanto’s

RoundUp, more than doubled in use, from 85-90 million pounds in 2001 to 180-185 million pounds in 2007 (EPA, 2011). Until recently, glyphosate was regarded as "biodegradable", "environmentally friendly" (Mercola, 2013), and "minimally toxic to humans" (Samsel and Seneff, 2013). The MSDS issued by Monsanto Company identifies glyphosate toxicologically as "practically non-toxic" and "not mutagenic" in lab animals, "practically non-toxic" in birds and arthropods, and "moderately toxic" in certain fish and water fleas. However, in a 2013 study conducted by Anthony Samsel and Stephanie Seneff (Samsel and Seneff, 2013), it was shown that glyphosate inhibits cytochrome P450 enzymes and is linked to gastrointestinal disorders, obesity, diabetes, heart disease, depression, autism, infertility, cancer, and Alzheimer's disease.

According to other more recent studies, over 1 billion pounds of pesticides are used annually in the United States and approximately 5.6 billion pounds are used worldwide (Alavanja, 2009). That translates to more than 1 billion pounds of toxic chemicals intentionally introduced into the environment and our food supply each year. According to the literature, those toxic chemicals do not solve pest problems (Cox, 2006) and may exacerbate emergence of secondary pest outbreaks that were previously not a problem (Pimentel and Levitan, 1986; Leigh, Roach, and Watson, 1996).

Even more alarming are the statistics for aerial pesticide application. It was reported that most aerially-sprayed pesticides do not reach target pests, flying insects in particular (Pimentel and Levitan, 1986). Under ideal conditions, less than 50% of pesticide reaches the intended crop and only 0.1% - 5% reaches the targeted pest (Pimentel and Levitan, 1986). Avoidance of pesticide use is the eventual goal for future farming systems in the United States (Lammerts van Bueren *et al.,* 2002).

The Melon

Origin of the Melon

Melons, cucumbers, watermelons, squashes, and pumpkins are distinct species included in the family *Cucurbitaceae*, and are denoted by the term “cucurbits.” Together, the cucurbits comprise a taxonomic group of very diverse origin and with significant effects on human nutrition. Although melons are extensively grown in most parts of the world today, the history and origin of this fruit is inconclusive (Sauer, 1993). References made in ancient times indicate that melon cultivation was very much existent during such time. Most food historians believe that cultivation of melons dates back to the Biblical period in Egypt and Greece (Kipple and Ornelas, 2000), while others believe that they were first cultivated in Persia, Armenia, and India (Sauer, 1993). The most ancient records of cultivated *Cucumis melo* are depicted in Egyptian mural paintings (Stepansky et.al., 1999). However, the ancient Egyptians seemingly made no distinctions between varieties (Kipple and Ornelas, 2000). It is thought that the ancient Romans imported their supply of melons from Armenia (Sauer, 1993) or from Persia or Caucasus around the 13th century (Stepansky *et.al*., 1999). A collection of ancient Roman recipes called "Apicius" identifies extensive use of melons (Kipple and Ornelas, 2000).

Traditional conception maintains that *Cucumis* originated in Africa, with *C. sativa* and *C. hystrix* thought to be the only species originating in Asia (Sauer, 1993). Similarly, the current consensus among food historians places melon origination in Africa and southwestern Asia, with China or India as possible secondary areas of diversity (Renner *et al.*, 2007). Studies conducted by Susanne Renner and colleagues (2007) show that origination of *Cucumis melo* more likely occurred somewhere is Asia and reached Africa from there; they suggest, however, further testing to confirm secondary origination in Africa.

According to Sauer (1993), wild melons growing in natural habitats have been identified in desert and savanna zones of Africa, Arabia, southwestern Asia, and Australia. Sauer (1993) suggests that it is not clearly understood where melon was domesticated and "it is conceivable that it was independently domesticated from different wild populations in Africa and southwestern Asia" (Sauer, 1993). Melon was an important food crop in ancient China, where archaeological data indicate that it has been cultivated for more than 5,000 years (Simoons, 1991). The earliest Cucurbit remains were excavated from the Hoabinhian stratum at Thailand dating to around 10,000-6,000 BC (Szabo *et al.,* 2008). Archaeological evidence additionally suggests that melon was cultivated in Iran about 5,000 years ago and in Greece and Egypt about 4,000 years ago (Simoons, 1991). In Europe, the oldest seed remains were discovered in Tiryns, Greece (700-800 A.D.) (Szabo *et al.,* 2008).

The oriental, pickling melon (*C. melo* ssp. *melo* var. *conomon*) is considered the most ancient form of melon domesticated in China (Szabo *et al.,* 2008). In the Chinese Book of Poetry ('Shih Ching'), written about 1000-500 B.C., four poems talk about melon ('*kua*') and give practical advice for intercropping melons with soybean (Szabo *et al.,* 2008). By 1100-771 B.C., records indicate that muskmelon and pickling melon were apparently the most important fruit-vegetables in China (Szabo *et al.,* 2008). Another Chinese book ('Essential Art for the People'), written around 533-544 A.D., devoted a chapter entirely to the cultivation, seed selection, germinating, weeding and harvesting of melon (Szabo *et al.,* 2008).

In the late fourteenth century, cultivation of melons was widespread in Italy, and in the fifteenth century, it is believed that they became popular in the southern part of Spain (Kipple and Ornelas, 2000). Around this time the Arabs cultivated the seeds and popularized the trade of melons in Andalusia (Kipple and Ornelas, 2000). Christopher Columbus introduced melons to the new world, particularly North America, during his second voyage in 1494 (Kipple and Ornelas, 2000). In North America, melons very quickly became popularized by the Indians who in turn produced wide ranges of new cultivars (Szabo *et al.,* 2008).

Around the sixteenth century, melon seeds brought from Armenia were planted in the Papal gardens in the city of Cantalupo, near Tivoli, Italy. The townsfolk referred to the melon as "cantalupo," so named after the city and a commune called *Cantalupo* (Kipple and Ornelas, 2000). In the seventeenth century, melon cultivation became very popular in the warm southern parts of France (Kipple and Ornelas, 2000). Conducive climatic conditions provided enough warmth for melons to ripen and sweeten. The French referred to these sweet melons as *sucrins,* which meant sugar. Today, the sweet melon variety, *Charentais*, is grown mostly in France (Kipple and Ornelas, 2000).

In 1881, the W. Atlee Burpee Company introduced a popular variety called the *Netted Gem* to the United States (Kipple and Ornelas, 2000). By 1895, melon production was underway in Colorado (Kipple and Ornelas, 2000). It was only after the Civil War that the melon crop became increasingly popular. During the 1900s, British writer Michael Arlen, while on a trip to Armenia, noted that the "casaba melon", which derived its name from the city Kasaba, in Turkey, made its way to California via Armenian travelers (Kipple and Ornelas, 2000). Today, many regions of the United States are popular for melon cultivation (Kipple and Ornelas, 2000), and in the Rio Grande Valley South Texas region, recommended hybrid varieties include Caravelle, Explorer, Mission, Hy Primo, and Cruiser; some trial varieties are: Marco Polo and Ovation, and TAM Uvalde and Perlita are open pollinated varieties (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). Another popular variety grown in South Texas is Hales Best Jumbo, grown for its ability to resist drought and powdery mildew (Cohen *et al.,* 2004). It is one of the most grown heirloom cantaloupe melons in the U.S. that was reportedly found growing in a California Japanese immigrant's garden in 1923 (Sustainable Seed Company Website).

As of the most recent 2009 statistics, approximately 1800 acres of cantaloupe out of 2500 planted acres in Texas are harvested every year totaling to an annual cash value of $6.7 million dollars (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). In 2007, the state ranked 3rd in honeydew production and 5th in cantaloupe production (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). The most devastating cantaloupe insect pests are whiteflies and melon aphids, with estimated yield losses from uncontrolled infestations totaling 75% for whiteflies and 60% for aphids (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009).

Taxonomy of the Melon

Genus *Cucumis* (n=12), along with 130 accepted genera, belong to the dicot family C*ucurbitaceae* (Renner *et al.*, 2007) and are taxonomically classified according to the following scheme (GRIN Taxonomy for Plants Database):

- **Family** Cucurbitaceae
  - **Subfamily** Cucurbitoideae
  - **Subfamily** Zanonioideae
    - **Tribe** Melothrieae
      - **Subtribe** Cucumerinae
        - **Genus** *Cucumis* L.
          - **Subgenus** *Cucumis*
          - **Subgenus** *Melo*

Species *Cucumis melo* L.

Subspecies *melo*

Subspecies *agrestis*

Today, more than 800 species of *Cucumis* have been identified (Renner *et al*., 2007). The two subfamilies — Cucurbitoideae and Zanonioideae— are well characterized: the former by having the styles united into a single column and the latter by small, striate pollen grains (Kipple and Ornelas, 2000). All of the food plants fall within the subfamily Cucurbitoideae (Kipple and Ornelas, 2000). Further definition places cucumber *(Cucumis sativus* L.*)* and melon *(Cucumis melo* L.*)* within the subtribe Cucumerinae, tribe Melothrieae. Within subgenus *Cucumis*, two species, *C. sativus* and *C. hystrix*, have been identified and thirty species identified within subgenus *melo* (Renner *et al*., 2007).

Melon Plant and Fruit Morphology

Cucumis melo has 2n=24 chromosomes and is considered the most diverse species of genus *Cucumis* (Silberstein *et al.,* 1999; Stepansky *et al.,* 1999; Renner *et al.,* 2007; Szabo *et al.,* 2008). Melons are mostly monoecious plants, depending on cultivar, with andromonoecious flower arrangement. They are frost-sensitive annuals with trailing vines that have nearly round stems bearing tendrils and circular to oval leaves with shallow lobes. A single *Cucumis melo* plant has imperfect [male] flowers and perfect [female] flowers that number 10-12 to 1 respectively (McGregor and Todd, 1952; Delaplane and Mayer, 2000). Staminate flowers arise from axillary clusters on the main stem, and perfect flowers begin appearing one to two weeks after initiation of the male flowers (McGregor and Todd, 1952). The perfect female flowers are found only on branch runners and are produced at the first node of lateral branches (Delaplane and Mayer, 2000).

As seen in Figure 1, the flower corolla is yellow with 5 petals joined as a tube at the base that form an outer whorl approximately 2-3.8 cm in diameter (Delaplane and Mayer, 2000) (Fig. 1). Female flower ovaries are inferior, pubescent, tricarpellate, and/or sericeous (Stepansky *et al.,* 1999) and increase in length each day prior to anthesis (Mann and Robinson, 1950) (Fig. 1). According to Stepansky and colleagues (1999), ovary shape is correlated with fruit shape. The imperfect flower has five stamens, two pairs are connate.

Each cream-colored seed is formed from the union of one pollen grain and one ovule. The flowers are insect-pollinated, and the fruits are many-seeded berries that vary in size, shape, rind characteristics, and flesh color depending on variety. Pollinators, mostly bees, transfer pollen from male flowers to female flowers making fruit set possible. Mis-shaped and undersized fruit are often caused by inadequate pollination, which results from low numbers of fertilized seed (McGregor and Todd, 1952). In general, quality fruit is related to external appearance, thick, well-colored interior flesh with high soluble solids (>10 percent), favorable weather conditions that are conducive to pleasant aroma and increased sugar content (Kipple and Ornelas, 2000), and adequate pollination (McGregor and Todd, 1952; Bohn and Davis, 1964). Soluble solid content is reduced when melons are grown under excessive soil moisture, rainfall, and/or poor water drainage conditions (USDA website [access date 23 October 2010]). Poor-quality melon fruits were previously believed to have resulted from the cross-pollination of melon with cucumber; this is not true, however, because these species are not compatible (Kipple and Ornelas, 2000).

The pollen grains are too sticky and too heavy to be carried by wind. Flowers open just after sunrise and release their pollen when the humidity is low. The stigma is receptive to pollen for a few hours in the morning, except when the temperature is unusually hot; during hot weather, the stigma is receptive for a mere few minutes (Delaplane and Mayer, 2000). It has been determined that flower and pollen sac opening times are controlled by temperature and that humidity, rain, wind, and light intensity affect anthesis proportionately to temperature (Mann and Robinson, 1950). Successful fruit production requires the transfer of 500 to 1,000 viable pollen grains to the stigma (McGregor and Todd, 1952). It has been estimated that foraging honey bees leaving hermaphrodite flowers carried up to 2,500 pollen grains on their body (McGregor and Todd, 1952). For this reason, it has long been know that insect-pollination, particularly honey bee pollination, is essential for successful melon production (Bohn and Davis, 1964). Interestingly, honey bees have been observed to visit consecutively planted melons in rows more frequently than melons not planted consecutively in rows (McGregor and Todd, 1952).

The Whitefly

Whitefly Taxonomy

Whiteflies are one of the most damaging melon pests in the Rio Grande Valley, South Texas (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). The whitefly family Aleyrodidae (Hemiptera), Westwood 1840, includes 166 genera and 1551 species in 3 living subfamilies (Aleurodicinae, Aleyrodinae and Udamosellinae), and one non-living (fossil) subfamily (Bernaeinae) (Evans, 2008). Identification of genera and species is generally based upon fourth instar (pupa) characteristics (Evans, 2008). Genus *Bemisia* and 2 accepted species (Global Invasive Species Database) belong to the order Hemiptera and are taxonomically classified according to the following scheme (BugGuide.net; Global Invasive Species Database):

Order Hemiptera

Suborder Sternorrhyncha

Superfamily Aleyrodoidea
  Family Aleyrodidae
    Subfamily Aleyrodinae
      Genus *Bemisia*
        Species *argentifolii* (Bellows & Perring), B biotype
        Species *tabaci* (Gennadius), Q biotype

Whitefly Origin and Biotypes

Whiteflies were originally classified as a *Bemisia tabaci* group, or complex, of species that were closely related to *B. tabaci* (Brown *et al*., 2000). One particular species of the complex, *Bemisia argentifolii*, was different from the other species biochemically, genetically, and behaviorally (Brown *et al.,* 2000). This variant, referred to as B biotype of *B. tabaci*, was identified as a separate species, *Bemisia argentifolii* Bellows & Perring, silverleaf whitefly. The two cryptic species, *Bemisia argentifolii* and *Bemisia tabaci*, and 19 *Bemisia* biotypes (biotypes A-T) have been since identified (Global Invasive Species Database). Of particular interest are the two phytophagus biotypes, B *(Bemisia argentifolii* Bellows & Perring, silverleaf whitefly*)* and Q (*Bemisia tabaci* Gennadius, sweetpotato whitefly*)*. Both biotypes are strongly resistant to pesticides (Leigh, Roach, and Watson, 1996; Jones *et al.*, 2008; USDA/ARS, 2008) and exhibit high population density and diverse host plant range, with over 900 host plants identified worldwide (Global Invasive Species Database). Morphologically they are indistinguishable from each other but are genetically distinctive with different biological characteristics (Leigh, Roach, and Watson, 1996; Calvert *et al*., undated). In the literature, investigators are still at odds in determining whether B and Q are unique and separate species or taxonomically just a biotype complex (McCreight and Simmons, 1998). Because of taxonomic ambiguity, the scientific and common names for the B and Q biotypes are used interchangeably in the literature.

According to the United States Department of Agriculture (USDA) National Agricultural Library Species Profile for silverleaf whitefly (Synonym: *Bemisia tabaci* Gennadius), it is believed that B biotype (silverleaf whitefly) is native to possibly India, evidence to such is inconclusive (Global Invasive Species Database), and was introduced accidentally into the United States in 1986 (USDA National Agricultural Library National Invasive Species Information Center). It is reported that whitefly Q biotype (sweetpotato whitefly) originated in the Mediterranean region and was introduced into the United States around December, 2004, in a poinsettia retail outlet in Arizona (Bethke *et al.,* 2006).

The Whitefly Problem in South Texas

The predominant whitefly in South Texas is *B. argentifolii* B biotype Bellows & Perring, silverleaf whitefly (SLW) (Leigh, Roach, and Watson, 1996) and is a threat to many crops of economic importance, including tomato, watermelon, cucumber, zucchini, squash, lettuce, okra, carrots, broccoli, cotton, and fruit crops (McCreight and Simmons, 1998). Whiteflies are the most damaging cantaloupe pest in South Texas, attributing to an estimated 75% yield loss from uncontrolled whitefly infestation during any given growing season (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). Plant nutrient depletion, stunting, poor growth, defoliation, reduced yields, and death occur when whiteflies puncture cantaloupe leaves and remove the sugary sap with piercing-sucking mouthparts (Bellows *et al*., 2002). Whitefly larvae and adults produce copious amounts of honeydew, which attract sooty mold fungus and ants leading to further plant damage (Bellows *et al*., 2002). Additionally, whiteflies are known to transmit more than 100 plant-pathogenic viruses that cause severe economic losses (American Phytopathological Society, 2007; Global Invasive Species Database).

In South Texas, whiteflies are late season pests that disperse (as adults) in large numbers predominantly from cotton crops to spring and summer gardens and vegetable crops (Leigh, Roach, and Watson, 1996). Of particular interest is the fact that whiteflies are strongly resistant to insecticides (Leigh, Roach, and Watson, 1996; Jones *et al.*, 2008; USDA/ARS, 2008), yet all cantaloupe crops in Texas are treated with a combination of insecticides, herbicides, and fungicides up to six times throughout the growing season (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009).

Control of *Bemisia* whiteflies is critical for sustained production of high quality melons in South Texas. Currently, melon growers in affected areas of Texas, namely South Texas, rely upon conventional farming practices to keep whitefly populations below the threshold level required to permit profitable cantaloupe production. Such grower management practices involve agrochemical interventions of more than a dozen different synthetic pesticides (Leigh, Roach, and Watson, 1996; Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009), despite the claims in the literature of whitefly resistance to pesticides.

According to the General Texas Production Information as of 2010 for cantaloupe, biological control practices incorporate the use of imidacloprid (Admire ®) followed by addition of parasites (USDA Vegetables 2010 Summary; Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). Imidacloprid is a neonicotinoid systematic insecticide that acts on post-synaptic nicotinic acetylcholine receptors within an insect's central nervous system (Gervais *et al.*, 2010). Once the nicotinic receptors are bound, impulses are spontaneously discharged followed by failure of neurons to propagate signals (Gervais *et al.*, 2010). Continued activation of the nicotinic receptors results because the acetylcholinesterases are not able to break down the pesticide (Gervais *et al.*, 2010). The binding process is irreversible (Gervais *et al.*, 2010), and the insect dies. The insect most commonly affected by imidacloprid is the *honey bee* (Gervais *et al.*, 2010). According to the Crop Profile for Cantaloupes and Honeydew melons in Texas (2009), "bees are rented to put in the field for pollination" in the second month after melon seeds are planted. Long known since the early 50's, honey bee pollination is essential for successful melon production (Bohn and Davis, 1964), yet following bee rentals during cantaloupe growing seasons, imidacloprid is routinely applied for whitefly control (Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009).

Aside from their natural resistance to pesticides, the distribution of whitefly within the plant canopy on the underside of the leaves in conjunction with their high reproductive potential (adult whiteflies mate within one to two days of emergence from the egg) attribute to the ineffectiveness of controlling the pest with conventional spray application methods (Leigh, Roach, and Watson, 1996). Additionally, research has shown that infestations appear to intensify following agro-chemical interventions because natural enemy complexes are severely disrupted, if not destroyed (Leigh, Roach, and Watson, 1996). This suggests that natural regulating factors, e.g. integrated pest management, would be more effective in the control of the melon whitefly pest in South Texas.

Integrated Pest Management

Integrated pest management (IPM) was defined in 1959 as "the integration of two or more compatible control strategies designed to maximize profitability and minimize hazards to humans and the environment” (Stern, 1973). IPM control strategies encourage reduction of pesticide use by integrating a variety of pest management options, such as biological control (augmentation and conservation), cultural control, mechanical control, chemical control, and varietal selection (Maupin and Norton, 2010). In general, IPM control programs aim to improve economic well-being while reducing deleterious environmental and health risks that pesticides pose. However, the plant and pest insect dynamics must be clearly understood before designation and initiation of a suitable IPM program. Employment of organic farming practices are more stringent but the greater level of biodiversity in combination with IPM strategies can further reduce pesticide use (Lammerts van Bueren *et al.,* 2002).

More recently, research has focused on the discovery of alternative bio rational control strategies, such as “botanical insecticides” from natural plant sources (Arnanson *et al.,* 1992). Botanical insecticides include allelochemicals, which are produced as secondary plant metabolites and are byproducts of primary plant metabolic processes (Narwal *et al.*, 2005). Allelochemicals have an effect on the growth and development of the same plant or neighboring plants. Allelochemicals include: 1) plant biochemicals that exert their physiological/toxicological action on plants (allelopathy, autotoxicity, or phytotoxicity), 2) plant biochemicals that exert their physiological/toxicological action on microorganisms (allelopathy or phytotoxicity), and 3) microbial biochemicals that exert their physiological/toxicological action on plants (allelopathy and phytotoxicity) (Narwal *et al.*, 2005). Allelochemicals can also be used to control insect pest species (Narwal *et al.*, 2005). Such plant biocidal chemicals have great potential as natural pest control agents and can function as an additional and effective IPM control strategy.

The Non-Crop Companion Plants

Companion planting refers to the growing of two or more crops in proximity to each other for the benefit of the crop system and/or each other. It is used to promote farm/garden biodiversity. Companion planting generally refers to small-scale planting of vegetable, herb, and flower crops selected based on the benefits they provide to neighboring plants and organisms. Benefits of companion planting might include providing shade or trellis support, suppressing weeds, providing nutrients, decreasing pest problems, or increasing pollination through the attraction of beneficial insects. Since organic systems rely heavily on populations of beneficial insects to maintain a natural balance between pest and predator species, creating biodiversity via companion planting can provide habitat and food sources to support beneficial insects. In addition to companion plants, flowering plants are an important component of an agro-ecosystem, providing pollen and nectar sources for species of native bees.

The non-crop companion plants for the organic cantaloupe systems in this project were chosen based on their ability to provide a desirable environment for beneficial insects and arthropods, particularly the predatory and parasitic species which help control pest populations. Predaceous insect species in South Texas include lady bird beetles, lacewings, hover flies, mantids, and robber flies. Non-insect predators include spiders and certain species of mites. The refugia established in this project included zinnias (*Zinnia elegans*) and dill *(Anethum graveolens),* which have been reported as pollinator attractive agents of insect beneficials such as bees, wasps, and syrphid flies (Kuepper and Dodson, 2001). It is reported that dill additionally acts as a repellant agent of aphids (Kuepper and Dodson, 2001). French marigolds *(Tagetes patula)* are known to repel whiteflies (Trinklein, 2010), and native Texas sage *(Leucophyllum frutescens)* is said to repel ants (Kuepper and Dodson, 2001).

French Marigold

It has long been known that plants synthesize thousands of chemical compounds that have medicinal and insecticidal properties with diverse modes of action, including hormonal, nutritional, enzymatic, and neurological (Priyanka *et al*., 2013). Several plant families have been known to synthesize certain alkaloids, phenolics, oils, phototoxins, and other secondary plant metabolites that can be used for insect control. More than 1000 plant species in the family Asteraceae synthesize secondary plant metabolites including amino acids, flavonoids, glucosinolates, lignas, tannins, and steroids, all of which have toxic effects on target insects (Nivsarkar *et al.,* 2001). One such non-crop companion plant specimen of interest in this study from the family Asteraceae is the yellow French marigold (*Tagetes patula*). Marigolds are taxonomically classified according to the following scheme:

Order Asterales
  Family Asteraceae
    Subfamily Asteroideae
      Tribe Tageteae
        Genus *Tagetes*

The French marigolds synthesize a phototoxic thiophene volatile called ά-terthienyl (aT) that adversely affects plant enemies such as disease-producing plant pathogens, parasitic nematodes, herbivorous insects, and competing plant species (Wang *et al.,* 2007). Studies have demonstrated that aT has a multidirectional toxicity in the larval stages of target insects, such as mosquitoes and moths (Nivsarkar *et al.,* 2001). It is activated by ultraviolet light and is toxic to a number of other insect species, such as *Manduca sexta*, *Piaria rapae*, *Musca domestica*, *Tribolium casteneum, Rhizopertha dominica,* and mosquito larvae, *Aedes atropalpus*, *Aedes aegypti* and *A. intruden* (Nivsarkar *et al.,* 2001). It generates oxygen radical species and has the ability to inhibit several enzymes both *in vivo* and *in vitro* (Nivsarkar *et al.,* 2001). Release of aT in French marigolds is reported to repel whiteflies (Trinklein, 2010), but its mechanism of toxicity specifically on whiteflies is unknown. Alpha-terthienyl possesses all the desirable properties of a good insecticide/pesticide. It is fast acting, non-toxic, economical, user-friendly, and safe. In the context of conventional control, aT may have comparable or better efficacy to conventional control agents, as these materials become ineffective because of insect resistance.

CHAPTER III

METHODOLOGY AND FINDINGS

Materials

Materials used in this project included plants and plant seeds, ant bait, gloves, shovels, hoes, rakes, a commercial grade Craftsman rototiller with an 18” tilling path, two Craftsman 22” self-propelled rear bag mowers equipped with mulching blades, fuel for rototiller and lawn mowers, a weed-eater, proper fuel for the weed-eater, Scotchman’s Choice compost soil, 2x4 lumber, 4x4 lumber, nails, bricks, insect aspirator and numerous plastic vials with caps, T-tube olfactometer, numerous drip irrigation supplies, and numerous chain link fencing supplies. Hale’s Best Jumbo (*Cucumis melo var. inodorus*) melon seeds, produced by organic breeding programs and suitable for organic production in South Texas, were purchased from Circle G Enterprises Inc. in McAllen, Texas. Yellow French marigold plants and packaged seeds, 5 gallon pots of cenizo, zinnia plants and dill plants and packaged seeds, bags of Scotchman’s Choice compost soil (2 cubic feet compost/bag), ant bait, and all drip irrigation supplies were purchased from Lowe’s and Home Depot hardware stores located in Edinburg and McAllen, Texas. The fencing supplies, gloves, shovels, hoes, rakes, rototiller, lawn mowers, 2x4 and 4x4 lumber, bricks, hose and irrigation water were readily available at the planting site in West Mission, Texas, West Mile 9 Road and Moorefield. The rototiller was used to plow through and till the soil in the designated planting sites. The mowers and weed-eater were used for maintenance in and around the garden plots. Other than tilling and mowing, the methods, i.e. planting, weeding, IPM, etc., used in this project were not hazardous or dangerous, but safety measures were adhered to at all times. Personal protective equipment included proper attire and shoes, gloves, sunglasses, caps, and sunscreen lotion. Drinking water was available at all times. Proper drinking habits were exercised when working in the garden, particularly on hot days. The research investigator was experienced in the use of the rototiller and was the sole person responsible for tilling the soil in the garden plots. Proper supervision and precautionary measures were taken when tilling, mowing and weed-eating the garden plot areas.

Study Sites

Phases I and III of this study were conducted in West Mission, Texas, West Mile 9 Road and Moorefield Road (Fig. 1) from March, 2010, to August, 2012.

Figure 1. Aerial image of study location in Mission, Texas.

Approximately one acre of arable land was selected for the intercropping experiments. Phase II was conducted at Moore Airbase on Moorefield Road in Mission, Texas, during the month of July, 2012.

Preliminary Study of Summer 2010

A preliminary intercropping study with the selected non-crop companion plants and melon plants was conducted from March to June, 2010. The study was for learning purposes only. However, the results were pivotal in the overall project, and its findings influenced the future direction of the thesis research.

In the preliminary study, each of the non-crop companion plants was strip-intercropped with the cantaloupe plants in the same plot (ten melon plants per ridge), Treatment Plot I. An identical replicate plot was constructed 2m away, Treatment Plot II. A monoculture plot of melons was planted approximately 91m away from the treatment plots, Control Plot I. An identical replicate plot was constructed 2m away, Control Plot II. For soil enrichment, five bags of Scotchman's Choice organic compost were mixed with the soil in each of the plots. All plots were the same size (5m x 5m). Each plot was weeded, cleared of debris, and irrigated weekly. Each of five healthy melon plants from the treatment and control groups was sampled once a week for two minutes. The leaf turn method was used to gather in-situ counts of arthropods on and within each melon plant canopy. Counts were performed from the oldest leaves if the plants had <6 true leaves or from the 5th leaves on the main terminal if plants had >6 true leaves (Liu, undated). All data were recorded and analyzed with Excel software.

Throughout the growing season, many different species of arthropods were observed in the treatment plots – digger bees, robber flies, long-legged flies, numerous butterfly species, the ladybird beetle complex, soft-wing flower beetles, earwigs, grasshoppers, potato beetles, squash bugs, cucumber beetles, ants, aphids, whiteflies, flesh flies, preying mantids, bees, wasps, mites, and spiders. Several rabbits, birds, and lizards were observed in each of the treatment plots but not the control plots. Compared to the treatment plots, very few different arthropod species were observed in the control plots – whiteflies, ants, aphids, mites, velvet ants, squash bugs, spiders, flesh flies, grasshoppers, and a few assassin bugs. All arthropod densities were determined and compared between plots. Results suggested that there were significant differences between treatment and control group arthropod densities. It was concluded that organically-managed cantaloupe systems grown with non-crop companion plants supported greater levels of biodiversity and species richness and abundance.

Of particular interest were the statistically significant differences between the mean whitefly ($t\ (28) = -3.800$, $p<.001$) and aphid ($t\ (28) = 4.427$, $p<.001$) population densities in the treatment and control groups. Whitefly population densities in the control groups were considerably greater than those in the treatment groups, and ant and aphid densities were substantially greater in the treatment groups than those in the control groups (Fig. 2).

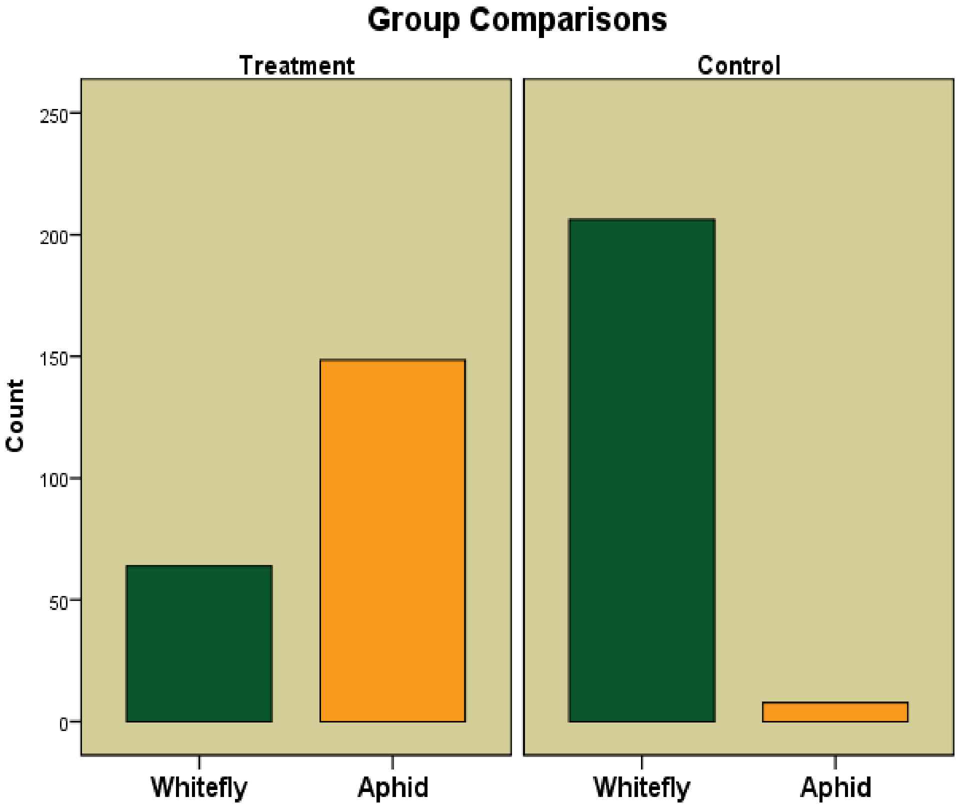


Figure 2. Graph of whitefly and aphid densities, Preliminary Study of 2010.

It was this interesting observation that changed the parameters and objectives of future research and experimentation. Unexplainable dynamics seemingly occurred in the treatment and control groups to cause whiteflies and aphids to preferentially populate one group over the other. New questions were asked. Did one or more of the companion plants in the treatment plots repel whiteflies and attract or fail to repel aphids? If so, which companion plant(s) repelled whiteflies and/or attracted or failed to repel aphids? Did the companion plants affect the natural enemy complex? If yes, then how? After repeated discussions with the thesis committee members, the decision was made to focus on the key melon pest in the Rio Grande Valley, whiteflies. A new hypothesis was formulated. The focus of the original hypothesis - organically-managed cantaloupe systems grown with non-crop companion plants support greater levels of biodiversity and natural control of pest species relative to conventional production systems – was re-directed. The goal now was to determine if one or more of the companion plants seemingly and effectively repelled whiteflies and attracted or failed to repel aphids. The new hypothesis was that the yellow French marigolds would foster an environmentally safe, effective, natural, and economical means of pest repellency relative to agrochemical intervention.

A late season influx of lepidopterous larvae eventually dominated and consumed all melon plants in the treatment groups, ending the preliminary study. The goal was to replicate the plot study thereafter and continue research throughout the summer. All seeds in both the new treatment and control plots were planted June 15th, 2010. However, two weeks later on June 30th, Hurricane Alex dropped 6 to 9 inches of rainfall throughout the Rio Grande Valley (RGV) region[1]. One week following the ravages of Alex on July 8th, Tropical Depression Two contributed to further flooding in the region and kept the RGV under flood conditions for most of the month of July[2].

Replication of this study was again attempted during the summer of 2011. All plots were constructed and seeds planted as previously discussed, but the study was terminated early because of severe state-wide drought conditions. The Texas Department of Agriculture declared the Texas drought of 2011 the worst and costliest in Texas history (Fannin, 2012).

---

[1] National Climatic Data Center (2010-06-30). "Event Record Details: Hurricane Alex." National Oceanic and Atmospheric Administration.

[2] National Hurricane Center (21 October 2010). "Tropical Cyclone Report: Tropical Depression Two (AL022010)." National Oceanic and Atmospheric Administration.

Phase I Plot Study

Replication of the 2010 preliminary study continued in March, 2012, but the design was changed. The most common experimental design used in crop research is the randomized complete block design (RCBD), in which treatment plots are grouped together randomly within replicated sections, or blocks (SARE Bulletin, 2004). The experimental design for the Phase I intercropping experiments was an RCBD with three replicate plots, Replicate I, Replicate II, and Replicate III (Table 1).

Replication I	Replication II	Replication III
CFM	HBJ	CC
CD	CZ	CFM
HBJ	CFM	CD
CC	CD	CZ
CZ	CC	HBJ

Habitat	Planting Model
Control (HBJ)	All ridges planted with cantaloupe (Hales Best Jumbo)
Cantaloupe-French marigold system (CFM)	French marigold planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle
Cantaloupe-Dill system (CD)	Dill planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle
Cantaloupe-Cenizo system (CC)	Cenizo planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle
Cantaloupe-Zinnia system (CZ)	Zinnia planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle

Table 1. Phase I RCBD plot designs for cantaloupe intercropping systems.

Each replicate plot was divided into five raised beds (1m x 5m) with a 1m space between each bed. All plant beds were raised and constructed in accordance with principals of organic naturalness (Lammerts Van Bueren *et al*., 2004; Tscharntke *et al*., 2005; Sandhu *et al*., 2007).

Additionally, all plant beds were relocated on the location property for purposes of consistency with principals of crop rotation in an organic farming system (Leigh, Roach, and Watson, 1996; Crop Profile for Cantaloupes and Honeydew Melons in Texas, 2009). Four cantaloupe intercropping systems were examined and evaluated for ability of polyculture plots to attract insect predators and pollinators and repel key insect melon pests, whiteflies and aphids. Because weeds are a significant problem in organic farming systems (Lammerts Van Bueren *et al.*, 2002), all beds were cleared of weeds and debris every other day. Water was delivered at 25psi via drip irrigation every other day for one hour in the morning.

Each bed consisted of at least 10 melon plants. All melon seeds were direct-seeded in rows, per the guidelines provided in the Crop Profile for Cantaloupes and Honeydew Melons in Texas (2009). Seeds were planted in rows because the preferred pollinators, honey bees, visit consecutively-planted melons in rows more frequently than melons not planted consecutively in rows (McGregor and Todd, 1952). The planting models in each of the plots were the same but arranged according to the RCBD plot designs for purposes of statistical analysis.

Figure 3. Photo, taken by investigator, demonstrating the scale and appearance of the plots in each replicate block.

In Replicate Plot 1, the first bed consisted of yellow French marigolds planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CFM). The second bed consisted of dill planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CD). The next monoculture bed of only cantaloupe was included for comparison with the other treatment beds within Plot I (HBJ). The fourth bed consisted of cenizo planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CC). The fifth bed consisted of zinnias planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CZ).

In Replicate Plot 2, the first monoculture bed of only cantaloupe was included for comparison with the other treatment beds within the plot (HBJ). Bed two consisted of zinnia planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CZ). Bed three consisted of yellow French marigold planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CFM). Bed four consisted of dill planted on both edges (25cm wide) of one row of cantaloupe planted in the middle, (CD). Bed five consisted of cenizo planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CC).

In Replicate Plot 3, the first bed consisted of cenizo planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CC). The second bed consisted of yellow French marigold dill planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CFM). The third bed consisted of dill planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CD). The fourth bed consisted of zinnias planted on both edges (25 cm wide) of one row of cantaloupe planted in the middle, (CZ). The last monoculture bed of only cantaloupe was included for comparison with the other treatment beds within the plot (HBJ).

Each of five healthy melon plants from each bed in each of the Plots was sampled once a week for two minutes. The leaf turn method was used to gather in-situ counts of mobile arthropods on and within each melon plant canopy. Counts were performed from the oldest leaves if the plants had <6 true leaves or from the 5th leaves on the main terminal if plants had >6 true leaves (Liu, undated). Leaf samples were collected and taken to the lab to estimate intensities of sedentary immature whiteflies and aphids and percentages of each that were parasitized, however, no observations of parasitism were identified. All mobile arthropods were counted and identified according to a species group, e.g. a ladybird, a spider, a bee, a wasp, etc. (individual species names were not identified) to determine species richness and abundance for each Plot. Each insect was later further classified as a pest, a predator, or a pollinator. Data from this classification was subjected to analysis of variance (ANOVA) using SPSS software and independently compared among the four different non-crop companion plants to determine their ability to attract insect pollinators and repel or suppress insect pests without affecting beneficial natural enemy complexes. The between-subjects factors are shown in Table 2.

Between-Subjects Factors

		Value Label	N
Treat	1	Yellow French Marigold	3
	2	Dill	3
	3	Cenizo	3
	4	Zinnia	3
	5	Control	3
Block	1	Replicate I	5
	2	Replicate 2	5
	3	Replicate 3	5

Table 2. Phase I univariate ANOVA, between-subjects factors for each replicate plot.

Results showed significant difference in whitefly densities within the treatment groups (whitefly F within treatment groups = 37.141, p<.001; within the blocks F = 1.622, p = .256) (Table 3) compared to aphid (aphid F within treatment groups = .315, p = .860; within the blocks F = .463, p = .645) (Table 4), and predator (predator F within treatment groups = .484, p = .748; within the blocks F = 3.389, p = .086) (Table 5). Tukey, HSD, and LSD comparisons tests showed no significant difference between whitefly, aphid, and predator densities within the blocks (Appendix 1). However, the same comparisons tests showed significant difference in whitefly densities within the treatment groups with French marigolds (Appendix 2), a possible indicator of whitefly repellency by the French marigolds. Comparison charts for each replicate block additionally showed significant whitefly densities within the treatment groups with French marigolds (Figs. 4, 5, and 6). Results of the Phase I Plot Study showed significantly higher whitefly repellency indices in intercropping treatments with French marigolds than any other companion plant.

Tests of Between-Subjects Effects

Dependent Variable: Whitefly

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	68284235.867[a]	7	9754890.838	591.563	.000
Treat	2449815.067	4	612453.767	37.141	.000
Block	53504.533	2	26752.267	1.622	.256
Error	131920.133	8	16490.017		
Total	68416156.000	15			

a. R Squared = .998 (Adjusted R Squared = .996)

Table 3. Phase I univariate ANOVA, effects of whiteflies within treatment and replicate plots.

Tests of Between-Subjects Effects

Dependent Variable: Aphid

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	614884.733[a]	7	87840.676	79.330	.000
Treat	1394.933	4	348.733	.315	.860
Block	1025.733	2	512.867	.463	.645
Error	8858.267	8	1107.283		
Total	623743.000	15			

a. R Squared = .986 (Adjusted R Squared = .973)

Table 4. Phase I univariate ANOVA, effects of aphids within treatment and replicate plots.

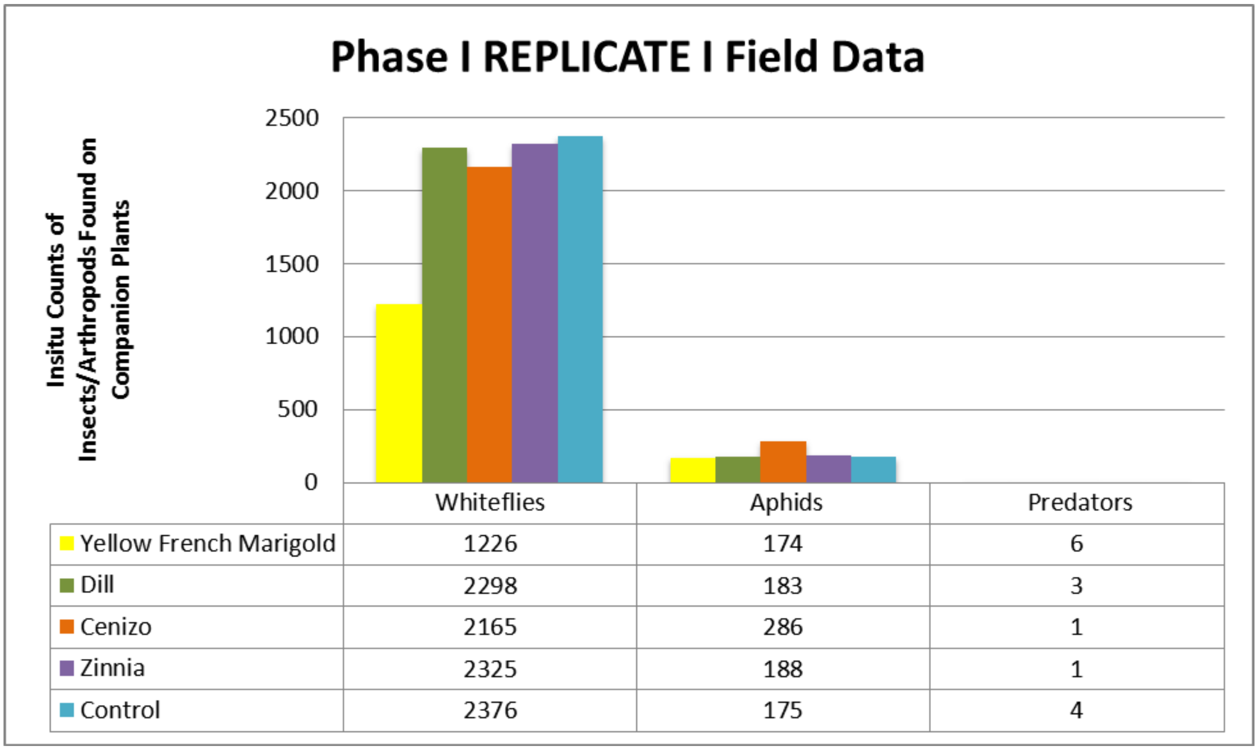
Tests of Between-Subjects Effects

Dependent Variable: Predator

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	55.067[a]	7	7.867	3.006	.073
Treat	5.067	4	1.267	.484	.748
Block	17.733	2	8.867	3.389	.086
Error	20.933	8	2.617		
Total	76.000	15			

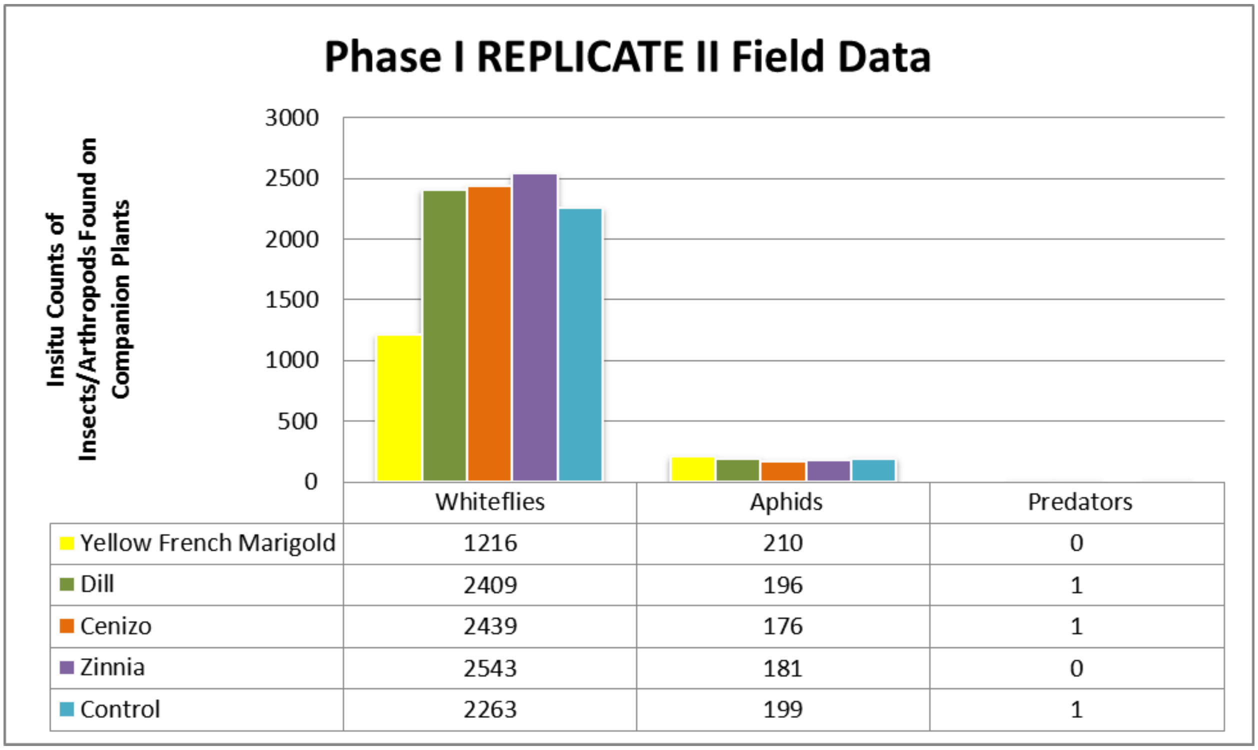
a. R Squared = .725 (Adjusted R Squared = .484)

Table 5. Phase I univariate ANOVA, effects of predators within treatment and replicate plots.



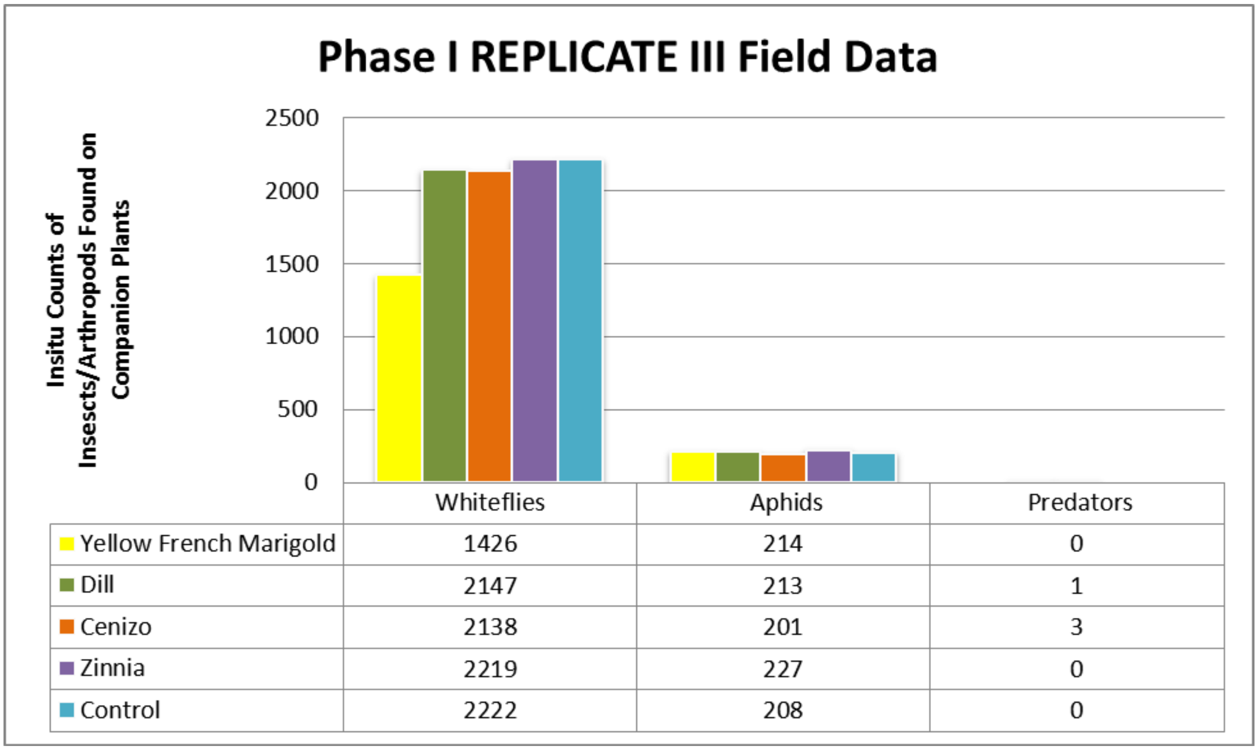
	Whiteflies	Aphids	Predators
🟨 Yellow French Marigold	1226	174	6
🟩 Dill	2298	183	3
🟧 Cenizo	2165	286	1
🟪 Zinnia	2325	188	1
🟦 Control	2376	175	4

Figure 4. Block comparison chart of Phase I Replicate I field data.



	Whiteflies	Aphids	Predators
🟨 Yellow French Marigold	1216	210	0
🟩 Dill	2409	196	1
🟧 Cenizo	2439	176	1
🟪 Zinnia	2543	181	0
🟦 Control	2263	199	1

Figure 5. Block comparison chart of Phase I Replicate II field data.



	Whiteflies	Aphids	Predators
🟨 Yellow French Marigold	1426	214	0
🟩 Dill	2147	213	1
🟧 Cenizo	2138	201	3
🟪 Zinnia	2219	227	0
🟦 Control	2222	208	0

Figure 6. Block comparison chart of Phase I Replicate III field data.

Though the results in each of the replicate blocks showed French marigold had a significant repellent effect on whiteflies, it was observed that the crop yields were low and the fruit quality was poor (fruit yields and quality analyses were not part of this study) (Fig. 7). It was additionally observed that many melon plants did not produce any fruit at all.

Figure 7. Photos, taken by investigator, showing small, irregular shape of mature fruits.

It is not known what caused the low yield and poor fruit quality observed in all of the replicate plots. What is known is that very few insect beneficials and natural enemy complexes were observed throughout the study. Only nineteen adult ladybirds, two adult assassin bugs, and one adult earwig were observed. Earwigs are predaceous insects, however not a typical beneficial common in agricultural production. Additionally, no species of wild bees or honeybees were ever seen. In the literature, quality melon production is significantly dependent upon insect pollination, primarily bee pollination. Research suggests that the abundance and diversity of wild bees and honeybees is on the decline (Gallai *et. al.*, 2009) Whether pollinator decline can be attributed to the low yield and poor fruit quality is unknown.

Phase II Olfactometer Study

In Phase II, the behavioral responses of adult *Bemesia* were investigated by means of two-choice tests using a modified T-tube olfactometer (Fig. 8) that was supplied by a team of USDA scientists at USDA/ARS Subtropical Research Laboratory at Weslaco.

Figure 8. Modified T-tube olfactometer.

A single piece of 1 x 2 wood was attached horizontally onto a 5ft piece of 2 x 4 wood to form the shape of a cross. The two-arm (East and West) apparatus was painted white and was housed in a small room (~3m x 3m) in a portable building at Moore Airbase, Mission, Texas. Oxygen tubing was attached across the arms and connected to a glass chamber on each distal end. The glass chambers were connected to a 2-port humidified air delivery system, and a gentle flow of clean air was delivered at a rate of 1.3 LPM. A hole was cut into the oxygen tubing in the middle where the 1 x 2 wood was attached to the 2 x 4 wood; this was the entry junction for the test insects. Natural sunlight from a standard-sized residential window (~89cm x 165cm) was the sole light source for the experiments.

Adult whiteflies were collected from the planting site in plastic vials using an insect aspirator. The vials of whiteflies, small fresh melon plants (planted in starter pots 3 weeks prior to experimentation) and small mature yellow French marigolds were transported to Mission Moore Airbase for use in three different experiments. Each experiment consisted of five 15-minute trials for a total of 50 individual choices. Separate vials of whiteflies were chilled in a freezer for 5 seconds prior to each trial. Approximately 10 chilled, immobile whiteflies were carefully placed into the oxygen tubing at the entry junction with the aid of a hand-made paper funnel (Fig. 9).

Figure 9. Paper funnel used to place immobile whiteflies into oxygen tubing.

At the end of 15 minutes, the individual insect choices were recorded. Whiteflies that remained at the entry junction after 15 minutes were scored as no-choice. No-choices were deemed unresponsive and excluded from the analyses.

In Experiment I, a marigold was placed in one of the glass chambers to produce the odor-loaded airflow. The clean air produced from the other glass chamber was the control. At least ten immobilized whiteflies were placed downwind at the entry junction in each of five trials and were considered to have made a choice when they moved either to the right or to the left of the junction (Fig. 10). A second experiment used the same methods to examine whitefly responses to a melon plant that was placed in one of the glass chambers to produce the odor-loaded airflow; the clean air produced from the other glass chamber was the control. Behavioral responses were assayed as in Experiment I. In Experiment III, a marigold was placed in one of the glass chambers and a melon plant in the other. Behavioral responses were assayed as in Experiments I and II. In between experiments, USDA staff at Moore Airbase cleaned all parts of the olfactometer set-up.

Figure 10. Whitefly behavior responses, Phase II, Experiment I.

Data were analyzed with a two-sided binomial test using SPSS software. Analysis of cumulative data from all trials in each of the experiments with the t-tube olfactometer showed French marigold repellency of whiteflies. In Experiment I, whiteflies were significantly attracted to the odor of air over French marigold (n=43, p<.001) (Table 6). In Experiment II, the response of whiteflies to cantaloupe was not significant (n=43, p=.761) (Table 7). In Experiment III, French marigold had a significant repellent effect on whiteflies (n=40, p<.001) (Table 8).

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Choice	Group 1	French Marigold	8	.19	.50	.000
	Group 2	Air	35	.81		
	Total		43	1.00		

Table 6. Phase II binomial test of cumulative data, Experiment I, French marigold and air.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Choice	Group 1	Cantaloupe	23	.53	.50	.761
	Group 2	Air	20	.47		
	Total		43	1.00		

Table 7. Phase II binomial test of cumulative data, Experiment II, cantaloupe and air.

Binomial Test

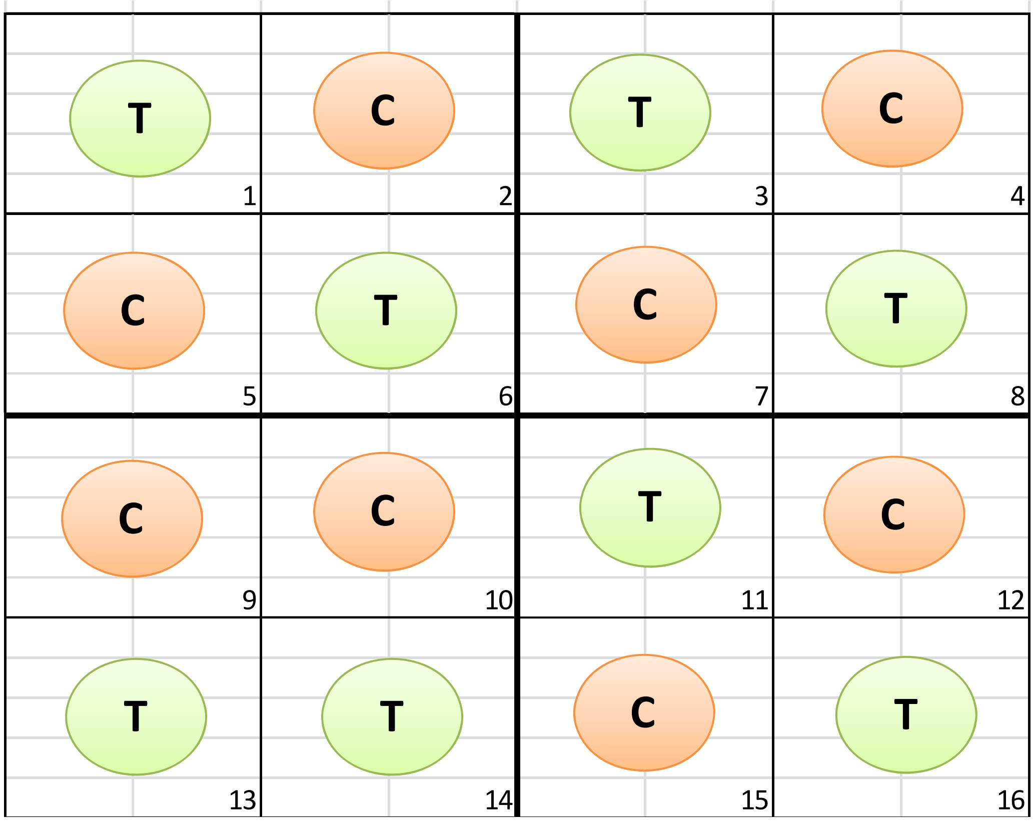
		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Choice	Group 1	French Marigold	8	.20	.50	.000
	Group 2	Cantaloupe	32	.80		
	Total		40	1.00		

Table 8. Phase II binomial test of cumulative data, Experiment III, cantaloupe and French marigold.

Analyses of data from all three experiments clearly demonstrated whitefly behavioral preference for odor-loaded airflow from the clean air and the melon plant and marigold repellency of whiteflies. To conclusively show French marigold repellency of whiteflies, a fourth olfactometer experiment was designed. In that experiment, a marigold and melon combination was to be placed in one of the glass chambers and a sole melon plant in the other. Unfortunately, this last experiment could not be completed because the olfactometer had to be returned to the USDA/ARS Subtropical Research Laboratory at Weslaco for use in other studies.

Phase III Paired Pot Study

In Phase III, a paired-pot study was conducted to further determine the effectiveness of yellow French marigold as a whitefly repellent plant. The RCBD with two treatment groups (T (treatment) = cantaloupe and yellow French marigold, and C (control) = cantaloupe only) replicated eight times was the most appropriate experimental design for this final phase of the thesis research project (Fig. 11).



T 1	C 2	T 3	C 4
C 5	T 6	C 7	T 8
C 9	C 10	T 11	C 12
T 13	T 14	C 15	T 16

Figure 11. Phase III RCBD paired-pot design.

Sixteen 5-gallon plastic terracotta-color pots were purchased from The Home Depot, McAllen, Texas. Each pot was numbered 1 through 16. Organically prepared soil was added to each pot, and melon seeds were direct-seeded three weeks prior to the pot arrangement (Fig. 12) in a one-acre field located at 1852 West Mile 9 Road, Mission, Texas. After three weeks, yellow French marigolds were transplanted into eight pots with melon plants (these were the treatment pots, “T”); no yellow French marigolds were transplanted into the remaining eight pots containing only melon plants (these were the control pots, “C”). All pots were kept in a partly shaded area for one week in order for the plants to adjust to their habitats. After one week, all sixteen pots were arranged 3m away from each other in a square matrix in the field (Fig. 12).

Drip irrigation was installed (1 emitter per pot), and the pots were watered daily for 30 minutes in the morning.

Figure 12. Phase III pot setup according to design matrix after one week of plantings.

During the next week, rabbits and birds were observed eating the plants in the pots. Cinder blocks were placed under each pot to an elevation of approximately 61cm above ground. Various decoys such as duck rattles and scarecrows that shook in the wind were placed in the field to discourage the wildlife from disturbing and feeding on of the plants. The pots were additionally painted white to prevent the soil from drying out quickly.

Each melon plant from each pot was sampled every day for two weeks. As in the Phase I study, the leaf turn method was used to gather in-situ counts of mobile whiteflies on and within each melon plant canopy. Counts were performed on all leaves within the diameter of the pot. Data were subjected to an unpaired t-Test using SPSS software. The group statistics are shown in Table 9 below.

Group Statistics

	Treatment Group	N	Mean	Std. Deviation	Std. Error Mean
Number of Whiteflies	Cantaloupe with Marigold	110	6.31	3.153	.301
	Cantaloupe Only	103	8.13	4.342	.428

Table 9. Phase III treatment group statistics.

An independent-samples t-test was conducted to compare the numbers of whiteflies identified on the leaves of melon plants in pots with melons and French marigold plants (T) and in pots with melon plants only (C). Results showed significant difference in whitefly densities for the treatment (T) (M = 6.31, SD = 3.15) and no treatment (C) (M = 8.13, SD = 4.34) conditions; t(211) = -3.51, p = .001) (Table 10). As in the Phase I and II studies of this project, the results suggest that yellow French marigold is an effective repellent plant of whiteflies. A comparison chart additionally showed significant whitefly densities within the treatment groups, T and C (Fig. 13).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	95% Confidence Interval of the Difference	
									Lower	Upper
Number of Whiteflies	Equal variances assumed	6.411	.012	-3.511	211	.001	-1.817	.518	-2.837	-.797
	Equal variances not assumed			-3.475	185.300	.001	-1.817	.523	-2.849	-.785

Table 10. Phase III independent-samples t-test comparing whitefly counts between treatment groups.

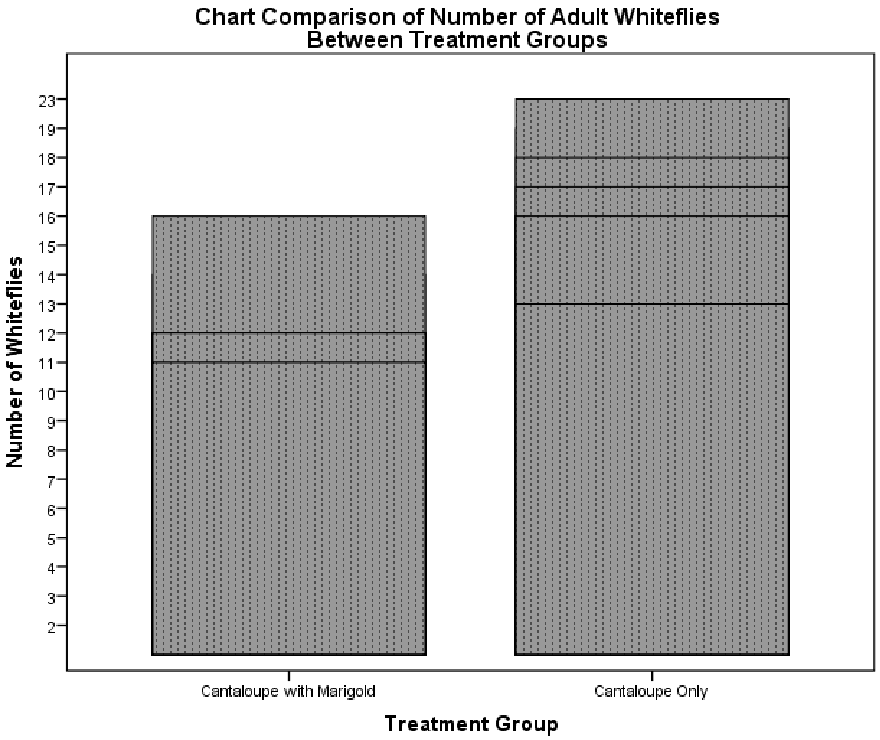


Figure 13. Chart comparison of number of adult whiteflies between treatment groups.

CHAPTER IV

SUMMARY AND CONCLUSION

Preliminary Study of Summer 2010

Intercroppings as one form of polyculture have been commonly used since ancient times. Many findings suggest that intercropping encourages biodiversity, species richness and abundance, increases abundance of natural enemies, and increases crop yields and quality. Therefore, many agricultural practices advocate intercropping in integrated pest management systems for insect pest suppression.

During the preliminary study of summer 2010, many different species of arthropods were observed in the treatment plots – digger bees, robber flies, long-legged flies, numerous butterfly species, the ladybird beetle complex, soft-wing flower beetles, earwigs, grasshoppers, potato beetles, squash bugs, cucumber beetles, ants, aphids, whiteflies, flesh flies, preying mantids, bees, wasps, mites, and spiders. Several rabbits, birds, and lizards were observed in each of the treatment plots but not the control plots. Compared to the treatment plots, very few different arthropod species were observed in the control plots – whiteflies, ants, aphids, mites, velvet ants, squash bugs, spiders, flesh flies, grasshoppers, and a few assassin bugs. All arthropod densities were determined and compared between plots. Results suggested that there were significant differences between treatment and control group arthropod densities. It was concluded that organically-managed cantaloupe systems intercropped with non-crop companion plants supported greater levels of biodiversity and species richness and abundance. Additionally, all phases of the ladybird lifecycle were identified in the treatment groups compared to the control groups, evidence that natural enemy complexes were not disturbed.

Cumulative results showed statistically significant differences between the mean whitefly (t (28) = -3.800, p<.001) and aphid (t (28) = 4.427, p<.001) population densities in the treatment and control groups. Whitefly population densities in the control groups were considerably greater than those in the treatment groups, and ant and aphid densities were substantially greater in the treatment groups than those in the control groups (Fig. 2). Unexplainable dynamics seemingly occurred in the treatment and control groups to cause whiteflies and aphids to preferentially populate one group over the other.

The original hypothesis - organically-managed cantaloupe systems grown with non-crop companion plants support greater levels of biodiversity and natural control of pest species relative to conventional production systems – was accepted. The goal now was to determine if one or more of the companion plants seemingly and effectively repelled whiteflies and attracted or failed to repel aphids. The new hypothesis was that the yellow French marigolds would foster an environmentally safe, effective, natural, and economical means of pest repellency relative to agrochemical intervention. With the formulation of a new hypothesis, new experiments were designed and performed in three separate phases - Phase I Plot Study, Phase II Olfactometer Study, and Phase III Paired Pot Study.

Phase I Plot Study

Replication of the 2010 preliminary study continued in March, 2012, but the design was changed to a randomized complete block design (RCBD), in which treatment plots were grouped together randomly within replicated blocks (Table 1). All results showed significant difference in whitefly densities within the treatment groups (whitefly F within treatment groups = 37.141, p<.001; within the blocks F = 1.622, p = .256) (Table 3) compared to aphid (aphid F within treatment groups = .315, p = .860; within the blocks F = .463, p = .645) (Table 4), and predator (predator F within treatment groups = .484, p = .748; within the blocks F = 3.389, p = .086) (Table 5). Tukey, HSD, and LSD comparisons tests showed no significant difference between whitefly, aphid, and predator densities within the blocks (Appendix 1) and significant difference in whitefly densities within the treatment groups with French marigolds (Appendix 2). Bar graphs for each replicate block additionally showed significant whitefly densities within the treatment groups with French marigolds (Figs. 4, 5, and 6). The results showed significantly higher whitefly repellency indices in intercropping treatments with French marigolds than any other companion plant.

Phase II Olfactometer Study

Analysis of cumulative data from all trials in each of the experiments with the t-tube olfactometer showed French marigold repellency of whiteflies. In Experiment I, whiteflies were significantly attracted to the odor of air over French marigold (n=43, p<.001) (Table 2). In Experiment II, the response of whiteflies to cantaloupe was not significant (n=43, p=.761) (Table 3), and in Experiment III, French marigold had a significant repellent effect on whiteflies (n=40, p<.001) (Table 4). Phase II results clearly demonstrate that the olfactory cues emitted from French marigold plants are significantly different than those of cantaloupe plants and that whiteflies can distinguish the odors of French marigolds and preferentially respond to the latter, but it is unknown whether the preferential behavior of whiteflies was attributed to aT or any other plant volatile in French marigolds.

According to the literature, the volatile emissions of certain plant-derived compounds, such as ά-terthienyl in French marigolds, function as target organism biocides, which could potentially explain the marigold repellency of whiteflies observed during each of the experiments. In the future, further studies to determine the efficacy of plant volatiles in French marigold, particularly aT, in whitefly repellency is needed. Additionally, a clearer understanding of the efficacy of ά-terthienyl as a suitable target organism biocide should be determined, which could guide future directions of the many other plant allelochemicals as potential biocides to replace synthetic pesticides.

Phase III Paired Pot Study

The final phase of the thesis research project was Phase III, a paired-pot study conducted to further determine the effectiveness of yellow French marigold as a whitefly repellent plant. The experimental design was a RCBD with two treatment groups (T (treatment) = cantaloupe and yellow French marigold, and C (control) = cantaloupe only) replicated eight times (Fig. 11). Results from an independent-samples t-test showed significant difference in whitefly densities for the treatment (T) (M = 6.31, SD = 3.15) and no treatment (C) (M = 8.13, SD = 4.34) conditions; t(211) = -3.51, p = .001) (Table 10). As in the Phase I and II studies of this project, the results suggest that yellow French marigold is an effective repellent plant of whiteflies. A comparison chart additionally showed significant whitefly densities within the treatment groups, T and C (Fig. 13).

In summary, all results from each phase study of this research project document characteristic olfactory cues associated with yellow French marigold plants by whiteflies, which have not previously been explored. The observations presented in this paper provide basic information about the chemical ecology of marigold-cantaloupe-whitefly interactions that may facilitate the development of integrated pest management strategies apprised by an understanding of underlying ecological mechanisms. The difference in crop structure and cultural practices, including habitat diversification, can significantly affect species densities and abundance, without disturbing natural enemy complexes, and incorporation of yellow French marigold into an organic melon farming system can effectively repel the whitefly pest. Future studies, however, are required to test the efficacy of alpha-terthienyl in yellow French marigolds, as well as all other species of marigolds, and compare crop yields and fruit quality between treatment groups.

REFERENCES

Adam, K. 2006. Squash Bug and Squash Vine Borer: Organic Control. *ATTRA*. [Online]. Available: www.attra.ncat.org/attra-pub/PDF/squash_pest.pdf

Alavanja, Michael C.R. 2009. Pesticides Use and Exposure Extensive Worldwide. *Rev Environ Health.* v. 24(4): 303-309.

Alliance for Healthy Homes. http://www.afhh.org/hps/hps_pesticides.htm

American Phytopathological Society (2007, January 19). Whitefly Spreads Emerging Plant Viruses. *ScienceDaily*. Retrieved March 21, 2011, from http://www.sciencedaily.com/releases/2007/01/070118161622.htm

Arnanson, J.T., Mackinnon, S., Isman, M.B., and Durst, T. 1992. Insecticides in tropical plants with non-neurotoxic modes of action. *Recent advances in Phytochemistry.* v. 28: 107-131.

Batish, D.R., Singh, H.P., Saxena, D.B., and Kohli, R.K. 2002. Weed Suppressing Ability of Parthenin – A Sesquiterpene Lactone from*Parthenium Hysterophorus*. *New Zealand Plant Protection*. v. (55): 218-221.

Bellows, T.S., Kabashima, J.N., and Robb, K. 2002. Pest Notes: Giant Whitefly. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 7400. [Online]. Available: http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7400.html

Bethke, James, Gilrein, Dan, Ludwig, Scott, Oetting, Ronald, and Osborne, Lance. 2006. The Q-biotype Whitefly. Pest Management. http://agrilife.org/etipm/files/2011/01/Whitefly-GrowerTalks.pdf.

Bohn, G.W. and Davis, G.N. 1964. Insect pollination is necessary for the production of muskmelons (*Cucumis melo v. reticulatus*). *Journal of Apicultural Research. v.* 3(1)**:** 61-63.

Brown, J.K., Perring, Thomas M., Cooper, A.D., Bedford, I.D., and Markham, P.G. 2000. Genetic Analysis of *Bemisia* (Hemiptera: Aleyrodidae) Populations by Isoelectric Focusing Electrophoresis. Biochemical Genetics. v. 38(1-2): 13-25.

Brussaard, L., Caron, P., Campbell, B., Lipper, L., Mainka, S., Rabbinge, R., Babin, D., and Pulleman, M. 2010. Reconciling biodiversity conservation and food security: scientific challenges for a new agriculture. *Science Direct*. v. 2: 34-42.

Calvert, L., Villarreal, N., and Frohlich, D. Undated. Using Molecular Techniques to Analyse Whitefly Species and Biotypes in Latin America. In: *Whiteflies and Whitefly-borne Viruses in the Tropics.* 251-262.

CDC, Fourth National Report on Human Exposure to Environmental Chemicals.

Cohen, R., Burger, Y., and Katzir, N. 2004. Monitoring physiological races of Podoshpaera xanthii (syn. Sphaerotheca fuliginea), the causal agent of powdery mildew in cucurbits: Factors affecting race identification and the importance for research and commerce. *Phytoparasitica*. v. 32(2): 174-183.

Collier, T. and Van Steenwyk, R. 2004. A critical evaluation of augmentative biological control. *Biological Control*. v. 31: 245-256.

Cox, Caroline. 2006. Ten Reasons Not to Use Pesticides. *J. of Pesticide Reform.* v. 26(2): 10-12.

Crop Profile for Cantaloupes and Honeydew Melons in Texas. 2009. www.ipmcenters.org/cropprofiles/docs/TXcantaloupes.pdf

Delaplane, K.S. and Mayer, D.F. Crop pollination by bees. [Internet]. CABI Publishing Series. 2000. [cited 2010 October 24]. ISBN 0851994482, 9780851994482. Available from http://books.google.com/books?id=ZHGZkXa7xE4C&dq=cantaloupe+flower+corolla&source=gbs__navlinks_s

EPA, 1999

Evans, Gregory A. 2008. The Whiteflies (Hemiptera: Aleyrodidae) of the World and their Host Plants and Natural Enemies. Last Revised September 23, 2008.

Fannin, Blair. 2012. Updated 2011 Texas Agricultural Drought Losses Total $7.62 Billion. Texas A&M Agrilife. http://today.agrilife.org/2012/03/21/updated-2011-texas-agricultural-drought-losses-total-7-62-billion/

Frank, S. 2009. Biological control of arthropod pests using banker plant systems: Past progress and future directions. *Biol Control*. v. 52: 8-16.

Gallai, Nicola, Salles, Jean-Michel, Settele, Josef, and Vaissiere, Bernard E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics*. v. 68:810-821.

Gervais, J. A.; Luukinen, B.; Buhl, K.; Stone, D. 2010. *Imidacloprid Technical Fact Sheet*; National Pesticide Information Center, Oregon State University Extension Services. http://npic.orst.edu/factsheets/imidacloprid.pdf.

Green, R.J., Cornell, S.J., Scharlemann, J.P.W., and Balmford, A. 2005. Farming and the fate of wild nature. *Science*. v. 307: 550-555.

Jones, C.M., Gorman, K., Denholm, I., and Williamson, M.S. 2008. High-throughput allelic discrimination of B and Q biotypes of the whitefly, Bemisia tabaci, using TaqMan allele-selective PCR. *Pest Manag Scie*. vol. 64(1): 12-15.

Kiple, K., Ornelas, K. The Cambridge World History of Food. [Internet]. 2000 October [cited 2010 October 23]. II.C. Important Vegetable Supplements, II.C.6. Cucumbers, Melons, and Watermelons. Available from http:// www.cambridge.org/us/books/kiple/*cucumbers*.htm

Kuepper, G. and Dodson, M. 2001. Companion Planting: Basic Concepts and Resources. *ATTRA*. July. p. 1-13.

Lammerts van Bueren, E.T., Struik, P.C., and Jacobsen, E. 2002. Ecological concepts in organic farming and their consequences for an organic crop ideotype. *Netherlands J. of Agricultural Sci*. v. 50: 1-26.

Lammerts van Bueren, E.T. and Struik, P.C. 2004. The consequences of the concept of naturalness for organic plant breeding and propagation. *NJAS*. v. 52(1): 85-95.

Leigh, T.F., Roach, S.H., and Watson, T.F. 1996. Characterization of Insects and Mites. In: *Cotton Insects and Mites: Characterization and Management* (E.G. King, J.R. Phillips, and R.J. Coleman, eds.) The Cotton Foundation Publisher, Tennessee, pp. 18-860.

Liu, T.X. undated. Efficacies of Selected Insecticides against Pest Insects on Melons in South Texas. Texas A&M Agricultural Experiment Station, Weslaco. The Texas A&M University System.

Macfadyen, S., Gibson, R., Raso, L., Sint, D., Traugott, M., and Memmott, J. 2009. Parasitoid control of aphids in organic and conventional farming systems. *Agriculture, Ecosystems, and Environment*. v. 133: 14-18.

Mann, L.K. and Robinson, J. 1950. Fertilization, Seed Development, and Fruit Growth as Related to Fruit Set in the Cantaloupe (*Cucumis melo* L.) *American Journal of Botany*. v. 37(9): 685-697.

Massey, G. Ancient Egypt - The Light of the World: A Work of Reclamation and Restitution in Twelve Books. [Internet]. NuVision Publications, LLC, 2004. [Cited 2010 October 23]. ISBN 1595479945, 9781595479945. Available from http://books.google.com/books?id=PbyDxabXrqgC&lpg=PA1&pg=PA587#v=onepage&q&f=false

Maupin, J. and Norton, G. 2010. Pesticide Use and IPM Adoption: Does IPM Reduce Pesticide Use in the United States? Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA, CAES, & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010.

McCreight, J.D. and Simmons, A.M. 1998. Silverleaf Whitefly Resistance Strategies in Melon. *Cucurbitaceae*. 113-117.

McGregor, S.E. and Todd, F.E. 1952. Cantaloup production with honey bees. *Journal of Economic Entomology*. v. 45(1): 43-47.

Mercola, Joseph. 2013. Monsanto's Roundup Herbicide May Be Most Important Factor in Development of Autism and Other Chronic Disease. http://articles.mercola.com/sites/articles/archive/2013/06/09/monsanto-roundup-herbicide.aspx

Murphy, K.M., Campbell, K.G., Lyon, S.R., and Jones, S.S. 2007. Evidence of varietal adaptation to organic farming systems. *Field Crops Research*. v. 102: 172-177.

Narwal, S.S., Palaniraj, R., and Sati, S.C. 2005. Role of Allelopathy in Crop Production. *Herbologia*. v. 6(2): 1-69.

Nivsarkar, M., Cherian, B., and Padh, H. 2001. Alpha-terthienyl: A plant-derived new generation insecticide. *Current Science*. v. 81(6): 667-672.

Pickett, C.H., Simmons, G.S., Lozano, E., and Goolsby, J.A. 2004. Augmentative biological control of whiteflies using transplants. *Biocontrol*. v. 49: 665-688.

Priyanka, Dixit, Shalini, Tripathi, and Navneet, Verma Kumar. 2013. A Brief Study on Marigold (Tagetes Species): A Review. IRJP. 4(1): 43-48.

Renner, S.S., Schaefer, H., and Kocyan, A. 2007. Phylogenetics of *Cucumis* (Cucurbitaceae): Cucumber (*C. sativus*) belongs in an Asian/Australian clade far from melon (*C. melo*). *BMC Evolutionary Biology,* 7:58. Available from http://www.biomedcentral.com/1471-2148/7/58

SARE Bulletin (2004, July). How to Conduct Research on Your Farm or Ranch. http://www.sare.org/Learning-Center/Bulletins/How-to-Conduct-Research-on-Your-Farm-or-Ranch

Samsel A, and Seneff S. 2013. Glyphosate's Suppression of Cytochrome P450 Enzymes and Amino Acid Biosynthesis by the Gut Microbiome: Pathways to Modern Diseases. Entropy. 15(4):1416-1463.

Sandhu, H.S., Wratten, S.D., Cullen, R., and Case, B. 2007. The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecological Economics*. v. 64: 835-848.

Sauer, J.D. Historical Geography of Crop Plants: A Select Roster. [Internet]. CRC Press LLC, 1993. [Cited 2010 October 23]. ISBN 0849389011, 9780849389016. Available from http://books.google.com/boods?id=qroRAuJqpZIC&printsec=frontcover&dq=jonathan+sauer,+1993&source=bl&ots=TOjgT0RZ8b&sig=CipIGDanQW_rJkz5b6pMIzOV4Hc&hl=en&ei=5CK3TJmTGYP88AaMI8SJBw&sa=X&oi=book_result&ct=result&resnum=2&sqi=2%ved=0CBoQ6AEwAQ#v=onepage%q=jonathan sauer%2C 1993&f=false

Silberstein, L., Kovalski, I., Huang, R., Anagnostou, K., Jahn, M.M.K., and Perl-Treves, R. 1999. Molecular variation in melon (*Cucumis melo* L.) as revealed by RFLP and RAPD markers. *Scientia Horticulturae*. v. 79: 101-111.

Simoons, F.J. Food in China: a cultural and historical inquiry. [Internet]. CRC Press, 1991. [Cited 2010 October 23]. ISBN 084938804X, 9780849388040. Available from http://books.google.com/books?id=Fo087ZxohA4C&dq=Zohary+and+Hopf+1988&source=gbs_navlinks_s

Stepansky, A., Kovalski, I., and Perl-Treves, R. 1999. Intraspecific classification of melons (*Cucumis melo* L.) in view of their phenotypic and molecular variation. *Plant Systematics & Evolution*. v. 217: 313-333.

Stern, V.M. 1973. Economic thresholds. Annu. Rev. Entomol. v. 18: 259-280.

Straub, C.S., Finke, D.L., Synder, W.E. 2007. Are the conservation of natural enemy biodiversity and biological control compatible goals? *Biological Control*. v. 45: 225-237.

Sulsen, V.P., Frank, F.M., Cazorla, S.I., Anesini, C.A., Malchiodi, E.L., Freixa, B., Vila, R., Muschiette, L.V., and Martino, V.S. 2008. Trypanocidal and Leishmanicidal Activities of Sesquiterpene Lactones from *Ambrosia tenuifolia* Sprengle (Asteraceae). *Antimicrobial Agents and Chemotherapy*. v. 52(7): 2415-2419.

Szabo, Z., Gyulai, G., Toth, Z., and Heszky, L. 2008. Morphological and molecular diversity of 47 melon (Cucumis melo) cultivars compared to an extinct landrace excavated from the 15th century. Cucurbitaceae 2008, Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceae. *INRA*. 313-321.

Trinklein, D. 2010. The Marvelous Marigold. [Online]. Available: ppp.missouri.edu/newsletters/meg/archives/v16n4/a2.pdf

Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I., and Thies, C. 2005. Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. *Ecology Letters*. v. 8: 857-874.

Tylianakis, J.M., Tscharntke, T., and Lewis, O.T. 2007. Habitat modification alters the structure of tropical host-parasitoid food webs. *Nature*. v. 445: 202-205.

University of Guelph (2010, June 23). Organic pesticides not always “greener” choice, study finds. *ScienceDaily*. Retrieved March 15, 2010, from http://www.sciencedaily.com/releases/2010/06/100622175510.htm

USDA/Agricultural Research Service (2008, July 2). New Silverleaf Whitefly Resistant To Many Pesticides. *ScienceDaily*. Retrieved March 21, 2011, from http://www.sciencedaily.com /releases/2008/06/080629074432.htm

USDA, ARS, National Genetic Resources Program. Germplasm Resources Information Network – (GRIN) [Online Database]. National Germplasm Resources Laboratory, Beltsville, aryland. URL: http://www.ars-grin.gov/cgi-bin/npgs/html/genform.pl (23 October 2010)

USDA/Agricultural Research Service (2008, July 2). New Silverleaf Whitefly Resistant To Many Pesticides. *ScienceDaily*. Retrieved March 21, 2011, from http://www.sciencedaily.com /releases/2008/06/080629074432.htm

USDA/Animal Plant Health Inspection Service (APHIS)

USDA National Agricultural Library. National Invasive Species Information Center. http://www.invasivespeciesinfo.gov/animals/sla.shtml.

Wang, K.H., Hooks, C.R., and Ploeg, A. 2007. Protecting Crops from Nematode Pests: Using Marigold as an Alternative to Chemical Nematicides. *College of Tropical Agriculture and Human Resources*. 1-6.

Way, M.J. and van Emden, H.F. 2000. Integrated pest management in practice – pathways towards successful application. *Crop Protection*. v. 19: 81-103.

Zahm, S.H., and Ward, M.H., Environmental Health Perspectives, “Pesticides and Childhood Cancer,” Vol. 106 Suppl. 3, pp. 893-908 (June 1998)

.

APPENDIX A

APPENDIX A

Phase I multiple comparisons tests within blocks shows the effects of each replicate plot on whiteflies, aphids, and predators.

Multiple Comparisons

Dependent Variable		(I) Block	(J) Block	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Whitefly	Tukey HSD	Replicate I	Replicate 2	-96.00	81.216	.495	-328.07	136.07
			Replicate 3	47.60	81.216	.831	-184.47	279.67
		Replicate 2	Replicate I	96.00	81.216	.495	-136.07	328.07
			Replicate 3	143.60	81.216	.240	-88.47	375.67
		Replicate 3	Replicate I	-47.60	81.216	.831	-279.67	184.47
			Replicate 2	-143.60	81.216	.240	-375.67	88.47
	LSD	Replicate I	Replicate 2	-96.00	81.216	.271	-283.28	91.28
			Replicate 3	47.60	81.216	.574	-139.68	234.88
		Replicate 2	Replicate I	96.00	81.216	.271	-91.28	283.28
			Replicate 3	143.60	81.216	.115	-43.68	330.88
		Replicate 3	Replicate I	-47.60	81.216	.574	-234.88	139.68
			Replicate 2	-143.60	81.216	.115	-330.88	43.68
Aphid	Tukey HSD	Replicate I	Replicate 2	8.80	21.046	.909	-51.34	68.94
			Replicate 3	-11.40	21.046	.853	-71.54	48.74
		Replicate 2	Replicate I	-8.80	21.046	.909	-68.94	51.34
			Replicate 3	-20.20	21.046	.621	-80.34	39.94
		Replicate 3	Replicate I	11.40	21.046	.853	-48.74	71.54
			Replicate 2	20.20	21.046	.621	-39.94	80.34
	LSD	Replicate I	Replicate 2	8.80	21.046	.687	-39.73	57.33
			Replicate 3	-11.40	21.046	.603	-59.93	37.13
		Replicate 2	Replicate I	-8.80	21.046	.687	-57.33	39.73
			Replicate 3	-20.20	21.046	.365	-68.73	28.33
		Replicate 3	Replicate I	11.40	21.046	.603	-37.13	59.93
			Replicate 2	20.20	21.046	.365	-28.33	68.73
Predator	Tukey HSD	Replicate I	Replicate 2	2.40	1.023	.106	-.52	5.32
			Replicate 3	2.20	1.023	.141	-.72	5.12
		Replicate 2	Replicate I	-2.40	1.023	.106	-5.32	.52
			Replicate 3	-.20	1.023	.979	-3.12	2.72
		Replicate 3	Replicate I	-2.20	1.023	.141	-5.12	.72
			Replicate 2	.20	1.023	.979	-2.72	3.12
	LSD	Replicate I	Replicate 2	2.40*	1.023	.047	.04	4.76

APPENDIX B

APPENDIX B

Phase I multiple comparison tests within treatment groups shows the effects of each treatment on whiteflies, aphids, and predators.

Multiple Comparisons

Dependent Variable		(I) Treat	(J) Treat	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Whitefly	Tukey HSD	Yellow French Marigold	Dill	-995.33*	104.849	0	-1357.56	-633.11
			Cenizo	-958.00*	104.849	0	-1320.23	-595.77
			Zinnia	-1073.00*	104.849	0	-1435.23	-710.77
			Control	-997.67*	104.849	0	-1359.89	-635.44
		Dill	Yellow French Marigold	995.33*	104.849	0	633.11	1357.56
			Cenizo	37.33	104.849	0.996	-324.89	399.56
			Zinnia	-77.67	104.849	0.941	-439.89	284.56
			Control	-2.33	104.849	1	-364.56	359.89
		Cenizo	Yellow French Marigold	958.00*	104.849	0	595.77	1320.23
			Dill	-37.33	104.849	0.996	-399.56	324.89
			Zinnia	-115	104.849	0.804	-477.23	247.23
			Control	-39.67	104.849	0.995	-401.89	322.56
		Zinnia	Yellow French Marigold	1073.00*	104.849	0	710.77	1435.23
			Dill	77.67	104.849	0.941	-284.56	439.89
			Cenizo	115	104.849	0.804	-247.23	477.23
			Control	75.33	104.849	0.946	-286.89	437.56
		Control	Yellow French Marigold	997.67*	104.849	0	635.44	1359.89
			Dill	2.33	104.849	1	-359.89	364.56
			Cenizo	39.67	104.849	0.995	-322.56	401.89
			Zinnia	-75.33	104.849	0.946	-437.56	286.89
	LSD	Yellow French Marigold	Dill	-995.33*	104.849	0	-1237.12	-753.55
			Cenizo	-958.00*	104.849	0	-1199.78	-716.22
			Zinnia	-1073.00*	104.849	0	-1314.78	-831.22
			Control	-997.67*	104.849	0	-1239.45	-755.88
		Dill	Yellow French Marigold	995.33*	104.849	0	753.55	1237.12
			Cenizo	37.33	104.849	0.731	-204.45	279.12
			Zinnia	-77.67	104.849	0.48	-319.45	164.12
			Control	-2.33	104.849	0.983	-244.12	239.45
		Cenizo	Yellow French Marigold	958.00*	104.849	0	716.22	1199.78
			Dill	-37.33	104.849	0.731	-279.12	204.45
			Zinnia	-115	104.849	0.305	-356.78	126.78
			Control	-39.67	104.849	0.715	-281.45	202.12
		Zinnia	Yellow French Marigold	1073.00*	104.849	0	831.22	1314.78
			Dill	77.67	104.849	0.48	-164.12	319.45
			Cenizo	115	104.849	0.305	-126.78	356.78
			Control	75.33	104.849	0.493	-166.45	317.12
		Control	Yellow French Marigold	997.67*	104.849	0	755.88	1239.45
			Dill	2.33	104.849	0.983	-239.45	244.12
			Cenizo	39.67	104.849	0.715	-202.12	281.45
			Zinnia	-75.33	104.849	0.493	-317.12	166.45

Aphid	Tukey HSD	Yellow French Marigold	Dill	2	27.17	1	-91.86	95.86
			Cenizo	-21.67	27.17	0.924	-115.53	72.2
			Zinnia	0.67	27.17	1	-93.2	94.53
			Control	5.33	27.17	1	-88.53	99.2
		Dill	Yellow French Marigold	-2	27.17	1	-95.86	91.86
			Cenizo	-23.67	27.17	0.9	-117.53	70.2
			Zinnia	-1.33	27.17	1	-95.2	92.53
			Control	3.33	27.17	1	-90.53	97.2
		Cenizo	Yellow French Marigold	21.67	27.17	0.924	-72.2	115.53
			Dill	23.67	27.17	0.9	-70.2	117.53
			Zinnia	22.33	27.17	0.917	-71.53	116.2
			Control	27	27.17	0.851	-66.86	120.86
		Zinnia	Yellow French Marigold	-0.67	27.17	1	-94.53	93.2
			Dill	1.33	27.17	1	-92.53	95.2
			Cenizo	-22.33	27.17	0.917	-116.2	71.53
			Control	4.67	27.17	1	-89.2	98.53
		Control	Yellow French Marigold	-5.33	27.17	1	-99.2	88.53
			Dill	-3.33	27.17	1	-97.2	90.53
			Cenizo	-27	27.17	0.851	-120.86	66.86
			Zinnia	-4.67	27.17	1	-98.53	89.2
	LSD	Yellow French Marigold	Dill	2	27.17	0.943	-60.65	64.65
			Cenizo	-21.67	27.17	0.448	-84.32	40.99
			Zinnia	0.67	27.17	0.981	-61.99	63.32
			Control	5.33	27.17	0.849	-57.32	67.99
		Dill	Yellow French Marigold	-2	27.17	0.943	-64.65	60.65
			Cenizo	-23.67	27.17	0.409	-86.32	38.99
			Zinnia	-1.33	27.17	0.962	-63.99	61.32
			Control	3.33	27.17	0.905	-59.32	65.99
		Cenizo	Yellow French Marigold	21.67	27.17	0.448	-40.99	84.32
			Dill	23.67	27.17	0.409	-38.99	86.32
			Zinnia	22.33	27.17	0.435	-40.32	84.99
			Control	27	27.17	0.349	-35.65	89.65
		Zinnia	Yellow French Marigold	-0.67	27.17	0.981	-63.32	61.99
			Dill	1.33	27.17	0.962	-61.32	63.99
			Cenizo	-22.33	27.17	0.435	-84.99	40.32
			Control	4.67	27.17	0.868	-57.99	67.32
		Control	Yellow French Marigold	-5.33	27.17	0.849	-67.99	57.32
			Dill	-3.33	27.17	0.905	-65.99	59.32
			Cenizo	-27	27.17	0.349	-89.65	35.65
			Zinnia	-4.67	27.17	0.868	-67.32	57.99

Predator	Tukey HSD	Yellow French Marigold	Dill	0.33	1.321	0.999	-4.23	4.9
			Cenizo	0.33	1.321	0.999	-4.23	4.9
			Zinnia	1.67	1.321	0.719	-2.9	6.23
			Control	0.33	1.321	0.999	-4.23	4.9
		Dill	Yellow French Marigold	-0.33	1.321	0.999	-4.9	4.23
			Cenizo	0	1.321	1	-4.56	4.56
			Zinnia	1.33	1.321	0.844	-3.23	5.9
			Control	0	1.321	1	-4.56	4.56
		Cenizo	Yellow French Marigold	-0.33	1.321	0.999	-4.9	4.23
			Dill	0	1.321	1	-4.56	4.56
			Zinnia	1.33	1.321	0.844	-3.23	5.9
			Control	0	1.321	1	-4.56	4.56
		Zinnia	Yellow French Marigold	-1.67	1.321	0.719	-6.23	2.9
			Dill	-1.33	1.321	0.844	-5.9	3.23
			Cenizo	-1.33	1.321	0.844	-5.9	3.23
			Control	-1.33	1.321	0.844	-5.9	3.23
		Control	Yellow French Marigold	-0.33	1.321	0.999	-4.9	4.23
			Dill	0	1.321	1	-4.56	4.56
			Cenizo	0	1.321	1	-4.56	4.56
			Zinnia	1.33	1.321	0.844	-3.23	5.9
	LSD	Yellow French Marigold	Dill	0.33	1.321	0.807	-2.71	3.38
			Cenizo	0.33	1.321	0.807	-2.71	3.38
			Zinnia	1.67	1.321	0.243	-1.38	4.71
			Control	0.33	1.321	0.807	-2.71	3.38
		Dill	Yellow French Marigold	-0.33	1.321	0.807	-3.38	2.71
			Cenizo	0	1.321	1	-3.05	3.05
			Zinnia	1.33	1.321	0.342	-1.71	4.38
			Control	0	1.321	1	-3.05	3.05
		Cenizo	Yellow French Marigold	-0.33	1.321	0.807	-3.38	2.71
			Dill	0	1.321	1	-3.05	3.05
			Zinnia	1.33	1.321	0.342	-1.71	4.38
			Control	0	1.321	1	-3.05	3.05
		Zinnia	Yellow French Marigold	-1.67	1.321	0.243	-4.71	1.38
			Dill	-1.33	1.321	0.342	-4.38	1.71
			Cenizo	-1.33	1.321	0.342	-4.38	1.71
			Control	-1.33	1.321	0.342	-4.38	1.71
		Control	Yellow French Marigold	-0.33	1.321	0.807	-3.38	2.71
			Dill	0	1.321	1	-3.05	3.05
			Cenizo	0	1.321	1	-3.05	3.05
			Zinnia	1.33	1.321	0.342	-1.71	4.38

Based on observed means.

The error term is Mean Square(Error) = 2.617.

*. The mean difference is significant at the .05 level.

BIOGRAPHICAL SKETCH

Ruth Renee Colyer was born in Toledo, Ohio. She graduated from McAllen Memorial High School in McAllen, Texas, and later attended The University of Texas – Pan American where she earned the degree of Bachelor of Science in May 2009. She subsequently entered the Graduate School of Science at The University of Texas – Pan American and earned the degree of Master of Science in August 2014.

While attending graduate school, she was employed by the United States Department of Agriculture as a Biological Technician at Mission Moore Airbase Quarantine Lab in Mission, Texas, and the USDA/ARS Subtropical Research Laboratory at Weslaco, Texas. In August 2012, she accepted a position as a Biology Teacher at Juarez-Lincoln High School, La Joya Independent School District, and the following year she additionally served as the Science Department Chair.

Ruth currently resides at 1852 West Mile 9 Road in Mission, Texas, 78573. She remains employed with La Joya Independent School District as a Biology Teacher and Science Department Chair.