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Managing bacterial wilt, caused by Erwinia tracheiphila, on muskmelon with early control of striped cucumber beetle (Acalymma vittatum (F)), and through varietal selection

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MANAGING BACTERIAL WILT, CAUSED BY *Erwinia tracheiphila*, ON MUSKMELON WITH EARLY CONTROL OF STRIPED CUCUMBER BEETLE (*Acalymma vittatum* (F)), AND THROUGH VARIETAL SELECTION

A Thesis

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Dedicated to my loving parents, brothers, sisters especially to my warm-hearted wife and children, who have supported and cheered me throughout the process. I have been very blessed and grateful for their support, encouragement and fortitude at entire of my life.

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ABSTRACT

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Muskmelon (*Cucumis melo* L), is an important vegetable crop in the United States. It is grown throughout the US, and Indiana ranked 4th in production after California, Arizona and Georgia with 12.4 thousand metric tons and market value of $7.6 million in 2015. Bacterial wilt of cucurbits, which is caused by *Erwinia tracheiphila* (E. F. Smith), and vectored by striped cucumber beetle (*Acalymma vittatum* (F)), is one of the most serious diseases of muskmelon that influences muskmelon quality and yield. Many cultivars of muskmelon are grown around the United States, especially in the Midwest. Muskmelon cultivars differ in attractiveness to the striped cucumber beetle (SCB) and susceptibility to BW, but no known cultivar resistant to BW has been introduced. The primary method for managing BW is controlling the striped cucumber beetle before it can infect the plant. However, it is not known whether there is a critical stage during early plant growth when muskmelon plants are more susceptible to infection and therefore control of striped cucumber beetle is especially important. We conducted three field experiments at two locations (Lafayette and Vincennes, IN) in 2013 and 2014 to investigate whether there is a critical period for striped cucumber beetle control sometime during the first three weeks after muskmelons are transplanted to the field. We found that using row covers that exclude beetles, seed treatment or soil drenches with insecticide thiamethoxam significantly reduces the beetle numbers and wilt and increases the number of marketable fruits yield compared to not controlling striped cucumber beetle. However, the length of time row covers were left on the plants (for 7, 14, or 21 days after transplanting, DAT), or the period beetles were permitted to feed on plants (0-7, 7-14, or 14-21 DAT), or the time when beetles began to feed on plants (0, 7, or 14

DAT) did not significantly influence disease influence or yield in a consistent manner. This suggests that there is no clear 'critical period' during early muskmelon growth when controlling striped cucumber beetles is especially important. The data show that maximum severity of bacterial wilt occurred in June and July, which corresponds to development of disease transmitted by feeding of overwintered beetles plus additional transmission by the first generation of adults to emerge in the summer.

We also conducted field studies in 2015 and 2016 with 10 to 12 cultivars at three locations (Lafayette, Wanatah and Vincennes, Indiana) to identify those most and least attractive to SCB and susceptible to BW. Replicated plots of each cultivar were grown and natural populations of SCB allowed to feed. At one location, additional plots of each cultivar were populated with 5 SCB per plant, and row covers applied to keep the SCB near the plants for 3 weeks. Results differed among locations. Without row covers, cultivars 'Diplomat', 'Dream Dew' and 'RML 9818' attracted higher numbers of SCBs than most other cultivars at one location each. 'Dream Dew' (at all locations) and 'RML 9818' (at two locations) had significantly higher percentages of BW than the least susceptible cultivars. Without row covers, 'Superstar', 'Aphrodite' and 'Wrangler' produced significantly greater yield than the lowest yielding cultivars at all locations. With row covers, early season beetle populations did not differ among cultivars and BW was greatest in 'Dream Dew' and least in 'Superstar' with other cultivars intermediate. With row covers, 'Athena' and 'Superstar' produced greater yield than many other cultivars. Over all 'Diplomat' and 'Dream Dew' were the most attractive to beetles and susceptible to BW. 'Aphrodite', 'Athena' and especially 'Superstar' were less attractive to beetles and showed more tolerance to BW in both 2015 and 2016. We found cucurbitacin A in leaves of 'Athena' and 'RML9818', and cucurbitacin B only in leaves and stems of 'Dream Dew' and 'RML9818'. All cultivars had cucurbitacin I in both leaves and stems. In leaves the highest level of cucurbitacin I was found in 'Hales Best' followed by 'Afg1' and 'Superstar', and the highest level of cucurbitacin A was found in 'RML9818'. Stems of 'Diplomat' had the most cucurbitacin I, followed 'Superstar', 'Dream Dew' and 'Hales Best'. Cucurbitacin B was the highest in stems of both 'Dream Dew' and 'RML9818'. Cucurbitacin E was present at similar levels in the stems of 'Diplomat', 'Hales Best' and 'Afg2'.

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Muskmelons (*Cucumis melo* L.) are important commercial vegetables belonging to the Cucurbitaceae. Other members of this family include cucumber, gourds, squash, pumpkin and watermelon. Melon is grown throughout the world. Muskmelons or cantaloupes are commonly grown in the United States, which ranked 5th after China, Turkey, Iran, and Egypt, with total production of 98.52 million metric tons in 2014. The per capita consumption of muskmelon in the United States was 3.95 kg in 2011 (USDA, 2014). Indiana ranked 4^{th} among the states after California, Arizona and Georgia, with 12,400 metric tons of total production, and farm value of $7.6 million. The United States is a major importer of muskmelon from Latin America during the off-season from December through May (Boriss et al., 2014; USDA, 2016).

Muskmelon growers face a good market, but muskmelon production is challenging, requiring management of several pests and diseases. In the United States, striped cucumber beetle (SCB) (*Acalymma vittatum* (F.)), (Coleoptera: Chrysomelidae) is the most serious economic pest of muskmelon. It is native to the United States and is distributed throughout North America. This insect is a serious problem for cucurbit growers in the Midwest, Mid-Atlantic, and Northeast regions, and southern Canada (Rojas et al., 2015). SCB can feed on leaves, flowers, stems, and fruit as adults and on roots as larvae. Most importantly, it transmits the bacterium *Erwinia tracheiphila* (E. F. Smith), into the plant causing the disease bacterial wilt (BW) of cucurbits.

SCB overwinter in field under dead leaves and debris, emerge when temperatures reach 12-15 $^{\circ}$C, and begin searching for cucurbit hosts. In the absence of cucurbits, SCB will feed on alternative crops such as such as aster, rose, and legumes (Wilson et al., 2014). SCB generally feed on the pollen and nectar of these plants until cucurbit hosts become available (Alston and Worwood, 2008). The number of generations depends on temperature, but in the Midwest there is usually a single generation per year. The bacterium is not transmitted from one generation to the next; it can only be acquired by a beetle feeding on infected plants (Alston and Worwood, 2008; Bachmann, 2013; Foster et al., 1995).

The bacterium overwinters in the gut of SCB. Transmission occurs when an infected beetle makes a feeding wound in the plant, defecates into that wound, and free water is present to move the bacterium into the xylem (Smith, 1911). The bacterium multiplies and spreads throughout the entire plant through the xylem, blocking the vascular bundles (xylem and phloem), which stops water and nutrients from moving to more distal parts of the plant. Disease symptoms include wilting of some or all parts of plants and discoloration of the stem tissues. First symptoms of bacterial wilt appear from 4 to 21 days after transmission of the bacterium into the plant (De Mackiewicz et al., 1998; Rojas et al., 2013; Smith, 1911; Yao et al., 1996). The feeding wound becomes dark green, and later the entire plant shows a dull green color. Seedlings develop symptoms more rapidly and the plants collapse more quickly than mature plants. The percent of infection ranges from 10-75, and can vary depending on the number of beetles per plant, presence of bacteria in their gut, availability of water, plant growth stage, cultivars, and management strategies (Brust and Foster, 1999; De Mackiewicz et al., 1998). Fruit harvested from infected plants are very low in sugar content and are not marketable (Foster, 2010).

Because of the potential losses associated with SCB and bacterial wilt in muskmelons, integrated pest management (IPM) is necessary. Preventing the beetles from feeding on the melon plants and thus avoiding transmission of the bacterium can be achieved with various types of insecticides, including seed treatments, soil drenches, and foliar sprays. Additionally, planting cultivars that are less attractive to the SCB or less susceptible to bacterial wilt would also contribute to successful melon production.

The main objectives of this dissertation research were:

1. To determine if there is a time in the first three weeks after transplanting when muskmelon plants are more susceptible to SCB feeding and transmission of bacterial wilt.
2. To determine the attractiveness of various cultivars to feral SCBs and susceptibility to BW under field conditions.

1- To determine the susceptibility of different cultivars inoculated with BW pathogen under controlled condition.

2- To determine whether the concentration or type of cucurbitacin in a cultivar is related to its attractiveness to SCB or susceptibility to BW.

1.2. Literature Review

1.2.1. Muskmelon

1.2.1.1. Muskmelon Origin and Production

Muskmelon *(Cucumis melo L.)* 2n = 24 is one of the most economically important horticultural crops. It belongs in the Cucurbitaceae, a family that includes other fruits and vegetables, such as watermelon, squash, cucumber, and pumpkin. Muskmelon is generally thought to have originated in western Africa (Purseglove, 1976; Whitaker and Bemis, 1975; Zeven and Zhukovsky, 1975), with further diversification occurring in China, India, Afghanistan and Iran (Robinson and Decker-Walters, 1997). Muskmelon was introduced to America in 1516, to Virginia in 1609, and to New York in 1629 (Mallick and Masui, 1986).

Melons are divided into seven groups of cultivars characterized by differences in plant vegetative and reproductive botany, as well as fruit taste, shape, and external and internal color. Common names of the groups, species, botanical cultivars, and descriptions as summarized by Stepansky et al. (1999); and species, subspecies, and botanical cultivars accepted by the U.S. Dept. of Agriculture Germplasm Resources Information Network (USDA, 2012) are in Table 1.1. The term muskmelon is sometimes used to include both cantaloupe and honey dew, although often the term is used as a synonym for cantaloupe, as it is in Table 1.1. 'Muskmelon' is derived from the words 'musk' describing the odor, and 'melon' describing the shape. Musk is a Persian word for a kind of perfume, and melon comes from the Latin melopepo, which means apple-shaped (Sturtevant, 1891). In this document we will use the term muskmelon for both orange-fleshed and green-fleshed muskmelons.

Even within melons that fit the narrower definition of muskmelon or cantaloupe there are subcategories recognized in the marketplace. For instance, 'western' or 'shipping' muskmelons are smaller than 'eastern' types, more uniform in shape, and have a heavily-netted rind and orange flesh. This type is broadly grown in the western United States. In contrast, the 'eastern' type of muskmelons are larger, less uniform in fruit shape with less heavily-netted rind, and have orange or salmon flesh. Among the inodorous group, honeydew melon is most common in the United States; it has green flesh and a smooth rind. (Boyhan et al., 2014; Mabalaha et al., 2007).

The origin of muskmelon is believed to go back to 300-2400 BC in Egypt, based on paintings of muskmelon in Egyptian art. Muskmelon arrived in Europe from Asia. Asia and Africa are believed to be where muskmelons were first domesticated from wild relatives (Jeffrey, 1980; Kirkbride, 1993; Pangalo, 1929). A DNA study of 100 *Cucumis* cultivars from Asia, Africa and Australia indicated that muskmelons originated in Africa and Asia (Sebastian et al., 2010).

How muskmelons are consumed depends on culture, availability and taste. Muskmelon can be used both fresh and preserved with common practice varying among countries.

In the United States in 2015, 21,550 ha of cantaloupe and 5,544 ha of honeydew were grown. Production was 608,400 metric tons of cantaloupe and 163,000 metric tons of honeydew. The average price per 45.4 kg was $19.5 for cantaloupe and $22.7 for honeydew. The value of production was $262 million for cantaloupe and $480.5 million for honeydew (USDA, 2016). The average per capita consumption of muskmelon in the United States was 3.95 kg in 2011 (USDA, 2013).

California is the biggest national producer of muskmelon in the United States with about 374,600 metric tons, followed by Arizona which produced 161,300 metric tons, Georgia with 22,900 metric tons and Indiana with 12,400 metric tons (USDA, 2016). The United States is a major importer of muskmelons especially from Latin America during the off-season from December through May (USDA, 2013).

Worldwide, China is the largest producer of muskmelon followed by Turkey, Iran, Brazil, United States and Egypt (Boriss et al., 2014; USDA, 2014). In 2014 the United States was the 5th largest muskmelon producer with total production of 985,000 metric tons, and was in 7th position in total harvested acreage in the world. Worldwide production of muskmelon was around 27.3 million metric tons. Sixty-three percent of total production comes from China, Turkey, Iran, Brazil, United States and Egypt (Boriss et al., 2014; USDA, 2014).

1.2.1.2. Muskmelon Nutritional Value

Muskmelon plays an important role in human health, nutrition and economy. Muskmelons are a good source of nutrients such as vitamins A and C and potassium, which help control blood pressure and heart diseases, cancer, and improve vision. Muskmelons are relatively low in calories, fat, and sodium. Chemical analysis of different cultivars of muskmelon indicates that they are good sources of protein, mineral, fiber, carbohydrate, and fatty acids such as linoleic and oleic acid. They are consumed fresh, as juice, mixed with other desserts, and used in skin care products, and for perfume in many countries (Boyhan et al., 2014; Ionica et al., 2015). Muskmelon has different medicinal properties such as, anti-oxidant, anti-inflammatory, analgesic, anti-platelet, anti-ulcer, anti-cancer, free radical scavenging, anti-microbial, anti-diabetic, hepato-protective, diuretic, and anti-fertility (Milind and Singh, 2011).

The quantity of different compounds in muskmelon fruits can vary due to their stage of growth and development. The dry matter and total soluble matter accumulation in muskmelon fruit increased constantly during the early stage of growth, but increased more rapidly at maturity. In addition, the total antioxidant content in muskmelon fruit increased during all stages of growth and development. (Ionica et al., 2015).

1.2.1.3. Muskmelon Characteristics

Muskmelons are vining plants that grow well when the temperature is between 18-27 °C, soil is well drained, and soil pH is between 6 and 6.5 (Foord and MacKenzie, 2009). Pollination is a key factor in determining yield. Muskmelons can be monoecious or andromonoecious, meaning male and female flower or perfect flowers are separate but located on the same plant. Female flowers appear after the male flowers, most of female flowers appear on the secondary branches. The first 7 flowers on a plant are generally male, after which female flowers are also produced. Fruit set and yield depend on pollinators, especially honeybees, to transfer pollen from the male to the female or perfect flowers. Melon flowers usually open in the early morning between 7-8 am. Each flower produces nectar after opening, which attracts honeybees until noon. Honeybee activity is less in the afternoon due to low nectar availability and high temperature. Flowers can be pollinated by wild honeybees, but usually providing 4 to 6 hives per hectare is necessary for high yield (Ribeiro et al., 2015). Fruit formation depends on the number of pollen grains that are deposited on the female flower, and about 500 viable pollen grains should be placed on the stigma to produce marketable fruit. Too many hives in an area can reduce yield because the bees compete with each other for pollen and may not leave enough on the stigma for good fruit set (Ribeiro et al., 2015). Other factors such as temperature, bees' activity, insecticides, rain and wind can also affect yield. The number of days from seeding to fruit maturity depends on cultivar and ranges from 75-85 days. From fruit set to maturity takes 45-55 days (Maynard, 2007).

Table 1.1 Characteristics of different melon groups

Common Name	Botanical Variety and description (after Stepansky et al., 1999)	Taxon from U.S. Dept. of Agr. Germplasm Resources Information Network
Muskmelon, cantaloupe	*C. melo var. cantalupensis*: Medium-large size fruits, smooth, scaly or netted rind of variable colour. Fruits are aromatic with sweet, juicy flesh, and abscise at maturity. Includes also former *var. reticulatus*. Andromonoecious flowering in most genotypes, hairy ovary. Includes "dessert" melon types such as Galia, Ananas, Charentais, "American shippers".	*C. melo ssp. melo var. cantalupo*
Winter melon	*C. melo var. inodorus*. Large-sized winter melons, with non-aromatic, non-climacteric and long-storing fruits, with thick, smooth or warty rind. Includes sweet dessert melons from Asia and Spain, such as honeydew and casaba type cultivars. Usually andromonoecious, hairy ovary.	*C. melo ssp. melo var. inodorus*
Snake or serpent melon	*C. melo var. flexuosus*. Fruits are very elongated, non-sweet, eaten immature as cucumbers. Found in the Middle East and Asia, where similar, less elongated types, adzhur and chate, have also been reported as ancient vegetable crops (Hammer et al., 1986; Pangalo 1929). Usually monoecious.	*C. melo ssp. melo var. flexuosus*
Pickling melon	*C. melo var. conomon*. Far-Eastern cultivars, where the smooth, white-fleshed, thin rinded fruits are eaten as pickles; includes also sweet, crisp fruits eaten with their rind. Andromonoecious vines bear dark, spiny leaves, sericeous ovaries. Corresponds to *Naudin's var. acidulus*.	*C. melo ssp. agrestis var. conomon*
Pomegranate melon, Queen Anne's pocket melon	*C. melo var. chito* and *dudaim* were described by Naudin, but grouped together by Munger and Robinson. The former was reportedly of American feral origin, with small plum-size, aromatic fruits used as pickles, monoecious vines and sericeous ovaries. The second is of Persian origin, andromonoecious, sericeous ovaries, bears small, aromatic, red or brown-striped fruits, grown as ornamentals in Oriental gardens.	*C. melo ssp. agrestis var. dudaim*
Snap melon	*C. melo var. momordica*. A group added by Munger and Robinson (1991) to include Indian accessions with monoecious vines, sericeous ovaries and large, non-sweet fruits with thin rind that splits at maturity	*C. melo ssp. agrestis var. momordica*
Ulcardo melon	*C. melo var. agrestis*: thin-stemmed, monoecious plants growing as weeds in African and Asian countries. Very small (< 5 cm), inedible fruits with very thin mesocarp and tiny seeds.	*C. melo ssp. agrestis var. agrestis*

(Stepansky, et al., 1999; USDA, 2012)

1.2.1.4. Production with Drip Irrigation and Plastic Mulch

Muskmelon is a warm season crop, and in the Midwest, it is typically transplanted onto raised beds covered with black plastic mulch to benefit from faster development that results from soil warming provided by the mulch. Beds are commonly centered 1.5- 2 m apart with 0.6-1 m between each plant within the row (Egel et al., 2016). Water is an important element of growing any crop. Muskmelons require water at all stages of growth and development, especially at flowering, fruit set and fruit maturation. A water deficit during critical stages can negatively affect plant growth, fruit development and postharvest management. Many producers have adopted drip irrigation, which was developed in the early 1960s, and can reduce water loss up to 50% compared with overhead irrigation (Ayars et al., 1999; Zeng et al., 2009). Drip irrigation also permits efficient fertilizer application, while maintaining soil moisture, used drip irrigation to improves yield and quality of products compared to other methods of irrigation (Ayars et al., 1999; Zeng, et al., 2009).

Overwatering can be dangerous for muskmelon plant and fruit quality, causing plant stress, and promoting diseases (Cabelloa et al., 2009; Zeng et al., 2009;). In addition, high moisture at the fruit ripening stage can reduce fruit quality (Egel et al., 2016). Several reports demonstrate that careful water management can increase yield and quality. A two-year study of the effect of subsurface and surface drip irrigation on muskmelon by Dogan et al. (2008) showed that irrigation significantly improved muskmelon fruit quality and quantity. Muskmelon produced greater yield and fruit size in both systems at maximum water availability. A different study investigated applying different levels of irrigation (100% based on crop evapotranspiration (ETc (control treatment)), 80% ETc, 60% ETc and 40% ETc (water stress treatment) with plastic mulches. Plants with the high level of irrigation were taller by 23.4- 24.8% and had greater leaf area (20.8-21.2%) than those in the water stress treatment (40% ETc). Also, the high level of water produced greater yield when plants were grown with plastic mulch than the control treatment (100% ETc) with no-mulch (Alenazi et al., 2015; Cabelloa et al., 2009).

Drip irrigation can also aid in managing soil pests and diseases because certain insecticides and fungicides can be applied through drip irrigation. Root knot nematode is one of the serious plant parasites that can be managed by applying pesticides through drip irrigation. Application of the fumigant dimethyl disulfide (DMDS) to the soil through drip irrigation had a significant effect on control of root knot nematode of muskmelon and tomato. The nematode populations were greater in untreated plots compared to the DMDS treatment (Sasanellia et al., 2014).

Providing fertilizers for the plants through drip irrigation has become common in many areas. Properly managed, this practice leads to more efficient fertilizer use because it helps to reduce excess application and places fertilizer close to the zone of highest root activity thereby increasing crop uptake. The amount of fertilizer recommended for muskmelon varies due to the soil type, cropping history, and production system. Nitrogen, phosphorous, and potassium are the main fertilizers that farmers apply to the soil. Recommendations for the Midwest include N at 36 to 54 kg per hectare before planting plus an additional 40 kg per hectare side dressing or in smaller increments through drip irrigation; P_2O_5 at 0 to 136 kg per hectare; and K_2O at 0 to 180 kg per hectare. Using plastic mulch with drip irrigation can decrease N leaching, thus the amount of N can be reduced (Egel et al., 2016). Applying fertilizers through drip irrigation as fertigation could increase fruit quality and quantity, as shown in an experiment to investigate the effect of phosphorus fertigation on muskmelon fruit (*Cucumis melo L*.) conducted by Martuscelli et al., (2015). The study showed that P found in the muskmelon plant increased from 0- 250 kg per hectare, and the fruit pulp thickness, fruit size, total soluble solids and yield increased with the amount of P uptake by muskmelon plants.

Combined use of drip irrigation and mulches for vegetable crops has increased since they were developed in the 1950s and 60s. Around 130,000 metric tons plastic mulch were used by producers in the United States (Shogren and Hochmuth, 2004), and worldwide around 700,000 metric tons in 2006 (Espi et al., 2006). Mulching is used for controlling weeds, maintaining soil moisture, preventing soil erosion, maintaining soil nutrients and controlling pests. There are plastic mulches based on colors including black, white, silver, red, blue, brown IRT (infrared transmitting), green IRT and yellow. Each color maintains the soil temperature at a different level and absorbs, transmits, and reflects different wavelengths, so they can be used in different seasons and crops based on the crop responses to the temperature and light environment they create (Orzolek and Lamont, 2016).

Plastic mulches can also increase yield if drip irrigation is used. Drip irrigation with plastic mulch significantly improved cantaloupe fruit weight, thickness, total yield, water use efficiency, and weed control compared to non-mulched (Seyfi and Rashidi, 2007). In the Alenazi study mentioned above (2015), the plastic mulch treatment with the high level of water produced 37.06-40.11% more yield than non-mulched treatment with the same amount of water, because the plastic mulches increased water use efficiency. Plastic mulches also have potential to influence SCB population dynamics because of the mulch effect on soil temperature. Beetle eggs hatch faster in warm soils up to 32 ˚C, but soils under plastic mulches could increase above 32 ˚C and so could inhibit emergence of larvae from the eggs (Ellers-Kirk and Fleischer, 2006; Necibi et al., 1992).

1.2.1.5. Harvesting and storage

Muskmelon is highly perishable because it contains more than 90% water. This perishability affects the marketing and consumption of muskmelon around the world. The majority of damage that reduces shelf life occurs during harvesting, handling, packaging, transporting and storage (Ma et al., 2012). Respiration is also a big factor of reducing shelf life of muskmelon, and it depends on temperature. Respiration rates at 0 - 25 ˚C are about 4 - 16 mg CO_2 kg^{-1} h^{-1}, and at 20 – 23 ˚C are about 54 mg CO_2 kg^{-1} h^{-1} (Gorny, 2001). Thus, the quality of melons in the marketplace is determined largely by the cultivar, time of harvesting, transportation, precooling, sorting, packaging and preserving. Postharvest losses are higher in developing countries, 20-50% compared to 5-35% in developed countries (Kader, 2002).

Harvesting at the proper stage is critical to minimize postharvest losses. Melons that form an abscission layer between fruit and peduncle (‘slip’ from the vine), such as cantaloupe, should be harvested before the abscission layer fully forms, at the ‘half-slip’ stage, for maximum shelf life. Fully mature fruits do not withstand postharvest handling and transport, leading to a shorter shelf life (Egel et al., 2016).

Storage temperature is important in maintaining melon quality after harvest. Gong et al. (2015) found that muskmelon fruits kept at 7°C maintained fruit quality, total soluble solids, and fruit firmness longer than fruits stored at 3 ˚C or 9 ˚C. Xuewen et al. (2012) showed that rates of respiration and ethylene formation in muskmelon were lower at 10 and 5 ˚C, than at 15, 20, or 25 ˚C, and fruits retained quality longer at the lower temperatures. Fresh cuts of muskmelon stored under controlled conditions at 14 -15 ˚C had a longer shelf life (about 4 days) compared to the uncontrolled environment 27 – 28 ˚C (about 2 days) (Falah et al., 2015).

The quality and freshness of melon can also be preserved by using anti-microbial agents such as, O_3, UV–C radiation, intense light pulses, super high O_2, N_2O and noble gas after harvesting, and especially during processing (Artes et al., 2009). The shelf life of muskmelons is also influenced by specific genes and by genetic variation in ethylene production. There are several genes known to be responsible for preserving the quality of muskmelons during storage. CmASN and CmHPD in melon are the genes that code for preserving freshness and quality of melon after harvesting (Cavaiuolo et al., 2015). An evaluation of 60 melon genotypes for ethylene production rate indicated that different genotypes produce amounts of ethylene ranging from 0-130 nl/g h. Fruits with netted rinds produce more ethylene than those with smooth rinds and green and white flesh. Netted fruits with high ethylene had shorter shelf life compared to those with smooth rinds (Zheng and Wolff, 2000).

1.2.2. Striped Cucumber Beetle (SCB) (*Acalymma vittata* (F.))

1.2.2.1. Striped Cucumber Beetle (SCB)

A number of different types of insect attack muskmelons, including seed corn maggots, aphids, wireworm, leafhopper, striped and spotted cucumber beetles, mites, thrips and whiteflies (Egel et al., 2016). They can feed on roots, leaves, stems, flowers, and fruits, and some of them can vector disease causing organisms to the plant. Striped cucumber beetles (SCB) are the most important pest of muskmelon in northeast and Midwest US.

1.2.2.2. Striped Cucumber Beetle Biology

Striped cucumber beetle (*Acalymma vittatum* (F.)) (Coleoptera: Chrysomelidae) is indigenous to the US and is distributed throughout North America (Brust et al., 1996; Burkness and Hutchison, 1998; Smith 1911; Snyder, 2015). SCB can damage cucurbits in different ways. The beetles feed on leaves, stems, flowers, and fruit. Larvae feed on roots (Figure 3.16). The adults can transmit the bacterium *Erwinia tracheiphila* into the plant and cause the disease bacterial wilt of cucurbits. Young cucurbits are more vulnerable to SCB feeding and are more susceptible to BW than older plants. In older plants, the fruits are more vulnerable, but they can stand up to 25 percent defoliation without yield loss (Ayyappath et al., 2002; Burkness and Hutchison, 1998; Synder, 2015;).

1.2.2.3. Striped Cucumber Beetle Life History

SCBs are small (5 - 8 mm long) insects with black and yellow striped bodies, black head and yellow prothorax. They pass the winter as an adult under debris, leaves and wood. Their activity is related to the temperature, thus when temperature goes above 12 $^{\circ}$C in the Midwest United States (Brust, 1997), they become active and feed on the alternative plants such as aster, rose, and legume (Wilson et al., 2014). They use the pollen and nectar of these plants until the main hosts become available. The overwintering generation feeds on different parts (stems, leaves, flowers) of cucurbits. Sasu et al. (2010) found out that 95% of flowers or nectaries of *Cucurbita. pepo* plants in Pennsylvania had bacterial infected frass.

Each female lays from 250 to 1200 yellow-orange eggs at the base of host plants. Eggs hatch after 10 days, and the larvae 8 - 12 mm long with a white, yellowish body and brown head feed on roots for a few weeks and then pupate (6 mm long) and adults of the first generation emerge after 7 - 10 days. SCBs mostly have one generation but, depending on the weather, they may produce two or more generations during a growing season. New generations do not carry bacteria until they feed on infected plants (Alston and Worwood, 2008; Bachmann, 2013; Foster, et al., 1995). Not all overwintering beetles are able to transmit bacteria, between 1 and 10% of them transmit bacteria, but transmission is less at the beginning of their activity and then increases by late season (Brust, 1997; Fleischer et al., 1999).

The number of beetles and percentage of damage are dependent on weather, host availability and kind of host plants. Muskmelon cultivars Superstar, Rising Star, Pulsar, Caravelle, Cordele, Legend, Makdimon, Galia, Rocky Sweet, and Passport were examined for their attractiveness and susceptibility to SCBs and bacterial wilt. Makdimon and Rocky Sweet were more attractive to SCBs and had higher amounts of BW compared to other cultivars (Brust and Rane, 1995). Another experiment on seven cultivars of muskmelon was conducted under greenhouse conditions to compare their vulnerability to BW. The results of this experiment indicated that all cultivars had the same susceptibility to BW when inoculated directly with the disease agent, *Erwinia tracheiphila* (Brust et al., 1996; Zehnder et al., 1997).

Cucurbitacins and volatiles that plants in the cucurbit family release attract the beetles. Cucurbitacins have a bitter taste and are present in leaves, roots, cotyledons and fruits. The plants produce cucurbitacins to protect themselves from some herbivores, but cucumber beetles have coevolved with cucurbits and are able to digest cucurbitacins. However, cucurbitacins act as a feeding arrestant for SCB, causing them to feed compulsively. At the same time, ingestion of cucurbitacins protect SCB from birds and other predators (Metcalf, 1979; Sharma and Hall, 1973).

Cucurbit flower volatiles help the beetles to find their hosts, but most SCB are attracted to plants by aggregation pheromone and feeding behavior of other SCB. Healthy flowers and infected leaves are more attractive to the beetles than unhealthy flowers and uninfected leaves. (Ferguson, 1985; Lewis et al., 1990; Metcalf and Lampman, 1989; Sasu, 2010; Shapiro et al., 2012; Siegfried and Mullin, 1990). Smyth and Hoffmann, (2003) also pointed out that male SCBs attract more beetles through their aggregation pheromone and other volatiles from their frass because they locate first on host plants. Cucurbitacins are not the main attractant of beetles, but they may help the beetles to find the host faster at early stages of growth (Lewis et al., 1990).

1.2.3. Bacterial Wilt

1.2.3.1. Bacterial Wilt Life Cycle

Bacterial wilt of cucurbits, which is caused by the pathogen *Erwinia tracheiphila*, is one of the most important diseases of cucurbits. The pathogen belongs to the family

Enterobacteriaceae. *E. tracheiphila* bacteria are fastidious (Slade and Tiffin, 1984). *E. tracheiphila* has a milky color with medium size colonies, so when it is grown in agar, it needs a few days to be visible. Temperatures of 25-30 $^{\circ}$C have been suggested for optimal growth (Bradbury, 1970). The bacteria are transmitted by striped and spotted cucumber beetles (Rand and Enlows, 1916; Smith, 1911). Muskmelon and cucumber are more susceptible to BW than squashes and pumpkin, and watermelon appears to be highly resistant, although some symptoms of BW were found on watermelon in New Mexico. (Brust, 1997; Shapiro et al., 2012, 2013, 2014; Smith, 1911; Yao et al., 1996). Bacterial wilt may cause death of 10 - 75 percent of muskmelon plants. (Brust and Foster, 1999; De MacKiewicz et al., 1998; Toussaint et al., 2013).

Bacterial wilt was observed first by Erwin F. Smith in Michigan in 1893 on muskmelon and cucumber. It remains a major disease of cucurbits in the United States (Latin, 1993; Smith, 1911), as well as South Africa, China, Japan, and Europe (Bradbury, 1970).

The bacteria that causes the disease spends the winter in the gut of striped and spotted cucumber beetles, usually in the foregut and hindgut of beetles, due to availability of spines and many folds in these regions (Garcia-Salazar et al., 2000). When the striped cucumber beetles emerge from overwintering in spring, they start feeding on cucurbit plants and create wounds, *E. tracheiphila* comes out from the gut of the cucumber beetle via the frass and enters the plant through the feeding wounds. The movement of the bacterium into the plant depends on the availability of free water on the wounds, (Zitter and Kennelly, 2000). Transmission via contaminated mouthparts is possible but less common (Mitchell and Hanks, 2009; Rand and Enlows, 1920).

The disease affects the plant vascular bundles, which reduces the water movement in the plant. *E. tracheiphila* blocks the plant xylem, restricting water and nutrient flow into distal parts of plant. The bacterium population may increase faster in stem than leaf, reaching around 2.5×10^2 CFU/cm of stem in susceptible plants, and 10 CFU/cm in resistant plants (Latin, 2000; Watterson et al., 1972).

Sasu et al. (2010) reported that beetles can transmit the bacteria to wild gourds through floral feeding. Bacterial DNA was found in frass for up to 72 h. In a greenhouse study, *E. tracheiphila* was found on muskmelon leaves after 2 days (Mitchell and Hanks, 2009; Rojas et al., 2015). Using real time quantitative PCR, Shapiro et al. (2014) estimated the population of bacteria in whole beetles and frass 3 and 24 h after gaining access to bacterial infected plants. Aggregation of beetles on the floral parts increases concentration of frass on the flower, which leads to increased transmission into plants (Sasu et al., 2010).

rDNA sequences indicate that the bacterial wilt organism (*E. tracheiphila*) shares around 95.5% of its genome with other bacterial plant pathogen genera such as *Pantoea* and *Enterobacter*. Isolates of *E. tracheiphila* from muskmelon cause disease on cucumber but not on squashes (Hauben et al., 1998; Smith, 1911). In another study the host performance of bacterial wilt strain was confirmed based on DNA fingerprinting profiles and inoculation (Rojas et al., 2013).

1.2.3.2. Disease Symptoms

Symptoms appear on young plants because the bacterium has blocked the xylem in locations proximal to the symptomatic leaves. When insects feed on the stems or leaves the bacteria move to the tissues, which produce extra polysaccharide, then bacteria spread to the entire plant and cause wilting (Latin, 2000). First symptoms appear about 4 to 21 days after transmission with the area around the wound becoming dark green, and later the entire plant shows a dull green color. Seedlings are usually more susceptible to infection because they collapse faster that full grown plants (De MacKiewicz et al., 1998; Rojas et al., 2013; Smith, 1911; Yao et al., 1996). The disease can be diagnosed in the field by cutting the wilted stem, joining the cut parts together, and then observing the gummy ooze when the ends are slowly pulled apart (Latin, 2000).

Fruit on vines with BW may fail to mature, resulting in economic loss (Zitter and Kennelly, 2000). A study in which of injection of bacterium into 56 cucurbit species at cotyledon, first and second leaf stages, showed that symptoms appeared faster at the cotyledon stage and slowly at the 1st and 2nd leaf stage (Watterson et al., 1971). Another study on muskmelon showed that the symptoms appeared faster on two-week old seedlings than on 6 to 8 week old seedlings (Liu et al., 2013). There is no evidence of transmission of *E. tracheiphila* by any other insect such as aphids, squash bugs, squash lady beetle, potato flea beetle, and honeybee (Rand and Enlows, 1920).

Disease severity correlates directly with the beetle population on the host plants; as the feeding increases, the chance of disease transmission increases (Brust and Foster, 1999). A study on the effect of feeding on muskmelon by Brust (1997) showed that muskmelon exhibited more infection when the bacteria was inoculated on a large wound than a small wound. Adding five beetles per plant under row covers increased disease severity to 8% (Brust and Foster, 1999). Percent of plant infection with bacterial wilt depends on how long beetles are allowed to feed. The percent of BW increased from 1.83% at 24 hours feeding, 4.53% wilt at 48 hours of feeding and 10.67% wilt at 72 hours feeding (Brust, 1997; Foster, 2010).

1.2.3.3. Bacterial Wilt Management

The only way that growers can avoid bacterial wilt in their muskmelon crops is to prevent SCB from feeding on the plants. Some of the methods available to growers for avoiding SCB feeding are; timing of planting, row covers, trap crops, and insecticides.

1.2.3.4. Row Covers

Farmers who use row covers for early planting to protect the plants from cold temperatures and seed corn maggot can also receive the benefit of increased plant vigor and protection from insects. Row covers protect muskmelon seedlings against beetle feeding without the use of insecticides (Metcalf and Lampman, 1989; Rojas et al., 2011). Organic growers in particular make use of row covers to protect their plants from SCB and BW.

Row covers can increase weed growth, so they are commonly used with plastic mulch and drip irrigation, which reduces weed populations. Because muskmelons are insect-pollinated, it is highly recommended to remove row covers after a few weeks, particularly when the first female flowers appear. Delaying removal of row covers for 10 days can reduce the percentage of bacterial wilt up to 33 - 50% compared to no row covers, and although harvest is delayed, yield and fruit quality are increased. Thus, even though using rows covers can increase the cost of production by up to 45% due to the cost of covers, wire hoops and installation, row covers can be a good method for organic production. Honeybees can be placed under the row covers for improving pollination (Rojas et al., 2011).

Using row covers in muskmelon and removing them at different times combined with application of organic pesticides had significant effects on yield and beetle damage. Removing row covers at the time of anthesis for two weeks spraying insecticides, and covering the plants again until harvest significantly reduced the percentage of bacterial wilt compared to other treatments (Caudle et al., 2013). In addition, another study in Kentucky showed that incidence of bacterial wilt was less with row covers, but the disease incidence was not affected by the date of row cover removal. More marketable fruits were obtained from the row covers treatment when row covers were removed 10 days after first flowers appeared than when they were removed earlier or not used (Sanchez et al., 2015).

1.2.3.5. Biological Control and Trap Crops

Steinernema riobravis was used for biological control of *Acalymma vittatum* larvae in organic and conventional systems and reduced the number of larvae up to 50 percent (Ellers-Kirk et al., 2000). When buckwheat was used as a flowering border in cucumber and squash, fewer striped cucumber beetles were observed on sticky traps, and the beetle population was 35% higher in sticky traps far from border. However, the effect can depend on time of flowering of host plants and weather conditions (Platt et al., 1999). Sticky traps should be monitored frequently to understand the beetle population and determine when a threshold is reached, as 20 beetles per trap after 2 days is considered equivalent to one beetle per plant, which is the economic threshold on muskmelon in the Midwest (Lam and Foster, 2005).

Organic systems can increase the population of beetles if there is no insecticide application, and they also increase larval survival (Ellers-Kirk et al., 2000). Planting radish, corn, or broccoli as an intercrop can reduce beetle populations (Bach, 1980). Among the cucurbit crops, squashes are highly attractive to the cucumber beetles, so planting this crop as a trap crop could reduce the number of beetles in muskmelons or cucumbers and reduce insecticide applications. A field experiment in 2003 and 2004 using Blue Hubbard squash as a border crop reduced insecticide applications up to 94%

and number of beetles in the main crop of butternut squash. Researchers confirmed in a second study that buttercup squash reduced the amount of insecticide used on the main crop of butternut squash up to 97 %, showing that buttercup can be a good trap crop for controlling cucumber beetles as well (Cavanagh et al., 2009, 2010).

Foster et al. (1995) indicate that cucumber is most susceptible to beetle feeding and bacterial wilt followed by cantaloupe, honeydew, casaba melon, winter squash, pumpkins, and summer squash, and the least susceptible is watermelon. McGrath (2001) found that both cucumber and muskmelon had fewer beetles per plant than others, but there was more wilting in cucumber than muskmelon. Zucchini plants were more attractive to beetles than cucumber. Comparing effects of inter-planting the cover crop sunn hemp (*Crotalaria juncea* L) and chicken manure on cucumber beetles in zucchini showed that the number of cucumber beetles were much lower in sunn hemp treatments than others, but there were no significant impacts on cucumber beetles due to fertilizers (Hinds and Hooks, 2013).

Crop rotation is another possible management method for striped cucumber beetles. It can be effective when crops are rotated far enough from the main field. Andenmatten et al. (2002) pointed out that for best results, the crop rotation should be far from the previous crop. Also delaying planting up to late June can reduce beetle populations because after overwintering if there are no cucurbit crops, beetles could search for alternative hosts or might migrate to other places.

1.2.3.6. Insecticides

Insecticides are the primary method of controlling insects, especially when the insect population reaches the threshold (economic) point, because of their fast action and easy application. They can be used as seed treatments, planting time drenches, in irrigation water and as foliar sprays.

Insecticides can be mixed with baits, like cucurbitacins, which promote beetle feeding. A combination of cucurbitacin bait with spinosad (organically accepted) or carbaryl (standard foliar insecticide) insecticides had no effect on beetle control in muskmelon, possibly due to the type of cucurbitacin that was used, but applying insecticides directly on the plants significantly reduced the number of beetles (Pedersen and Godfrey, 2011). Imidacloprid (Admire Pro®) and thiamethoxam (Platinum®), both systemic neonicotinoid insecticides, are used commonly as a soil drench, in drip irrigation, or in furrow for controlling striped cucumber beetles. It is also advised that these products should not be used as a foliar application because they are highly toxic to other beneficial insects. Some systemic neonicotinoid products like thiamethoxam (Actara®) can be used as a foliar spray, but not at the time of bloom (Hazzard and Cavanagh, 2013).

Applying neonicotinoid insecticides to soil at the seedling stage, especially at the time of transplanting, will protect the young seedling from beetle feeding and bacterial wilt because the insecticides are absorbed rapidly by roots and move to the other parts of the plants, which can be destructive and poisonous for beetle. McLeod (2006) found that application of insecticides at planting time reduced beetles feeding, and beetle mortality was higher compared to the control treatment.

Neonicotinoids can have a negative impact on pollinators which play an essential role in plant production quality and quantity (Klatt et al., 2014). Most insecticides have negative effects on pollinators' activity, and can also increase mortality. A study on the impact of insecticide on bees indicates that seed coating with neonicotinoids had negative effects on pollinators. Residues of insecticides were found in pollen, nectar and wax (Godfray et al., 2015; Rundlof et al., 2015).

The combination of fungicides and insecticides as a seed treatment for managing insects and diseases has become common for cucurbit production. FarMore® seed treatment technology helps farmer to maximize their crop production by minimizing insects and diseases because several FarMore® seed treatments contain both fungicides and insecticide. There are three types of FarMore®: a) FarMore® F300, which contains fungicides mefenoxam, fludioxonil and azoxystrobin for improving plant vigor, yield and protecting seed and seedling from diseases, b) FarMore® F1400, which contains both fungicides from F300 and thiamethoxam insecticide, which protects cucurbits and leafy vegetables from pests and diseases, c) FarMore® F1500, which contains the same ingredients as F1400 plus another insecticide (spinosad), which is used for onion production and against seed maggots (Syngenta, 2016).

A study on the potential impact of neonicotinoid insecticides on honey bees shows that application of thiamethoxam applied as a FarMore® seed treatment, as a Platinum® transplant water drench, as an Actara® foliar spray, and imidacloprid as an Admire Pro® transplant water drench could have harmful effects on honeybees because pollen had high concentrations of these chemicals. Platinum®, Admire Pro® and Actara® reduced striped cucumber beetle numbers, but FarMore® had no effect on beetle numbers (Nixon, 2014).

Applying a solid stream of imidacloprid with a precision injector reduced imidacloprid use up to 84.5% per hectare compared to continuous in-furrow treatments. Both methods resulted in higher beetle mortality than untreated, from 70 - 100%, on pumpkin, zucchini and cucumber crops in 2004 and 2005 (Jasinski et al., 2009).

It is important to apply insecticides only when necessary, because it could help to reduce insecticide applications and protect other beneficial insects, especially pollinators. For muskmelons, control is necessary, when there are 0.5-1 beetle per plant (Brust et al. 1996). Additionally, certain methods of applying insecticides can be more effective for protecting pollinators and increasing yield. For example, Brust and Foster (1995) found that using bait with a combination of carbaryl insecticide, and cucurbitacin as a stimulator led to high numbers of pollinators, which increased total yield compared to weekly spraying with carbaryl even though sprays reduced the number of beetles faster than the bait treatment.

CHAPTER 2. EXPERIMENTS 2013 AND 2014

Integrated Pest Management (IPM) For Early Season Cucumber Beetle Control to Manage Bacterial Wilt in Muskmelon

2.1. Introduction

Muskmelon (*Cucumis melo var. reticulatus*), also called cantaloupe, is a major vegetable crop in the United States, including Indiana. The states of California, Arizona and Indiana are the major producers of muskmelon in the United States. Indiana ranked 4^{th} in total production of muskmelon in U.S., with about $7.6 million annual farm income in 2015 (USDA, 2016).

Factors limiting yield include weather, insects and diseases, especially bacterial wilt (*Erwinia tracheiphila*). It is one of the most serious diseases of muskmelon, and is transmitted by the striped cucumber beetle (SCB) (*Acalymma vittatum* (F.)), (Coleoptera: Chrysomelidae). SCB is the most serious pest of muskmelon in the United States, Adult beetles spend the winter hibernating under the debris, dead leaves and logs near the field (Brust et al., 1996; Brust, 1997; Burkness and Hutchison, 1998; Snyder, 2015). The bacterium overwinters in the gut of beetles. SCBs feed on leaves, stems, flowers, and fruit but by far the greatest losses occur because it vectors the causal agent of bacterial wilt (Sasu et al., 2010).

Among the cucurbit crops, muskmelon and cucumber are most susceptible to bacterial wilt. When SCB feed on the plants, bacteria in the beetle's frass enters the plant through the wounded area when free water is present. The bacteria move to different parts of the plant through the xylem, reproduce, and block the vascular bundles, causing wilting of part or the whole plant (Latin, 2000; Watterson et al., 1972). The bacterium can also be transferred through the beetle's mouthparts, if they feed on infected plants (Mitchell and Hanks 2009; Rand and Enlows, 1920). Plants at early stages of growth are more vulnerable to the beetles' feeding and infection by the bacterium. Bacteria can move faster in the seedlings, because seedlings are small and their defense mechanisms are weak compared to the full grown plant. The diseases symptom can appear 1 - 3 weeks after infection. (De MacKiewicz et al., 1998; Rojas et al., 2013; Smith, 1911; Yao et al., 1996).

Controlling beetles before they transmit the bacterium is the only option to manage bacterial wilt, because once a plant is infected by the bacterium, it cannot be controlled or managed. Management options for SCB and bacterial wilt include row covers, date of planting and applying insecticides as seed treatments, bedding tray drenches, planting time treatments, or foliar sprays. Foliar sprays should be applied when the beetle population reaches the economic threshold, one beetle per plant (Brust and Foster, 1995).

Because younger plants are more susceptible to bacterial wilt infection, we wanted to investigate if there was a specific time shortly after transplanting when muskmelon plants would be more vulnerable to the disease. Thus, in our two years (2013 and 2014) experiments, which were conducted in Lafayette and Vincennes, Indiana, we compared row covers, different dates of planting, seed treated with insecticide (FarMore®) and insecticides applied as a soil drench or as a foliar spray for managing SCB and bacterial wilt.

The objective of these experiments was to determine if there is a time in the first three weeks after transplanting when muskmelon plants are more susceptible to SCB feeding and transmission of bacterial wilt. The hypothesis was that muskmelon plants would be more susceptible to the SCBs feeding and BW at early stages of growth.

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2.2. Material and Methods

Field experiments were conducted in 2013 and 2014 at two Indiana locations: Purdue Meigs Farm at Throckmorton/Meigs Purdue Agriculture Center (TPAC) near Lafayette, IN, and Southwest Purdue Agriculture Center (SWPAC) near Vincennes, IN. Untreated and FarMore® (insecticide: thiamethoxam and fungicides: Dynasty®) treated seeds of Athena muskmelon were planted in 72-cell black seedling flat trays and grown in a greenhouse. Four week-old seedlings were transplanted to raised beds (0.66 m wide) covered with black plastic much with drip irrigation in all studies. All studies were arranged in a Randomized Complete Block Design (RCBD) with four replications (Figures 2.1 to 2.6).

2.2.1. Experiment 1 (TPAC 1)

The goal of Experiment 1 was to investigate whether there was a 7-day period during the first 3 weeks after transplanting in which muskmelon plants were more susceptible to infection with bacterial wilt. Muskmelon seeds were planted in the greenhouse on 10 May 2013 and 25 April 2014 and transplanted into the field on 5 June 2013 and 15 May 2014. Experimental units consisted of a single row 12.2 m long with 1.2 m between plants within the row, and 10 plants per row.

Plants in some treatments had row covers (Robert Marvel Plastic Mulch, Annaville, PA) supported by wire hoops placed over them immediately after transplanting. Row covers are fabric consisting of polypropylene fibers, weighing 15.6 g per 0.86 $meter^2$ that protect plants from insects and frost and increase plant growth. Covers transmit about 85% of available light, but this can vary depending on brand and weight of row cover. The edges of the row cover material were sealed with soil to prevent striped cucumber beetles from either entering or leaving the row of plants.

Among the cucurbit family squashes are more attractive to striped cucumber beetles, which may be due to large flowers and volatiles and other attractive compounds that are released by these plants, but they are more tolerant to feeding and not as susceptible to bacterial wilt as some other members of this family (Cavanagh, et al., 2009, 2010; Foster, et al., 1995). Squash seedlings were transplanted a few weeks earlier than muskmelon seedlings, in a separate field away from the muskmelon plots. Beetles were collected from squash plants with aspirators and released under row covers. In 2014 the beetles did not appear in our squash field in time, so beetles were collected from Silverthorne Farm, Rossville, IN (Figure 3.10).

Once beetles were collected, a portion of the row cover was opened at several locations per plot and the beetles sprinkled onto the ground. An average of 5 beetles per plant (50 beetles per experimental unit) was selected because previous research had shown that population density was sufficient to cause significant levels of bacterial wilt (Brust and Foster, 1995). Beetles were allowed to feed on plants under row covers for seven days at different plant stages, then row covers were removed, and Warrior® (lambda-cyhalothrin) insecticide applied with a CO_2 powered backpack sprayer at a rate of 13.6 g a.i. per 0.4 ha was used to kill the beetles. Row covers were replaced immediately after spraying. All row covers were removed on day 21 after transplanting, followed by weekly Warrior® insecticide applications to the entire plots until a few weeks before harvest so that transmission of bacterial wilt could only occur during the first 21 days after transplanting. The treatments were:

1. Control/no row cover.
2. Row covers were placed immediately after transplanting. 50 beetles under row cover on day 0. Beetles killed on day 7. Row covers replaced, but removed on day 21.
3. Row covers were placed immediately after transplanting. 50 beetles under row cover on day 7. Beetles killed on day 14. Row covers replaced, but removed on day 21.
4. Row covers were placed immediately after transplanting. 50 beetles under row cover on day 14. Beetles killed on day 21.
5. Row covers placed immediately after transplanting. No beetles added. Row cover removed on day 21.

2.2.2. Experiment 2 (TPAC 2)

In the second experiment at TPAC, striped cucumber beetles were again added underneath row covers at different plant ages, but the planting dates were staggered by 7 days between treatments so that beetles were all added on the same day, but the treatments were different ages. The seeding dates in 2013 were 17 May, 24 May, and 30 May and the transplanting dates were 5 June, 12 June, and 19 June. In 2014, the seeding dates were 25 April, 1 May and 7 May and the transplanting dates were 28 May, 4 June, and 10 June. The plot details were the same as in Experiment 1 with the exception of planting dates. No insecticides were used in this study until day 21.

1. Control. Transplanted day 0. No row cover.
2. Row covers were placed immediately after transplanting on day 0 and 50 beetles per experimental unit were added on day 14.
3. No row cover. Transplanted on day 7.
4. Row covers were placed immediately after transplanting on day 7. 50 beetles per experimental unit were added on day 14.
5. No row cover. Transplanted on day 14.
6. Row covers were placed immediately after transplanting on day 14. 50 beetles per experimental unit were added on day 14.

All row covers were removed on day 21 (three weeks after transplanting on day zero), followed by weekly Warrior® insecticide (13.6 g a.i. per 0.4 ha) application the same as Experiment number 1.

2.2.3. Experiment 3 (SWPAC)

Only naturally occurring populations of striped cucumber beetles were used in experiments at SWPAC. The strategy for these studies was to reduce the populations of striped cucumber beetles on the plants with insecticides in various forms and by exclusion with row covers to determine the effect of those practices on transmission of bacterial wilt. Seeds were planted in the greenhouse of 15 April 2013 and 20 April 2014 and transplanted into the field on 15 May 2013 and 20 May 2014. The seedlings were transplanted onto raised beds 0.6 m wide covered with black plastic mulch, and with 0.6 m between each plant and 1.8-2.4 m between each row, and 12 plants per row.

1. Control: untreated seeds, no row cover, no insecticides.
2. No row cover, untreated seeds, Warrior® (lambda-cyhalothrin) insecticide applied at a rate of 13.6 g a.i. per 0.4 ha on day 0, 7, 14, and 21).
3. No row cover, FarMore® treated seeds, no insecticides.
4. Row covers applied immediately after transplanting and removed day 7, untreated seeds, no insecticides.

5. Row covers placed immediately after transplanting and removed on day 14, untreated seeds, no insecticides.
6. Row covers placed immediately after transplanting and removed on day 21, untreated seeds, no insecticides.
7. No row cover, seedlings treated with Platinum® (thiamethoxam) insecticide a rate of 78.0 g a.i per ha as a soil drench in the transplant hole immediately after transplanting.
8. Row covers were applied, Platinum® used as a soil drench after transplanting as in treatment 7, row covers removed on day 21 (three weeks after transplanting).

2.3. Data Components

2.3.1. Striped Cucumber Beetle Sampling

The number of live and dead beetles were counted manually on 5 plants per treatment per replication by looking on the upper and lower leaf surfaces, beneath plants, inside flowers, and inside the transplant holes. SCBs shelter beneath leaves or move into the transplant holes to escape from sun and rain. Beetle sampling started one week after transplanting and was done 1 to 2 times per week until the end of July. In treatments with row covers, no counts were made until after the row covers were removed.

2.3.2. Bacterial Wilt Severity

Plants with bacterial wilt symptoms (Figure 3.15) were estimated throughout the growing season until second harvest, using the Horsfall-Barratt rating scale for assessing disease, which is designed to compensate for human error in interpretation of the percentage of foliage infected (Horsfall and Barratt, 1945), and converted to percent using the ELANCO tables (Redman et al., 1974). Bacterial wilt percentage was assessed visually by walking through each replication and giving a number from 0-11 to each experimental unit depending on the disease severity. Assessments began one week after transplanting and continued every week until second harvest. At the end the percentages of bacterial wilt in each assessment were converted to a graph mean, which has been calculated using the ELANCO tables (Horsfall and Barratt, 1945). The Area Under the Disease Progress Curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977). They have generated a formula for AUDPC calculation as follows:

$$\text{AUDPC} = \sum_{i=1}^{n} \left[\frac{(Y_{(i+1)} + Y_i)}{2}\right] \left[X_{(i+1)} - X_i\right]$$

Yi = Disease severity per unit (the Horsfall-Barratt number) at each observation.

Xi = Time (days) at each observation.

n = Total number of observations.

2.3.3. Plant Vigor

Plant vigor was rated beginning 4-5 weeks after transplanting and every week thereafter to document relative growth and health of plants in different treatments over the season. We used a qualitative number from 1-10 corresponding to 10-100, which was given for each plot. Plants in each plot with no damage, disease, and not missing were given the highest number. All ratings were multiplied by 10 before reordering to provide an estimate of vigor as a percentage of the most vigorous plot.

2.3.4 Number of Marketable Fruits and Total Yield Record

Muskmelon fruit maturity takes place around 50-55 days after flowering, but it can vary depending on weather. We timed harvest based on the standard index of maturity for muskmelons which includes changing rind color and easily 'slipping' from the vine. In 2013, harvest started on July 10 at SWPAC (14 harvests) and ended August 9, and at TPAC harvests began on August 12 and ended September 11 (9 harvests). In 2014, first harvest began on July 10 and ended August 7 (13 harvests) at SWPAC, and at TPAC it started on August 8 and continued until August 21 (5 harvests). Fruits were harvested every 2-3-days. During each harvest, total weight and number of marketable fruit per replication were recorded. Fruits with yellow color, not damaged, not diseased, and more than 1 kg were counted and weighed as marketable. Average and total yield for all harvests were calculated as well.

All data were analyzed with one-way analysis of variance followed by post-hoc Fishers Least Significant Difference (LSD) test, 95 percent confidence by using SPSS (IBM SPSS Statistics 22).

Treatments	Row Cover	Beetles Added	Beetles Killed
T_1	No	0	Day 21
T_2	Yes	Day 0 (50 beetles per 10 plants)	Day 7
T_3	Yes	Day 7 (50 beetles per 10 plants)	Day 14
T_4	Yes	Day 14 (50 beetles per 10 plants)	Day 21
T_5	Yes	0	Day 21

Figure 2.1 Experiment 1 (TPAC) treatment descriptions 2013 and 2014.

T_1	T_4	T_2	T_5	T_3	IV
T_5	T_2	T_1	T_4	T_3	III
T_1	T_3	T_5	T_2	T_4	II
T_4	T_2	T_1	T_3	T_5	I

Figure 2.2 Experiment 1 (TPAC) layout 2013 and 2014.

Legends

Row cover

Control, no row cover

Treatments	Row Cover	Plant Date	Beetles Added
T_1	No	Day 0	0
T_2	Yes	Day 0	Day 14 (50 beetles per 10 plants)
T_3	No	Day 7	0
T_4	Yes	Day 7	Day 14 (50 beetles per 10 plants)
T_5	No	Day 14	0
T_6	Yes	Day 14	Day 14 (50 beetles per 10 plants)

Figure 2.3 Experiment 2 (TPAC) treatment descriptions 2013 and 2014.

T_6	T_5	T_2	T_3	T_4	T_1	IV
T_2	T_3	T_5	T_1	T_4	T_6	III
T_2	T_1	T_6	T_4	T_3	T_5	II
T_4	T_5	T_6	T_3	T_2	T_1	I

Figure 2.4 Experiment 2 (TPAC) layout 2013 and 2014.

Legends

Treatments 1 and 2 planted on day 0 (June 5 2013 and May 28 2014)

Treatments 3 and 4 planted on day 7 (a week after day 0)

Treatments 5 and 6 planted on day 14 (2 weeks after day 0)

Treatments	Row Cover	Removal Date	Planting Treat	Spray Dates
T_1	No	0	No	None
T_2	No	0	No	Day 0,7,14,21
T_3	No	0	FarMore	None
T_4	Yes	Day 7	No	None
T_5	Yes	Day 14	No	None
T_6	Yes	Day 21	No	None
T_7	No	0	Platinum	None
T_8	Yes	Day 21	Platinum	None

Figure 2.5 Experiment 3 (SWPAC) treatment descriptions 2013 and 2014.

T_3	T_5	T7	T_8	T_6	T_4	T_1	T_2	IV
T_8	T_6	T_4	T_3	T_7	T_5	T_1	T_2	III
T_2	T_8	T_1	T_6	T_5	T_7	T_4	T_3	II
T_2	T_1	T_5	T_3	T_6	T_4	T_8	T_7	I

Figure 2.6 Experiment 3 (SWPAC) layout 2013 and 2014.

Legends

Row Covers

FarMore seed treated

No row cover

2.4. Results and Discussion

2.4.1 Results

2.4.1.1. Number of Striped Cucumber Beetles (SCB)

Number of SCBs per plant in all experiments was significantly higher in the control plots without row covers or insecticides than in plots with row covers for three weeks. Weekly foliar spraying of insecticide significantly reduced the number of beetles per plant to zero.

2.4.1.2. Bacterial Wilt Percentage and AUDPC

Both disease percentage in the late season and Area Under Disease Progress Curve (AUDPC) in experiment 1 (TPAC) in 2013 and 2014 were significantly higher in the control than in other treatments, however, there was no significant difference between the remaining treatments (Table 2.1). The results reveal that beetles feeding under row covers for 7 days did not affect disease transmission or development of the bacteria, there was no beetle feeding during the first 21 days (Table 2.1).

In experiment 2 (TPAC) BW percentage at the time of harvest and AUDPC were significantly higher in control without row cover (BW 37.5 % and AUDPC 199.5) and by treatment 2 with row covers planting day 0, and beetles added on day 14 (BW 8.4 and 7.7 % and AUDPC 116.5) in 2013. In 2014 there was significant difference only between control and other treatments (Table 2.2). The plants had less BW and higher AUDPC in 2013, but higher BW and low AUDPC in 2014 (Table 2.2). The results also indicate that the timing of beetle feeding at the early stage of growth during the first 3 weeks after transplanting does not affect the amount of disease and AUDPC (Table 2.2). Both early planting treatments (with or without row covers, 1 and 2) had more wilt than later plantings in 2013 but not 2014, when only the treatment without row covers had more wilt (Table 2.2). Also, 1 week of beetle feeding (treatment 2) resulted in less disease than 3 weeks of feeding (treatment 1) in both years, but significantly so in 2014 (Table 2.2). Over all, an extended period of feeding (3 weeks) was needed for lots of disease. One week of exposure (treatments 2, 4, 5, 6), or 2 weeks (treatment 3) was not enough.

The results of experiment 3 (SWPAC) show that there was no significant difference in disease between all treatments in 2013 or 2014, $p>0.05$ (Table 2.3). The lack of differences is likely the result of very low level of bacterial wilt in this location during 2013 and 2014

2.4.1.3. Plant Vigor

Plant vigor was significantly greater in row covers treatments than control at all experiments (TPAC 1 and 2 and SWPAC) in 2013 and 2014.

2.4.1.4. Number, Yield (kg) and Individual Weight of Marketable Fruits

For experiment 1 (TPAC) in 2013 and 2014, the number and weight of marketable fruits were significantly different between treatments with row covers and the control treatment during early harvests (Aug 12-16) (Tables 2.4 and 2.5). There were no differences between treatments during mid and late harvests in 2013 or at late harvests in 2014. The control treatment had the fewest fruits at early harvests (1.3 and 12.5 fruits in 2013 and 2014, respectively) and the fewest total fruits (18.8 and 17.8 in 2013 and 2014, respectively. Treatment 3, followed by treatments 2 and 5 recorded higher yield and number of fruits at mid harvests (Aug 18-21) in 2014 (Table 2.5). Generally, early harvests had higher number of fruits compared to the mid and late harvests. Thus it indicates that number of fruits decline after each harvest. Significantly greater yield (kg) was produced by row cover treatments than non-row cover treatments at early harvests in experiment 1 (TPAC) in 2013 (Table 2.4). In 2014, total yield was also significantly greater with row covers than without row covers (Table 2.5). In 2014, treatment 4 had lowest yield for mid harvests (14.1 kg) and total yield (94.6 kg) among the row cover followed by control. The results of 2013 and 2014 make it clear that row covers increase total yield compared to no-row covers. Also, treatments with row cover with beetle feeding for 7 days and the treatments with row cover but no beetles were not significantly different.

In experiment 2 (TPAC) in 2013, treatment 3 (no row cover, planted day 7) produced significantly fewer total fruit (22.8 fruits) than all other treatments except treatment 1 (no row cover, planting day 0) and less total weight (63.0 kg) than all except treatments 1 and 2 (row cover, planted day 0, beetles added day 14) (Table 2.6). In 2014, treatment 1 produced the lowest total number and weight of fruits, but significantly less only that treatment 2 (Table 2.6). In experiment 2 (TPAC) the number of fruit, yield, and distribution of yield over the season differed in 2013 and 2014, but some results were consistent across years. The results of both years 2013 and 2014 indicate that allowing a known number of beetles (5 beetle per plant) to feed on plants under row covers for different 1-week periods did not affect yield.

In experiment 3 (SWPAC) the number and weight of marketable fruits at early, mid, late and all harvests did not statistically differ among treatments in 2013 or 2014, $p>0.05$ (Tables 2.7 and 2.8).

2.4.2 Discussion

Row covers, date of planting, seed treatment, soil drench and foliar spray of insecticides are part of Integrated Pest Management (IPM). The combination of these methods can reduce insect pest feeding and damage, and disease severity through the season. They work at different times and plant growth stages, and in different situations, insect behavior, and climate conditions. Most plants are susceptible to insects feeding and diseases because some diseases can be transferred by insects through chewing, saliva and frass. Bacterial wilt is one of the serious diseases of muskmelon which is transmitted by striped cucumber beetles through their frass (Brust and Foster, 1995; Smith, 1911). The only way to manage the bacterial wilt is to control striped cucumber beetles, especially at early stage of growth.

In experiment 1 (TPAC) we tested the hypothesis that severity of bacterial wilt would depend on when beetles fed on newly-transplanted muskmelon: 0 to 7, 7 to 14, or 14 to 21 days after transplanting. We used row covers to keep a defined number of beetles near plants during the desired period and killed beetles with insecticide at the end of that period. Control treatments included plants without row covers and exposed to natural SCB populations for 21 days, and plants with row covers for 21 days and no exposure to beetles. Row covers increased plant vigor whether or not beetles were introduced under the row covers. When row covers were removed after three weeks, there was no difference between treatments where beetles were introduced at different times or where no beetles were introduced. Plants did not show symptoms of bacterial wilt when row covers were removed, even by the end of the season. The percentages of bacterial wilt were very low in all the row cover treatments, in contrast to the control treatment that had the highest percentage of BW and AUDPC.

There are several possible explanations for the low level of bacterial wilt in the row cover treatments, even when beetles were introduced. The number of beetles introduced under the row covers may have been too low to create significant disease. Not every beetle has the bacteria in its gut, and if bacterial numbers were low, disease transmission could be low. High temperatures and lack of water sprinkling onto plant leaves in the row cover treatments could also have reduced disease transmission. Water on the leaves is necessary for the bacterium to enter into the plant tissues. Higher temperature under row covers could have meant that any water on the surface of leaves evaporated more quickly than without row cover. Although the row cover permits rain to pass through, it is possible that not as much water landed on the leaves of plants under the row cover, and so bacteria did not move into plants as readily.

The results of this experiment show that the time of feeding by a limited number of beetles is not important in the period three weeks after transplanting.

In experiment 2 at TPAC we also tested the hypothesis that the severity of bacterial wilt would depend on when beetles fed on newly-transplanted muskmelons. Muskmelons planted on three consecutive weeks were grown without row covers and exposed to natural populations of SCB for 0 - 21, 0 - 14, or 0 - 7 days after transplanting, for the first, second and third dates, respectively. Under row covers, muskmelons planted on the same three dates were exposed to defined numbers of beetles for 14 - 21, 7 - 14, or 0 - 7 days after transplanting.

Similar to experiment 1, the muskmelons grown without row cover and exposed to ambient populations of SCB for 21 days after transplanting had the most bacterial wilt, and other treatments did not differ in the amount of bacterial wilt. This may due to availability of more beetles on plant, availability of water (rain) for bacteria to enter into the plant tissues, and multiply in the plant xylem. An exception to this occurred in 2014 when the muskmelons under row cover and exposed to SCB 14 - 21 days after transplanting had bacterial wilt levels measured by AUDPC not significantly different from those exposed for 21 days. The somewhat higher bacterial wilt in this treatment than remaining treatments could have been due to the succulent plant growth that occurred under the row covers, which might attract beetles to feed more. Plants in this treatment would have been larger than in other treatments because they were planted on the first planting date and were under row covers for the longest period of time before beetles were introduced.

The results of this experiment show that the time of feeding by a limited number of beetles is not important in the period three weeks after transplanting.

At SWPAC we compared early season management strategies for SCB and BW. Bacterial wilt percentage and AUDPC were not significantly different between untreated plots and Platinum® soil drench, FarMore® seed treatment, weekly foliar spray of Warrior® insecticide, protecting plants with row covers for 7, 14 or 21 days after transplanting in either year. Platinum® soil drench with row covers or weekly foliar sprays of Warrior® reduced the number of beetles significantly, but did not reduce disease. Low BW percentage and AUDPC even when beetle feeding is uncontrolled can be due to lack of water on the surface of the plants at certain times because water helps the bacterium enter into plant, or fluctuation of temperature, because beetles feed less when it is hot or cold.

The results of all experiments at three location show that row covers increase plant vigor. There is not any particular period in the 21 days after transplanting when feeding on the plants by a defined number of beetles is more effective in causing BW in muskmelons. Weekly foliar spray of insecticide reduces or eliminates the number of beetles, which leads to reduced beetle feeding and bacterial wilt, and increased marketable fruits.

Table 2.1 Severity of bacterial wilt disease on muskmelon exposed to striped cucumber beetles at various times during early growth reported as percent of foliage affected on two sampling dates and Area Under the Disease Progress Curve (AUDPC) over the entire season. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC) in Lafayette, Indiana, in 2013 and 2014

Treatments [z]	Bacterial Wilt Severity in Percent [y]					
	2013			2014		
	5 Aug	14 Aug	AUDPC [x]	28 Jul	31 Jul	AUDPC [x]
1	7.7a	11.3 a	486.1 a	32.0 a	37.0 a	132.8 a
2	0.0 b	3.5 b	78.8 b	3.5 b	3.5 b	9.7 b
3	2.9 b	1.2 b	103.7 b	1.2 b	1.2 b	9.7 b
4	1.7 b	2.9 b	75.7 b	6.4 b	4.1 b	11.2 b
5	1.2 b	2.3 b	27.5 b	3.5 b	4.1 b	9.7 b
P	0.02	0.06	0.001	0.04	0.03	0.001

[z] Treatments: 1= Control, no row cover (transplanted day 0 (5 June 2013 and 29 May 2014)).
2= Row Cover (beetles added day 0 (5 June 2013 and 29 May 2014)) and beetles killed day 7 (12 June 2013 and 5 June 2014).
3= Row Cover (beetles added day 7 (12 June 2013 and 5 June 2014)) and beetles killed day 14 (19 June 2013 and 13 June 2014).
4= Row Cover (beetles added day 14 (19 June 2013 and 13 June 2014)) and beetles killed day 21 (26 June 2013 and 20 June 2014).
5= Row Cover (no beetles, and no spray until day 21 (26 June 2013 and 20 June 2014)).
[y] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables (Redman et al., 1974). Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.
[x] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).

Table 2.2 Severity of bacterial wilt disease on muskmelon exposed to striped cucumber beetles at various times during early growth reported as percent of foliage affected on two sampling dates and Area Under the Disease Progress Curve (AUDPC) over the entire season. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC) in Lafayette, Indiana, in 2013 and 2014.

Treatments [z]	Bacterial Wilt Severity in Percent [y]					
	2013			2014		
	29 Jul	14 Aug	AUDPC [x]	31 Jul	14 Aug	AUDPC [x]
1	37.5 a	37.5 a	199.5 a	55.0 a	84.2 a	33.2 a
2	8.4 ab	7.7 ab	116.5 ab	5.0 b	15.8 b	13.0 b
3	0.0 b	1.7 b	11.2 b	11.3 b	11.3 b	11.2 b
4	0.6 b	0.6 b	9.6 b	4.7 b	9.4 b	17.7 b
5	0.0 b	0.6 b	9.6 b	1.2 c	2.3 b	10.3 b
6	0.0 b	0.0 b	9.1 b	3.5 b	4.7 b	11.5 b
P	0.02	0.02	0.001	0.002	0.001	0.01

[z] Treatments: 1= Control, no row cover (planting date day 0 (5 June 2013 and 28 May 2014)).
2= Row Cover (planting date day 0 (5 June 2013 and 28 May 2014)) and beetles added day 14(19 June 2013 and 11 June 2014).
3= No Row Cover (planting date day 7 (12 June 2013 and 4 June 2014)).
4= Row Cover (planting date day 7 (12 June 2013 and 4 June 2014)) and beetles added day 14(19 June 2013 and 11 June 2014).
5= No Row Cover (planting date day 14 (19 June 2013 and 11 June 2014)).
6= Row Cover (planting date day 14 (19 June 2013 and 11 June 2014)) and beetles added day 14 (19 June 2013 and 11 June 2014).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.
[y] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables (Redman et al., 1974).
[x] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).

Table 2.3 Severity of bacterial wilt disease on muskmelon exposed to striped cucumber beetles at various times during early growth reported as percent of foliage affected on two sampling dates and Area Under the Disease Progress Curve (AUDPC) over the entire season. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC) in Vincennes, Indiana, in 2013 and 2014.

Treatments [z]	Bacterial Wilt Severity in Percent [y]					
	2013			2014		
	2 July	10 July	AUDPC [x]	8 July	15 July	AUDPC [x]
1	1.7	1.7	37.2	2.9	6.4	35.0
2	1.2	1.6	27.5	3.5	5.4	30.9
3	4.7	1.2	213.0	4.7	9.4	70.8
4	3.5	3.5	66.0	2.9	4.7	83.7
5	5.4	3.5	173.6	1.7	2.9	30.5
6	5.4	4.7	121.1	4.7	13.4	54.8
7	2.3	2.3	48.2	1.7	4.1	38.1
8	2.3	2.9	38.8	3.4	6.4	37.6
P	0.66	0.15	0.40	0.35	0.15	0.17

[z] Treatments: 1= (Control, no row cover, no insecticide)
2= No Row Cover (spray Warrior on day 0 (15 May 2013 and 20 May 2014), 7 (22 May 2013 and 27 May 2014), 14 (29 May 2013 and 3 June 2014) and 21 (5 June 2013 and 10 June 2014)).
3= No Row Cover (FarMore®)
4= Row Cover (removal Date day 7 (22 May 2013 and 27 May 2014)).
5= Row Cover (removal date day 14 (29 May 2013 and 3 June 2014)).
6= Row Cover (removal date day 21 (5 June 2013 and 10 June 2014)).
7= No Row Cover (soil drench with Platinum®).
8= Row Cover and soil drench with Platinum® (Removal date day 21 (5 June 2013 and 10 June 2014)).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.
[y] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables (Redman et al., 1974).
[x] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).

Table 2.4 Number and yield per plot of marketable fruits at early, mid, late and all harvests. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC) in Lafayette, Indiana, in 2013.

Treatments [z]	No. of Fruits 12-16 Aug Early (3 harvests)	Yield (kg) 12-16 Aug Early (3 harvests)	No. of Fruits 19-26 Aug Mid (3 harvests)	Yield (kg) 19-26 Aug Mid (3 harvests)	No. of Fruits 29Aug-11Sep Late (3 harvests)	Yield (kg) 29Aug-11 Sep Late (3 harvest)	Total No. of Fruits (9 harvests)	Total yield (kg) (9 harvests)
1	1.3 b	3.3 b	4.0	9.4 b	13.5	30.2	18.8 b	42.9 b
2	19.5 a	46.8 a	8.3	22.6	16.8	36.1	44.5 a	105.4 a
3	23.3 a	60.9 a	5.3	13.5	14.3	33.6	42.8 a	108.0 a
4	21.3 a	61.3 a	7.5	17.9	21.8	48.0	50.5 a	127.3 a
5	25.3 a	67.4 a	6.3	15.2	22.3	52.3	53.8 a	134.9 a
P	0.001	0.001	0.44	0.32	0.18	0.29	0.001	0.001

[z] Treatments: 1= Control, no row cover (transplanted day 0 (5 June 2013 and 29 May 2014).
2= Row Cover (beetles added day 0 (5 June 2013 and 29 May 2014)) and beetles killed day 7 (12 June 2013 and 5 June 2014).
3= Row Cover (beetles added day 7 (12 June 2013 and 5 June 2014)) and beetles killed day 14 (19 June 2013 and 13 June 2014).
4= Row Cover (beetles added day 14 (19 June 2013 and 13 June 2014)) and beetles killed day 21 (26 June 2013 and 20 June 2014).
5= Row Cover (no beetles, and no spray until day 21 (26 June 2013 and 20 June 2014)).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 2.5 Number and yield per plot of marketable fruits at early, mid, late and all harvests. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC) in Lafayette, Indiana, in 2014.

Treatments [z]	No. of Fruits 8-14 Aug Early (2 harvests)	Yield (kg) 8-14 Aug Early (2 harvests)	No. of Fruits 18-21 Aug Mid (2 harvests)	Yield (kg) 18-21 Aug Mid (2 harvests)	No. of Fruits 25 Aug Late (1 harvest)	Yield (kg) 25 Aug Late (1 harvest)	Total No. of Fruits (5 harvests)	Total yield (kg) (5 harvests)
1	12.5 b	35.4 b	5.0 b	12.1 c	0.3	0.6	17.8 c	48.1 c
2	30.3 a	85.1 a	8.25 ab	20.1 b	1.75	3.7	40.3 ab	108.95 ab
3	35.5a	102.6 a	14.8 a	33.6 a	0.8	1.7	51.0 a	138.0 a
4	27.0 a	79.4 a	7.0 b	14.1 bc	0.5	1.1	34.5 b	94.6 b
5	28.0 a	85.9 a	13.0 ab	29.7 ab	2.0	4.3	43.0 ab	120.0 ab
P	0.002	0.001	0.05	0.04	0.34	0.36	0.001	0.001

[z] Treatments: 1= Control, no row cover (transplanted day 0 (5 June 2013 and 29 May 2014)).
2= Row Cover (beetles added day 0 (5 June 2013 and 29 May 2014)) and beetles killed day 7 (12 June 2013 and 5 June 2014).
3= Row Cover (beetles added day 7 (12 June 2013 and 5 June 2014)) and beetles killed day 14 (19 June 2013 and 13 June 2014).
4= Row Cover (beetles added day 14 (19 June 2013 and 13 June 2014)) and beetles killed day 21 (26 June 2013 and 20 June 2014).
5= Row Cover (no beetles, and no spray until day 21 (26 June 2013 and 20 June 2014)).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 2.6 Total number of marketable fruits from and total marketable yield (kg) all harvests. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC) in Lafayette, Indiana, in 2013 and 2014.

Treatments [z]	2013		2014	
	Total No. of Fruits (9 harvests)	Total yield (kg) (9 harvests)	Total No. of Fruits (5 harvests)	Total yield (kg) (5 harvests)
1	36.3 ab	83.7 ab	14.8 b	39.6 b
2	43.5 a	106.4 ab	34.0 a	96.2 a
3	22.8 b	63.0 b	25.0 ab	58.1 ab
4	46.3 a	118.9 a	26.0 ab	59.9 ab
5	44.5 a	111.1 a	29.5 ab	62.9 ab
6	46.0 a	111.2 a	24.0 ab	53.9 ab
P	0.02	0.05	0.04	0.01

[z] Treatments: 1= No Row Cover (planting date day 0 (5 June 2013 and 28 May 2014)).
2= Row Cover (planting date day 0 (5 June 2013 and 28 May 2014)) and beetles added day 14 (19 June 2013 and 11 June 2014).
3= No Row Cover (planting date day 7 (12 June 2013 and 4 June 2014)).
4= Row Cover (planting date day 7 (12 June 2013 and 4 June 2014)) and beetles added day 14 (19 June 2013 and 11 June 2014).
5= No Row Cover (planting date day 14 (19 June 2013 and 11 June 2014)).
6= Row Cover (planting date day 14 (19 June 2013 and 11 June 2014)) and beetles added day 14 (19 June 2013 and 11 June 2014).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 2.7 Number of marketable fruits per plot at early, mid and late harvests, total number of fruits from all harvests, marketable yield (kg) at early, mid and late harvests, and total yield (kg). The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC) in Vincennes, Indiana, in 2013.

Treatments [z]	No. of Fruits 10-19 July Early (5 harvests)	Yield (kg) 10-19 July Early (5 harvests)	No. of Fruits 22-31 July Mid (5 harvests)	Yield (kg) 22-31 July Mid (5 harvests)	No. of Fruits 2-9 Aug Late (4 harvests)	Yield (kg) 2-9 Aug Late (4 harvests)	Total No. of Fruits (14 harvests)	Total yield (kg) (14 harvests)
1	14.8	32.6	15.0	45.6	3.8	9.6	33.5	87.8
2	11.8	26.0	13.5	40.1	7.3	18.4	32.5	84.4
3	17.0	32.1	9.0	26.3	5.8	16.9	31.8	75.4
4	13.5	26.9	13.0	36.1	5.3	12.3	31.8	75.4
5	18.5	35.0	10.5	30.0	5.3	14.0	34.3	79.0
6	17.0	39.7	11.8	27.4	1.8	4.3	30.5	71.4
7	14.0	30.2	12.5	36.9	6.0	15.7	32.5	82.7
8	16.5	39.1	16.0	36.9	2.3	5.6	34.8	81.7
P	0.32	0.22	0.23	0.15	0.17	0.15	0.81	0.22

[z] Treatments: 1= Control (no row cover, no insecticide)
2= No Row Cover (spray Warrior on day 0 (15 May 2013 and 20 May 2014), 7 (22 May 2013 and 27 May 2014), 14 (29 May 2013 and 3 June 2014) and 21 (5 June 2013 and 10 June 2014)).
3= No Row Cover (FarMore®).
4= Row Cover (removal date day 7 (22 May 2013 and 27 May 2014)).
5= Row Cover (removal date day 14 (29 May 2013 and 3 June 2014)).
6= Row Cover (removal date day 21 (5 June 2013 and 10 June 2014)).
7= No Row Cover (soil drench with Platinum®).
8= Row Cover and soil drench with Platinum® (Removal date day 21 (5 June 2013 and 10 June 2014)).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 2.8 Number of marketable fruits per plot at early, mid and late harvests, total number of fruits from all harvests, marketable yield (kg) at early, mid and late harvests, and total yield (kg). The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC) in Vincennes, Indiana, in 2014.

Treatments [z]	No. of Fruits 10-19 July Early (5 harvests)	Yield (kg) 10-19 July Early (5 harvests)	No. of Fruits 22-31 July Mid (5 harvests)	Yield (kg) 22-31 July Mid (5 harvests)	No. of Fruits 2-7 Aug Late (3 harvests)	Yield (kg) 2-7 Aug Late (3 harvests)	Total No. of Fruits (13 harvests)	Total yield (kg) (13 harvests)
1	3.6	6.5	16.5	48.3	4.0	12.0	24.3	66.8
2	5.5	12.3	15.5	46.2	2.0	5.6	23.0	64.1
3	4.0	8.5	15.5	46.4	3.5	9.6	23.0	64.4
4	5.3	9.7	11.0	34.4	4.8	14.4	21.0	58.5
5	5.3	10.6	16.8	50.4	3.8	11.1	25.8	72.1
6	3.5	9.1	18.0	48.7	3.5	10.3	25.0	68.1
7	4.8	9.9	15.3	47.3	5.0	13.9	25.0	71.0
8	3.8	9.5	20.0	57.0	1.5	4.2	25.3	70.7
P	0.73	0.83	0.11	0.23	0.39	0.31	0.61	0.59

[z] Treatments: 1= Control (no row cover, no insecticide)
2= No Row Cover (spray Warrior on day 0 (15 May 2013 and 20 May 2014), 7 (22 May 2013 and 27 May 2014), 14 (29 May 2013 and 3 June 2014) and 21 (5 June 2013 and 10 June 2014)).
3= No Row Cover (FarMore®).
4= Row Cover (removal date day 7 (22 May 2013 and 27 May 2014)).
5= Row Cover (removal date day 14 (29 May 2013 and 3 June 2014)).
6= Row Cover (removal date day 21 (5 June 2013 and 10 June 2014)).
7= No Row Cover (soil drench with Platinum®).
8= Row Cover and soil drench with Platinum® (Removal date day 21 (5 June 2013 and 10 June 2014)).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

CHAPTER 3. EXPERIMENTS 2015 AND 2016

Variation among Muskmelon Cultivars in Attractiveness to Striped Cucumber Beetle and Severity of Bacterial Wilt Infection

3.1. Introduction

Introducing different muskmelon cultivars that vary in size, color, taste, shelf life, shipping and handling ability, and resistance or tolerance of pests and diseases, allows growers to select best cultivars to meet market demands. Most muskmelon cultivars are not resistant to most insects and diseases, but some of them can tolerate some insect feeding and some diseases. Striped cucumber beetle (SCB) and bacterial wilt (BW) are the most serious insect pest and disease of muskmelon. SCB feed on muskmelon plants, but are most important because they transmit the bacterium that causes BW.

The presence of volatiles could attract SCB to muskmelon plants initially, but male SCBs attract more beetles by signaling or releasing pheromone (Ferguson 1985; Lewis et al., 1990; Metcalf and Lampman, 1989; Sasu, 2010; Shapiro et al., 2012; Siegfried and Mullin, 1990). Cucurbitacin is produced by cucurbit plants as a chemical defense against herbivores. Even though cucurbitacin has a bitter taste and may be produced at different amounts by different cultivars, it attracts more beetles by causing them to compulsively feed, and helps them to find their host when plants are at early stages of growth (Lewis et al., 1990). Unfortunately, there are no cultivars resistant to this pest and disease. As a first step towards introducing resistant cultivars, there is a need to look for the most tolerant and susceptible cultivars that can be used for breeding purposes.

We hypothesized that;

1- The amount of BW correlates with the amount or location of SCB feeding.

2- Different cultivars have different reactions to the SCBs feeding and BW due to their ability to produce cucurbitacins, which have a profound effect on SCB feeding behavior.

The main objectives of these experiments were;

1- To determine the attractiveness of various cultivars to feral SCBs and their susceptibility to BW under field conditions.
2- To determine the susceptibility of different cultivars inoculated with BW pathogen under controlled condition.
3- To determine whether the concentration of cucurbitacin in a cultivar is related to its attractiveness to SCB or susceptibility to BW.

3.2. Materials and Methods

Field comparisons of muskmelon cultivars were carried out in 2015 and 2016 at three locations: Purdue Meigs Farm at Throckmorton/Meigs Purdue Agriculture Center (TPAC) near Lafayette, IN, Southwest Purdue Agriculture Center (SWPAC) near Vincennes, IN, and Pinney Purdue Agriculture Center (PPAC), near Wanatah IN. Ten to twelve common cultivars of muskmelon (Table 3.1 and Figures 3.12, 3.13, 3.14), including (cantaloupe and honeydew) were planted in 72-cell black seedling flat trays and grown in a greenhouse. Four-week-old seedlings were transplanted to raised beds (0.66 m wide) covered with black plastic mulch and supplied with drip irrigation in all studies (Figure 3.9). All experiments were laid out in randomized completed block designs (RCBD) with four replications (Figures 3.1, 2, 3). The goal was to identify cultivars most and least attractive to SCB, and most and least susceptible to BW at different locations. The cultivar Majus was not available in 2016, so we replaced it with Tirreno, a similar cultivar. No insecticides were applied in any experiments except experiment 2 (TPAC) with row covers, weekly Warrior® insecticide (13.6 g a.i. per 0.4 ha) was applied after removing row covers on day 21 after transplanting until few weeks before harvest.

Table 3.1 Cultivars of muskmelon which were used at three locations (TPAC, SWPAC and PPAC) in Indiana, US. 2015 and 2016.

Cultivars	Type	Year	Locations	Seed Source	Comments
Athena	orange flesh	2015 and 2016	TPAC, SWPAC, PPAC	Seedway	Hybrid
Savor	orange flesh	2015 and 2016	TPAC, SWPAC, PPAC	Johnny’s Selected Seeds	Hybrid
Diplomat	green flesh	2015 and 2016	TPAC, SWPAC, PPAC	Johnny’s Selected Seeds	Hybrid
Aphrodite	orange flesh	2015 and 2016	TPAC, SWPAC, PPAC	Seedway	Hybrid
Superstar	orange flesh	2015 and 2016	TPAC, SWPAC, PPAC	Harris Moran	Hybrid
Majus	orange flesh	2015	TPAC, SWPAC, PPAC	Rupp	Hybrid
Tirreno	orange flesh	2016	TPAC, SWPAC, PPAC	Rupp	Hybrid
Wrangler	orange flesh	2015 and 2016	TPAC, SWPAC, PPAC	Johnny’s Selected Seeds	Hybrid
Hales Best	orange flesh	2015 and 2016	TPAC, SWPAC, PPAC	Rupp	Open pollinated
Dream Dew	green flesh	2015 and 2016	TPAC, SWPAC, PPAC	Harris Moran	Hybrid
RML 9818	orange flesh	2015 and 2016	TPAC, SWPAC, PPAC	Syngenta	Hybrid
Green	green flesh	2015 and 2016	SWPAC	Syngenta	Open pollinated
Afg1	green flesh	2016	TPAC, SWPAC, PPAC	Afghanistan	Open pollinated
Afg2	green flesh	2016	TPAC, SWPAC, PPAC	Afghanistan	Open pollinated

	North				
	IV	III	II	I	
	RML9818	Hales Best	Dream Dew	Athena	
	Dream Dew	Athena	Afg2	Diplomat	
	Tirreno	Wrangler	Superstar	Afg2	
	Athena	Savor	Diplomat	Dream Dew	
	Superstar	Aphrodite	Wrangler	Hales Best	
West	Wrangler	Dream Dew	Afg1	Aphrodite	East
	Afg1	Tirreno	Aphrodite	Savor	
	Aphrodite	Diplomat	Hales Best	Afg1	
	Hales Best	Afg1	Savor	RML9818	
	Afg2	RML9818	Tirreno	Superstar	
	Diplomat	Afg2	Athena	Tirreno	
	Savor	Superstar	RML9818	Wrangler	
	South				

Figure 3.1 Cultivar Trials (TPAC), 2016

				South				
West	Aphrodite	Green	Tirreno	Athena	Superstar	Diplomat	IV	**East**
	Wrangler	Dream Dew	Afg1	Afg2	Savor	Hales Best	IV	
	Hales Best	Dream Dew	Diplomat	Afg1	Green	Athena	III	
	Wrangler	Tirreno	Aphrodite	Savor	Afg2	Superstar	III	
	Savor	Afg2	Athena	Aphrodite	Dream Dew	Green	II	
	Wrangler	Afg1	Tirreno	Superstar	Hales Best	Diplomat	II	
	Superstar	Savor	Aphrodite	Dream Dew	Wrangler	Diplomat	I	
	Afg1	Afg2	Green	Hales Best	Athena	Tirreno	I	
				North				

Figure 3.2 Cultivar Trials (SWPAC), 2016

	East			
IV	Wrangler		Superstar	III
IV	Aphrodite		Dream Dew	III
IV	Athena		Hales Best	III
IV	Afg2		Diploma	III
IV	Superstar		Athena	III
IV	Dream Dew		Wrangler	III
IV	Savor		Aphrodite	III
IV	RML9818		Afg1	III
IV	Hales Best		Tirreno	III
IV	Afg1		Savor	III
IV	Tirreno		RML9818	III
IV	Diploma		Afg2	III
North				South
II	RML9818		Afg1	I
II	Savor		Hales Best	I
II	Diplomat		Savor	I
II	Superstar		RML9818	I
II	Afg1		Diploma	I
II	Wrangler		Aphrodite	I
II	Dream Dew		Tirreno	I
II	Aphrodite		Athena	I
II	Tirreno		Afg2	I
II	Afg2		Wrangler	I
II	Hales Best		Superstar	I
II	Athena		Dream Dew	I
	West			

Figure 3.3 Cultivar Trials (PPAC) , 2016

3.2.1. Experiment 1 (TPAC)

The seeds of muskmelon cultivars were planted in the greenhouse on 21 April 2015 and 18 April, 2016. Four-week-old seedlings were transplanted into the field on 21 May, 2015 and 17 May, 2016. Experimental units consisted of a single row 12.2 m long with 1.22 m between plants within the row, with 2 m between rows, and 10 plants per row.

3.2.2. Experiment 2 (TPAC)

The main goal of this experiment was to take out attraction as factor and insure that there were beetles feeding on the plants with no choice, and to determine susceptibility to BW, assuming that beetles placed under row covers carried the bacterium and would feed on the plants. Muskmelon seedlings were grown and transplanted into the field as described in experiment 1. Row covers (Robert Marvel Plastic Mulch, Annaville, PA) supported by wire hoops were placed over two plants immediately after transplanting. Ten beetles which were collected from Silverthorne Farm, Rossville, IN (Figure 3.10), were released under the row covers and left to feed for three weeks. Row covers were removed after three weeks to allow pollination. Only in 2016, after removal of the row covers, lambda cyhalothrin (Warrior®) insecticide (13.6 g a.i. per 0.4 ha) was applied weekly to protect the plants from feeding.

3.2.3. Experiment 3 (SWPAC)

In this experiment, seeds of 11-12 cultivars were planted in black flat trays in greenhouse on 13 April 2015 and 2016. Four-week-old seedlings (16 seedlings) were transplanted on 13 May 2015 and 12 May 2016. Each experimental unit was in a single row 9.8 m long with 0.6 m between plants and 1 m between rows, and 12 plants per row.

3.2.4. Experiment 4 (PPAC)

The seeds of the same 10-12 cultivars were planted on 14 April 2015 and 18 April 2016. Seedlings (20 seedlings) were transplanted on 14 May 2015 and 12 May 2016. Each experimental unit was in a single row 12.2 m long with 0.61 m between plants and 2 m between rows, and 20 plants per row.

3.3. Data Components

3.3.1. Striped Cucumber Beetle Sampling

The number of live and dead beetles were counted manually on 5 randomly selected plants per replication by looking on the upper and lower leaf surfaces, beneath plants, inside flowers, and inside the transplant holes. Beetle sampling started one week after transplanting and was done 1-2 times per week until the end of July. In treatments with row covers, no counts were made until after the row covers were removed. Beetle days were also calculated by multiplying the number of SCBs per plant per observation times the number of days between each observation, and adding all together. For the first observation, the number of days since transplanting was multiplied by the number of SCB per plant.

3.3.2. Bacterial Wilt Severity

The percentage of plants showing symptoms of bacterial wilt (Figure 3.15) was estimated on each sampling date throughout the growing season using the Horsfall-Barratt rating scale for assessing disease, which is designed to compensate for human error in interpretation of the percentage of foliage infected (Horsfall and Barratt, 1945), and converted to percent infection using the ELANCO tables (Horsfall and Barratt, 1945). Bacterial wilt percentage was assessed visually by walking through each replication and giving each subplot a number from 0-11 depending on the disease severity. At the end the percentages of bacterial wilt in each observation was converted to a graph mean, which has been calculated and recommended by Horsfall-Barratt. The Area Under the Disease Progress Curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977). They have generated a formula for AUDPC calculation as follows:

$$\text{AUDPC} = \sum_{i=1}^{n} \left[\frac{(Y_{(i+1)} + Y_i)}{2}\right] \left[X_{(i+1)} - X_i\right]$$

Yi = Disease severity per unit (the Horsfall-Barratt number) at each observation.

Xi = Time (days) at each observation.

n = Total number of observation.

3.3.3. Cucurbitacin Analysis

Muskmelon seeds (12 cultivars) were planted in the greenhouse, Department of Horticulture and Landscape Architecture, Purdue University, West Lafayette, Indiana, on 6 July 2016. Five g leaves and 5 g stems from each cultivar were collected on 5 Aug 2016 and placed into separate 1 gallon Ziploc® bags and stored at -80 ˚C. The cucurbitacin analysis was conducted at Bindly Bioscience Center at Discovery Park on the Purdue University campus, West Lafayette, Indiana.

Sample Preparation: Leaf/stem sample 1 g was pulverized using Precellys CK28-R tubes. Before pulverization 100 uL of acetonitrile (ACN) and an internal standard solution containing 10 uL 7a,24(R/S)-dihydroxycholestenone (d7) (500 ng/mL in 50% water:50% acetonitrile) was added. The pulverized sample was then centrifuged at 13,000 g for 8 minutes. The supernatant was collected and dried overnight under low pressure centrifugation. The dried samples were dissolved in 50 µL of a solution of H2O (65%) + ACN (50%) by sonication and vortex mixing and transferred to HPLC vials for further analysis.

HPLC/MS-MS Analysis: Cucurbitacin A, B, E and I levels were quantitated by HPLC/MS-MS. Separation was performed on an Agilent Rapid Res 1200 HPLC system using an Atlantis dC18 (2.1x150 mm, 3.5 um) column. Mobile phase A was H_2O with 0.1% formic acid and mobile phase B was ACN with 0.1% formic acid. A linear gradient elution was used as follows: initial conditions 5% B; 0-1 min, 100% ,1-5 min, 100% 5-9, 5%, 9-10 min; Column re-equilibration was 10 – 16 min, 5% B; Column flow rate was 0.3 mL/min. Retention time for CuA, CuB, CuE, and CuI were 5.16 min and 4.56 min respectively.

Analytes were quantified using MS/MS utilizing an Agilent 6460 Triple Quadrupole mass spectrometer with CuA in negative mode while CuB, E and I in positive electrospray ionization (ESI) with collision energy of 20 eV. Quantitation was based on Multiple Reaction Monitoring (MRM). Transitions were 573.2 to 531.2 for CuA and 576.7 to 500.6 for CuB, 574.4 to 498.6 for CuE and 497.1 to 479.6 for CuI. The retention times were 7.00 min, 7.10 min, 8.00 min and 11.54 min for CuA, B, E and I.

3.3.4. Plant Vigor

The percentage of growth was assessed beginning 4-5 weeks after transplanting to understand the growth and development, and adaptation of each cultivar through the entire season. We used a qualitative number from 1-10 corresponding to 10-100, and given for each plot. Plants in each plot with no damage, disease, and not missing were given the highest number. All ratings were multiplied by 10 before recording to provide an estimate of vigor as a percentage of the most vigorous plot.

3.3.5. Number and Yield (kg) of Marketable and Unmarketable (Cull) Fruits Record

Muskmelon fruit maturity was reached on different dates depending on location and cultivar (Table 3.2). Changing color and easy slip from the stem were the index of muskmelon maturity. Yield was divided into three phases as early, mid and late harvests. Fruits were harvested at 2 to 4 day intervals. During each harvest, the number of fruit per plot and total weight of marketable and cull fruits were recorded. Fruits with yellow color, no damage, no disease, and weighing more than 1 kg were counted and weighted as marketable fruit. We recorded the individual fruit weight in each harvest, and at the end average and total yield for all harvests were calculated as well. Fruits that were diseased, damaged by insects or other pests, over ripe or small fruits (less than 1 kg) were considered unmarketable fruits.

All data were analyzed with one-way analysis of variance followed by post-hoc Fishers Least Significant Difference (LSD) test, 95 percent confidence by using SPSS (IBM SPSS Statistics 22).

Table 3.2 First and last harvest and total number of harvests per season at different locations (TPAC, PPAC and SWPAC) in 2015 and 2016.

Year	Locations											
	TPAC 1			TPAC 2			SWPAC			PPAC		
	First harvest	Last harvest	Total harvests	First harvest	Last harvest	Total harvests	First harvest	Last harvest	Total harvests	First harvest	Last harvest	Total harvests
2015	31 Jul	13 Aug	5 harvests	31 Jul	10 Aug	4 harvests	13 Jul	31 Jul	9 harvests	10 Aug	3 Sep	8 harvests
2016	25 Jul	17 Aug	9 harvests	25 Jul	17 Aug	9 harvests	11 Jul	5 Aug	10 harvests	28 Jul	13 Aug	4 harvests

3.4. Results and Discussion

3.1.1 Results

3.4.1.1.Striped Cucumber Beetles and Beetle Days

In 2015, experiment 1 (TPAC) beetle counting was started on June 5 and continued till July 10. The number of beetles per plant late in the season (July 10) was significantly higher in Savor followed by Diplomat, Hales Best and RML9818 (Table 3.3). The lowest numbers of beetles (on July 10) were observed on Superstar, Aphrodite, Athena, Majus, Wrangler and Dream Dew (Table 3.3). Beetle days of 7 samples were significantly higher in cultivars Diplomat and Savor. As beetle populations increase, they distribute throughout the experiment although they were higher on some cultivars through the season.

In 2016, experiment 1 (TPAC), significantly fewer beetles were counted on Savor, Aphrodite, Hales Best and Superstar on May 31 than on Dream Dew (Table 3.4). Dream Dew and RML9818 had significantly fewer number of beetles on June 13 than five other cultivars. From June 20 until July 8 Dream Dew had significantly fewer beetles than eight or nine other cultivars. Significantly fewer beetle days were accumulated in Dream Dew and RML9818, and Tirreno, Wrangler, and Savor, had the most beetle days (Table 3.4). The results of 2016 show that number of beetles on each cultivar are not consistent from year to year, although they prefer green-fleshed cultivars (Diplomat, Dream Dew) at early season.

In 2015, experiment 2 (TPAC) with row covers during the first three weeks, the number of beetles at all observations and beetle days were not significantly different at all observations, $p>0.05$ (Table 3.5). The results reveal that beetles distributed in all cultivars almost equally after row covers were removed.

Number of beetles and beetle days in 2016 are not presented because after removing the row covers on day 21 after transplanting, the plots were sprayed weekly with insecticide until a few weeks before harvesting, so the number of beetles was almost zero in all treatments.

In 2015, Experiment 3 (SWPAC), the number of beetles per plant and cumulative beetle days did not differ significantly between cultivars on any dates (Table 3.6). In 2016, cultivars Savor and Tirreno had significantly higher numbers of beetles than all other cultivars except Diplomat and Wrangler on June 15 (Table 3.7). Maximum beetle days were calculated on Savor, which was significantly more than all others except Tirreno (Table 3.7). Green had significantly fewer beetle days than all others except Superstar, Dream Dew and Afg2. The number of beetles per plant was generally the same on all cultivars through the season except on 15 June (Table 3.7).

In 2015, experiment 4 (PPAC), the number of beetles was not statistically different between cultivars on any date except late in the season on August 6, when RML9818 had significantly more beetles than all others except Dream Dew and Savor (Table 3.8). RML9818 also had the most beetle days, significantly more than Athena, Aphrodite, Superstar, Majus, Wrangler and Hales Best (Table 3.8). Savor, Diplomat and Dream Dew had beetle days between RML9818 and the other cultivars although there was no statistically significant difference in beetle days for those three and the remaining cultivars (Table 3.8). The results show that the maximum number of beetles were counted on most of the cultivars at late season.

In 2016, experiment 4 (PPAC), there was no difference between cultivars in number of beetles at most observations ($p>0.05$). However, on 16 June, Dream Dew had significantly more beetles, than any other cultivar, and on 14 July Aphrodite had significantly fewer beetles, than Savor and Afg1 (Table 3.9). There was no significant difference among cultivars for beetle days, $p>0.05$ (Table 3.9).

Generally, the number of beetles was higher on cultivars, Savor, Diplomat, RML9818 and Dream Dew followed by Wrangler and Tirreno at most locations, although at some locations (SWPAC and PPAC) the number of beetles and beetle days were not statistically significantly different. Also the highest number of beetles and beetle days were counted at PPAC then TPAC and the lowest at SWPAC.

3.4.1.2 Muskmelon Cultivar Ranking Based on Beetle Days and Cucurbitacin Ratio

Muskmelon cultivars were ranked based on beetle days per plant. The results (Figure 3.4) show that Savor and Diplomat had the highest beetle days followed by Wrangler. Cucurbitacin level and presence/absence differed in stems and leaves of muskmelon plants (Table 3.10 and Figures 3.5, 3.6). Cucurbitacin A was present only in leaves of Athena, RML9818 and Afg2, and cucurbitacin B only in leaves and stems of Dream Dew and RML9818. All cultivars had cucurbitacin I in both leaves and stems. No cucurbitacin A was present in stems; cucurbitacin E was found in stems of Diplomat, Hales Best, and Afg2; and cucurbitacin B in stems of Dream Dew and RML9818 (Table 3.10). In leaves the highest level of cucurbitacin I was found in Hales Best followed by Afg1 and Superstar, and the highest level of cucurbitacin A was found in RML9818. Stems of Diplomat had the most cucurbitacin I, followed Superstar, Dream Dew and Hales Best. Cucurbitacin E was present at similar levels in the stems of Diplomat, Hales Best and Afg2.

3.4.1.3 Bacterial Wilt Severity and Area Under Disease Progress Curve (AUDPC)

In 2015, experiment 1 (TPAC), the first observation took place on June 22 and the last on August 3 (Table 3.11). Cultivars Dream Dew and Diplomat tended to have significantly higher percentage of BW than most other cultivars throughout the season although there was quite a bit of variation from date to date. After the first observation date, the percentage for Dream Dew was significantly higher than for all other cultivars except RML9818 on June 29; RML9818, Diplomat and Savor on July 6; RML9818 and Diplomat on July 10; Diplomat on July 17 and 24, and Diplomat, RML9818, Athena, Hales Best and Savor on August 3. (Table 3.11). The AUDPC was significantly higher for Dream Dew (703.2) than for all other cultivars Diplomat and RML9818 also had higher AUDPC numbers. Superstar, Aphrodite, Athena and Majus had the lowest AUDPC values. These four cultivars did not differ significantly from one another or from three others, but did have significantly lower AUDPC than Dream Dew, RML9818, and Diplomat (Table 3.11).

In 2016, experiment 1 (TPAC), significantly higher percentages of BW were observed on Diplomat, Dream Dew and RML9818, than for the cultivar or cultivars with the lowest percentage of BW at all dates, and the same was true for Wrangler on July 24 and 27. A very low percentage of BW was seen on Superstar at all dates (Table 3.12). The AUDPC for Dream Dew was the highest again followed by RML9818 and Diplomat. Superstar, Hales Best and Afg1 had lower AUDPC than other cultivars in 2016 (Table 3.12).

In 2015, experiment 2 (TPAC), the plants were under the row covers for three weeks, and so the first BW estimation was on July 10. On 17 and 24 July cultivar Savor had significantly more BW than some other cultivars, indicating that when equal numbers of beetles are present, Savor may be more susceptible to BW than some of the other cultivars (Table 3.13). Savor and Dream Dew had the highest AUDPC values followed by Diplomat and RML9818. These four cultivars had significantly higher AUDPC than Superstar and Athena (Table 3.13).

In 2016, experiment 2 (TPAC), bacterial wilt severity was almost zero on Superstar and significantly higher on Dream Dew on 25 July. AUDPC was not significantly different between all cultivars, but the data show that Superstar had the lowest AUDPC (Table 3.14).

In 2015, experiment 3 (SWPAC), Dream Dew consistently had the highest or second highest BW, significantly more than the least-affected cultivars at all observations except June 10 and June 24 (Table 3.15). Diplomat, RML9818 and Green did not have significantly less BW than Dream Dew on July 1 or later dates, but did not always differ significantly from the least-affected cultivars (Table 3.15). The lowest BW percentage tended to be from Athena, Aphrodite, Superstar, Majus and Wrangler. Dream Dew and Green followed by Diplomat had highest AUDPC values. The remaining cultivars all had similar AUDPC values (Table 3.15).

In 2016, experiment 3 (SWPAC), BW severity was low, with Diplomat, Dream Dew and Green having the highest levels (Table 3.16). Diplomat and Dream Dew cultivars had highest AUDPC values and the lowest AUDPC were found in Superstar and Afg1, although the values were not significantly lower than many other cultivars (Table 3.16).

In 2015, experiment 4 (PPAC), RML9818, Diplomat, Dream Dew, Wrangler and Savor tended to have the highest level of BW. Aphrodite and Superstar had significantly less BW than RML9818 and Diplomat on August 14 and significantly less than RML 9818, Dream Dew, Diplomat, Savor, and Wrangler on August 28. The data show that there were no statistically significant differences among cultivars in AUDPC, $p>0.05$ (Table 3.17).

In 2016, experiment 4 (PPAC), Dream Dew, RML9818 and Diplomat had the highest level of BW (Table 3.18). Athena, Aphrodite and Superstar had the lowest amounts of BW. Similar results were found with the AUDPC, although other cultivars with low wilt were frequently not significantly different, and Hales Best, Aphrodite, and Athena did not have significantly higher AUDPC than Superstar.

3.4.1.4. Ranking of Muskmelon Cultivars Based on AUDPC Severity

Eight cultivars (Athena, Savor, Diplomat, Aphrodite, Superstar, Wrangler, Hales Best and Dream Dew) that were planted in both years (2015 and 2016) at all locations were ranked in order based on AUDPC severity. A mean rank for each cultivar from four experiments across 2 years was calculated. The results show that cultivars Dream Dew and Diplomat had the highest AUDPC, and Superstar followed by Aphrodite and Athena ranked lowest for AUDPC. The results indicate that Superstar, Aphrodite and Athena are less likely to develop BW than other cultivars, especially Dream Dew and Diplomat, which had more BW (Figure 3.7).

3.4.1.5.Plant Vigor

In 2015, experiment 1 (TPAC), plant vigor was significantly greater for most of the orange-fleshed cultivars, especially Superstar, Aphrodite, Savor, Majus and Wrangler than for Dream Dew and RML 9818 on June 22 (Table 3.19). Although plant vigor decreased overtime, Superstar remained at or near the top vigor throughout the season. Diplomat, Dream Dew and RML9818 cultivars were the least vigorous over the season, and by August 3 their vigor was related less than 10% (Table 3.19).

In the same experiment in 2016, plant vigor was significantly superior for orange-fleshed cultivars except RML9818 than green-fleshed and three new cultivars orange-fleshed Tirreno, and green-fleshed Afg1 and Afg2 (Table 3.20). The results of both years 2015 and 2016, show that orange-fleshed (except RML9818) cultivars grow better and more vigorously than green-fleshed.

In 2015, experiment 2 (TPAC), most cultivars had high vigor not significantly different from Superstar on June 22, except Savor, Dream Dew, and RML9818 (Table 3.21). Plant vigor declined overtime, but Athena, Aphrodite, Hales Best, and Superstar remained with significantly more vigor than Majus, Savor, Diplomat and Dream Dew on August 3 (Table 3.21).

In 2016, experiment 2 (TPAC), plant vigor remained much greater over the season for most cultivars except Dream Dew and RML9818 (Table 3.22). The maximum plant vigor was 100% and lowest was 72%. RML9818 and Dream Dew consistently received the lowest ratings for vigor, although not significantly lower than all other cultivars (Table 3.22). By comparing the results of 2015 and 2016, it indicates that plant vigor was greater in 2016 than 2015 after removing the row covers.

In 2015 and 2016, experiment 3 (SWPAC), plant vigor was recorded significantly superior for most cultivars, except Diplomat, Dream Dew, RML9818, Afg1 and Afg2. In both years Diplomat had lowest vigor at the end of the season (Tables 3.23 and 3.24).

In 2015, experiment 4 (PPAC), all cultivars had similar vigor, except Diplomat and RML9818, which had lower vigor on 16 July, 14 and 28 August, and Savor and Dream Dew which had lower vigor on 28 August, although differences with other cultivars were not all significant (Table 3. 25). In 2016, on the final date, Dream Dew had the lowest vigor, but was not significantly less than RML9818, Afg1, Afg2, Diplomat, or Tirreno. (Table 3.26). The vigor results from all locations show that Superstar and some other orange-fleshed cultivars grow better and more vigorously than green-fleshed cultivars.

3.4.1.6.Number, Yield (kg) and Individual Weight of Marketable Fruits

In 2015, experiment 1 (TPAC), Savor, Diplomat, Hales Best, Dream Dew and RML9818 had the lowest number of fruits and smallest yield for all harvests combined (Table 3.27). Number of fruits and yield were not significantly different among the cultivars at mid-harvest. Significantly more fruit and higher yields were collected from Aphrodite, Wrangler and Superstar. The highest individual fruit weights were calculated for Superstar and Aphrodite, although there were no significant differences among cultivars (Table 3.27).

In 2016, experiment 1 (TPAC), the total number of fruits and yield were significantly greater for Superstar and Aphrodite with Athena and Wrangler ranked third and fourth, respectively. Savor, Dream Dew, and Afg2 produced no marketable fruit, but their yield was not significantly less than RML9818, Afg1, Tirreno, Diplomat, or Hales Best (Table 3.28). Yield components were higher than most other cultivars for Superstar and Aphrodite at all stages of harvest, followed by Athena at mid-harvests for number of fruits. Individual fruit weights were significantly superior for the Superstar and Aphrodite than for most other cultivars (Table 3.28).

In 2015, experiment 2 (TPAC), Superstar, Tirreno and Diplomat had greater yield at early harvests, then Superstar plus Athena during mid harvests (Table 3.29). Total number of marketable fruits and yield were highest for Superstar and Athena, and maximum fruit weight was calculated for Superstar (5.9 kg), Aphrodite (3.8 kg) and Athena (4.5 kg). In contrast; Diplomat and Hales Best had the smallest fruits (Table 3.29).

The smallest number of fruits and lowest total yield were collected from Savor and Afg2 followed by Diplomat and Hales Best in 2016 (Table 3.30). Athena produced the highest total number of fruits, but not significantly more than Superstar, Tirreno, Wrangler, or RML 9818. Athena and Superstar produced the highest total yields, followed by Wrangler, Tirreno, Dream Dew and Aphrodite which were not significantly lower. Superstar had the largest individual fruit weight, although six other cultivars were not significantly smaller. (Table 3.30). The results of 2015 and 2016 show green-fleshed cultivars (Diplomat, Dream Dew, Afg1 and Afg2) and orange-fleshed (RML9818) had lowest yield than other cultivars.

In 2015, experiment 3 (SWPAC), the significantly highest number of fruits and yield at early harvests were recorded for Diplomat (Table 3.31). Superstar, Aphrodite and Wrangler had greater number of fruits at mid harvests than most other cultivars. At late harvest Hales Best produced significantly more fruits than any other cultivar except Wrangler, but there were no significant differences in yield ($p>0.05$). Wrangler had significantly more total number of fruits than any other cultivar, followed by Hales Best. Superstar and Aphrodite had significantly higher yield than other cultivars except for Wrangler and Athena. Maximum individual fruit weight was produced by Superstar and Aphrodite (Table 3.31).

In 2016 (SWPAC), the highest number of fruits were recorded for Diplomat and Wrangler at early harvests, then Wrangler and Athena at mid-harvest, and Green, Athena, Tirreno, Wrangler and Hales Best at late harvests (Table 3.32). Additionally, significantly greater yield was produced by Diplomat at early harvests, and Athena, Superstar and Aphrodite at mid harvests, and Dream Dew, Green Aphrodite and Athena at late harvests (Table 3.32). Athena and Wrangler had the greatest total number of fruits. The highest total yield was produced by Dream Dew followed Athena, Aphrodite, Superstar and Wrangler. Savor produced the lowest number of fruits at all harvest in 2015, and Savor, Afg1 and Afg2 produced the lowest number of fruits in 2016 (Table 3.32).

In 2015, experiment 4 (PPAC), no fruits were harvested for RML9818, Savor and Hales Best had low yields at early harvests (Table 3.33). Athena, Superstar, and Aphrodite had maximum yield and number of fruits at most harvests. Low yields were produced by Savor and Dream Dew at late harvests. Total number of fruits was highest for Superstar followed by Athena, Aphrodite, Majus and Dream Dew, which were not significantly lower. Individual fruits weight was significantly higher for Superstar than for other cultivars except Athena, Aphrodite and Dream Dew (Table 3.33).

The greatest number of fruits and yield at early harvests in 2016 (PPAC) were recorded for Superstar, then Superstar and Athena and Aphrodite at mid harvests, and at late harvest no significant difference was found (Table 3.34). Significantly greater total number of fruits and yield were produced by Superstar and Athena than most other cultivars, and largest fruits were recorded for Superstar, Aphrodite and Athena (Table 3.34). The results of 2015 and 2016 indicate that Savor, Dream Dew, RML9818, Afg1 and Afg2 had the least number of fruits and yield. Also, yield components were greater in 2015 than 2016 (Table 3.34).

Number of fruits and total yield were high for most orange-fleshed cultivars, except Savor, Hales Best, and RML9818. Superstar, Aphrodite and Athena produced more fruits and greater yield at all locations. Individual fruit weight was higher for those cultivars followed by Dream Dew.

Results for unmarketable fruit number and yield are presented in Appendix B 2.

3.4.2 Discussion

Selection of proper cultivars that are adapted to the local climate and meet market demands, and also resistant or tolerant to the insect feeding and diseases are important keys to profitable production. Some resistant cultivars of different crops are well established. As bacterial wilt is an important disease of muskmelon which is transmitted by striped cucumber beetles, there is a need to introduce a cultivar that less susceptible to beetle feeding and bacterial wilt. The results of muskmelon cultivars trials at three locations in 2015 and 2016, indicate that different cultivars had different reaction, tolerance and susceptibility to SCBs feeding and BW. Most orange-fleshed cultivars, except RML9818 had more tolerance than green-fleshed. Among 12 cultivars, Superstar, Aphrodite and Athena had less BW and AUDPC. In particular, Superstar which produced significantly bigger fruits had less feeding damage, a lower percentage of BW and smaller AUDPC.

Plant vigor, total number of fruits and yield were greater on these cultivars that were less affected by BW. In contrast, green-fleshed cultivars such as Diplomat (a galia type) and Dream Dew (honeydew) were more attractive to the SCBs and had high BW and AUDPC. These difference could be due to the plants reaction to feeding or defense mechanisms, which involves releasing different chemicals to repel the insects or reduce feeding.

One of main compounds that is produced by the cucurbit is cucurbitacin. This compound has a bitter taste and most insects do not like it, but SCBs are attracted to this compound. The cucurbitacin concentration results show that green-fleshed cultivars produce higher levels of cucurbitacin than orange-fleshed cultivars, but there is no correlation between number of beetle and level of cucurbitacin in each cultivar.

The low number of marketable fruits and yield observed in some cultivars were due to plant wilting from BW, because as the plant wilts, it affects fruits as well. Diplomat and Dream Dew showed wilting symptoms earlier in the season and had higher BW and AUDPC at the end of season, which caused low numbers of marketable fruits and yield. Plants grown under row covers with beetles added had increased vigor, especially cultivars Athena, Aphrodite and Superstar.

Table 3.3 Number of live striped cucumber beetles (SCB) and cumulative beetle days (over 7 sample periods) per plant for ten muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center(TPAC), Lafayette, IN, in 2015.

Treatments	5 Jun	9 Jun	15 Jun	22 Jun	29 Jun	6 Jul	10 Jul	Beetle days
Athena	1.1	8.6	11.6	6.3	11.3 b	5.3	9.8 b	80.2 bc
Savor	1.7	10.2	9.5	7.3	16.8 a	10.1	19.7 a	104.4 ab
Diplomat	6.5	10.9	13.9	9.2	13.4 ab	7.6	13.6 ab	112.4 a
Aphrodite	1.7	5.2	6.7	4.4	11.9 b	6.1	7.9 b	70.2 c
Superstar	1.2	7.1	8.1	5.6	9.8 bc	8.5	8.5 b	68.8 c
Majus	1.9	3.7	7.4	6.1	8.9 bc	4.1	5.3 b	62.8 c
Wrangler	2.2	6.7	7.5	6.5	9.7 bc	5.5	9.8 b	74.3 c
Hales Best	1.0	4.7	6.1	4.1	9.0 bc	6.5	13.9 ab	64.4 c
Dream Dew	3.6	7.0	7.9	5.8	9.7 bc	7.0	6.9 b	67.5 c
RML 9818	1.8	7.2	10.2	4.8	5.8 c	10.2	11.8 ab	72.3 c
P	0.11	0.65	0.28	0.09	0.001	0.18	0.03	0.01

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.4 Number of live striped cucumber beetles (SCB) and cumulative beetle days (over 9 sample periods) per plant for twelve muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2016.

Treatments	26 May	31 May	6 Jun	13 Jun	20 Jun	27 Jun	1 Jul	8 Jul	15 Jul	Beetle days
Athena	1.1	3.8 ab	1.7	3.6 ab	5.1 abc	3.7 ab	3.4 abc	5.1 ab	6.2	180.3 abc
Savor	1.8	1.4 b	1.7	2.9 abc	6.2 ab	3.9 ab	5.2 a	6.1 ab	5.9	192.2 ab
Diplomat	0.2	4.3 ab	2.8	3.1 abc	6.4 ab	2.9 abc	3.2 abc	4.6 ab	2.5	180.7 abc
Aphrodite	0.1	1.5 b	2.4	2.8 abc	6.1 ab	3.3 ab	3.2 abc	4.8 ab	5.5	161.7 abc
Superstar	0.2	1.2 b	1.8	3.8 ab	5.5 abc	3.9 ab	4.0 ab	5.4 ab	4.1	169.6 abc
Tirreno	1.0	2.9 ab	1.7	3.9 ab	7.1 a	4.4 a	4.0 ab	6.4 a	5.7	206.0 a
Wrangler	1.0	2.5 ab	2.7	4.4 a	6.8 a	3.4 ab	3.4 abc	4.7 ab	7.5	193.3 ab
Hales Best	0.5	0.9 b	1.7	4.4 a	6.3 ab	2.9 abc	3.7 abc	4.4 ab	6.0	168.2 abc
Dream Dew	3.3	5.6 a	0.7	0.2 c	0.8 d	0.5 d	0.2 d	0.5 c	0.9	69.2 c
RML 9818	1.4	4.0 ab	0.9	0.3 c	2.1 cd	1.1 cd	1.3 cd	2.5 bc	3.2	86.9 c
Afg 1	1.2	3.9 ab	1.4	1.0 bc	2.2 cd	1.0 cd	1.2 cd	2.7 abc	5.1	97.0 abc
Afg 2	2.3	2.9 ab	1.2	2.2 abc	3.0 bcd	1.8 bcd	2.3 bcd	4.1 ab	6.2	130.3 abc
P	0.25	0.005	0.14	0.04	0.001	0.001	0.002	0.05	0.17	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.5 Number of live striped cucumber beetles (SCB) and cumulative beetle days (over 5 sample periods) per plant for ten muskmelon cultivars after row covers were removed 21 days after transplanting. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2015.

Treatments	22-Jun	29-Jun	2-Jul	6-Jul	10-Jul	Beetle days
Athena	1.5	2.8	2.9	2.2	2.7	45.8
Savor	2.0	3.1	2.9	2.0	3.4	52.3
Diplomat	2.3	3.1	2.6	2.1	2.7	51.3
Aphrodite	1.5	2.7	1.9	1.7	2.4	37.3
Superstar	2.0	2.2	2.8	2.2	2.2	43.2
Majus	1.6	2.8	1.9	1.1	1.9	35.5
Wrangler	1.5	2.3	1.8	1.9	2.6	36.4
Hales Best	1.6	2.7	2.5	1.9	3.0	42.8
Dream Dew	2.0	2.2	2.5	2.5	2.1	46.7
RML 9818	1.3	2.4	1.8	2.0	4.2	40.5
P	0.57	0.39	0.81	0.40	0.16	0.24

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.6 Number of live striped cucumber beetles (SCB) and cumulative beetle days (over 7 sample periods) per plant for eleven muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2015.

Treatments	20 May	27 May	3 Jun	10 Jun	17 Jun	24 Jun	1 Jul	Beetle days
Athena	0.0	0.3	3.7	1.0	5.9 ab	3.2	13.3	111.8
Savor	0.3	1.4	5.3	2.4	6.6 ab	4.6	16.4	160.9
Diplomat	0.0	2.6	4.0	1.4	5.8 ab	3.6	6.0	128.1
Aphrodite	0.0	0.6	1.3	1.8	3.2 b	3.7	7.7	81.5
Superstar	0.5	2.4	2.9	1.1	4.8 ab	5.8	10.0	131.9
Majus	0.6	0.6	4.3	2.7	10.2 a	3.4	6.0	159.4
Wrangler	0.0	0.6	1.8	3.8	4.6 b	5.1	10.2	122.1
Hales Best	0.2	1.9	4.8	2.4	3.2 b	1.9	11.9	112.7
Dream Dew	0.3	1.4	4.0	3.0	2.7 b	3.8	11.8	119.2
RML 9818	0.8	2.2	2.7	2.6	2.7 b	4.5	10.4	118.9
Green	0.2	1.1	3.8	2.4	2.9 b	3.7	10.3	108.9
P	0.76	0.30	0.79	0.67	0.15	0.91	0.83	0.75

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.7 Number of live striped cucumber beetles (SCB) and cumulative beetle days (over 7 sample periods) per plant for twelve muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2016.

Treatments	25 May	1 Jun	8 Jun	15 Jun	21 Jun	30 Jun	5 Jul	Beetle days
Athena	0.1	0.3	0.4	1.9 b	1.9	2.1	1.1	44.8 b
Savor	0.4	0.5	1.5	3.1 a	2.8	2.0	2.2	72.2 a
Diplomat	0.4	0.2	1.3	2.3 ab	1.8	1.0	1.4	48.8 b
Aphrodite	0.0	0.2	0.7	1.2 b	1.6	1.3	1.0	34.7 b
Superstar	0.3	0.3	0.4	1.3 b	1.3	1.7	1.4	36.0 bc
Tirreno	0.0	0.5	1.1	3.3 a	1.8	2.2	1.6	59.1 ab
Wrangler	0.5	0.1	0.5	2.3 ab	1.2	1.6	1.9	41.9 b
Hales Best	0.4	0.2	0.5	1.4 b	1.6	1.9	1.4	40.7 b
Dream Dew	0.1	0.2	0.5	1.2 b	1.6	1.9	2.0	37.8 bc
Green	0.3	0.3	0.4	1.7 b	1.0	1.6	2.3	35.6 c
Afg1	0.2	0.1	0.6	1.5 b	1.6	2.8	2.6	45.3 b
Afg2	0.1	0.2	0.4	1.2 b	1.5	2.2	1.8	38.0 bc
P	0.82	0.75	0.20	0.001	0.28	0.11	0.28	0.003

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.8 Number of live striped cucumber beetles (SCB) and cumulative beetle days (over 7 sample periods) per plant for ten muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2015.

Treatments	25 Jun	2 Jul	9 Jul	16 Jul	23 Jul	29 Jul	6 Aug	Beetle days
Athena	0.0	0.8	4.6	13.0	11.4	15.2	19.4 bc	323.0 b
Savor	0.0	2.2	5.0	8.4	19.6	32.6	30.2 abc	485.2 ab
Diplomat	1.0	9.8	9.6	11.0	13.8	24.2	11.4 c	483.1 ab
Aphrodite	0.1	0.8	2.8	16.4	9.4	15.0	22.0 bc	323.8 b
Superstar	0.0	0.0	0.6	14.0	10.0	20.4	12.4c	317.4 b
Majus	0.1	1.0	4.2	10.4	13.2	23.4	18.4 bc	371.0 b
Wrangler	0.0	1.2	8.0	9.6	13.2	21.0	24.2 bc	382.0 b
Hales Best	0.0	3.2	4.2	12.2	12.2	17.6	26.8 bc	360.4 b
Dream Dew	0.0	0.6	8.8	12.8	14.6	32.6	37.0 ab	508.2 ab
RML 9818	0.7	12.4	12.0	19.6	18.4	36.0	51.4 a	726.4 a
P	0.56	0.34	0.38	0.92	0.15	0.08	0.01	0.01

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.9 Number of live striped cucumber beetle (SCB) and cumulative beetle days (over 7 sample periods) per plant for twelve muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2016.

Treatments	31 May	9 Jun	16 Jun	23 Jun	30 Jun	7 Jul	14 Jul	Beetle days
Athena	0.0	0.3	6.9 b	7.5	9.3	5.0	3.9 bc	205.5
Savor	0.0	0.7	7.2 b	11.8	10.9	7.8	7.7 a	275.75
Diplomat	0.0	0.4	6.6 b	8.6	7.3	5.9	4.6 abc	205.5
Aphrodite	0.0	0.7	5.4 b	8.5	8.2	2.7	2.5 c	179.55
Superstar	0.0	0.1	5.5 b	7.2	8.8	4.6	4.0 bc	186
Tirreno	0.0	0.5	6.4 b	12.7	11.8	3.9	3.9 bc	249.9
Wrangler	0.0	0.4	6.7 b	8.8	9.7	4.1	2.7 bc	209.9
Hales Best	0.2	0.7	7.2 b	8.8	9.2	4.1	3.7 bc	214.3
Dream Dew	0.0	0.7	11.8 a	10.3	8.0	6.6	4.9 abc	265.25
RML 9818	0.2	0.8	7.9 b	11.6	9.4	8.8	4.9 abc	275.5
Afg1	0.1	1.3	7.8 b	9.2	6.7	6.0	5.7 ab	222.9
Afg2	0.3	0.7	6.9 b	11.0	7.6	5.8	5.1 abc	231.1
P	0.26	0.63	0.02	0.06	0.53	0.09	0.04	0.06

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

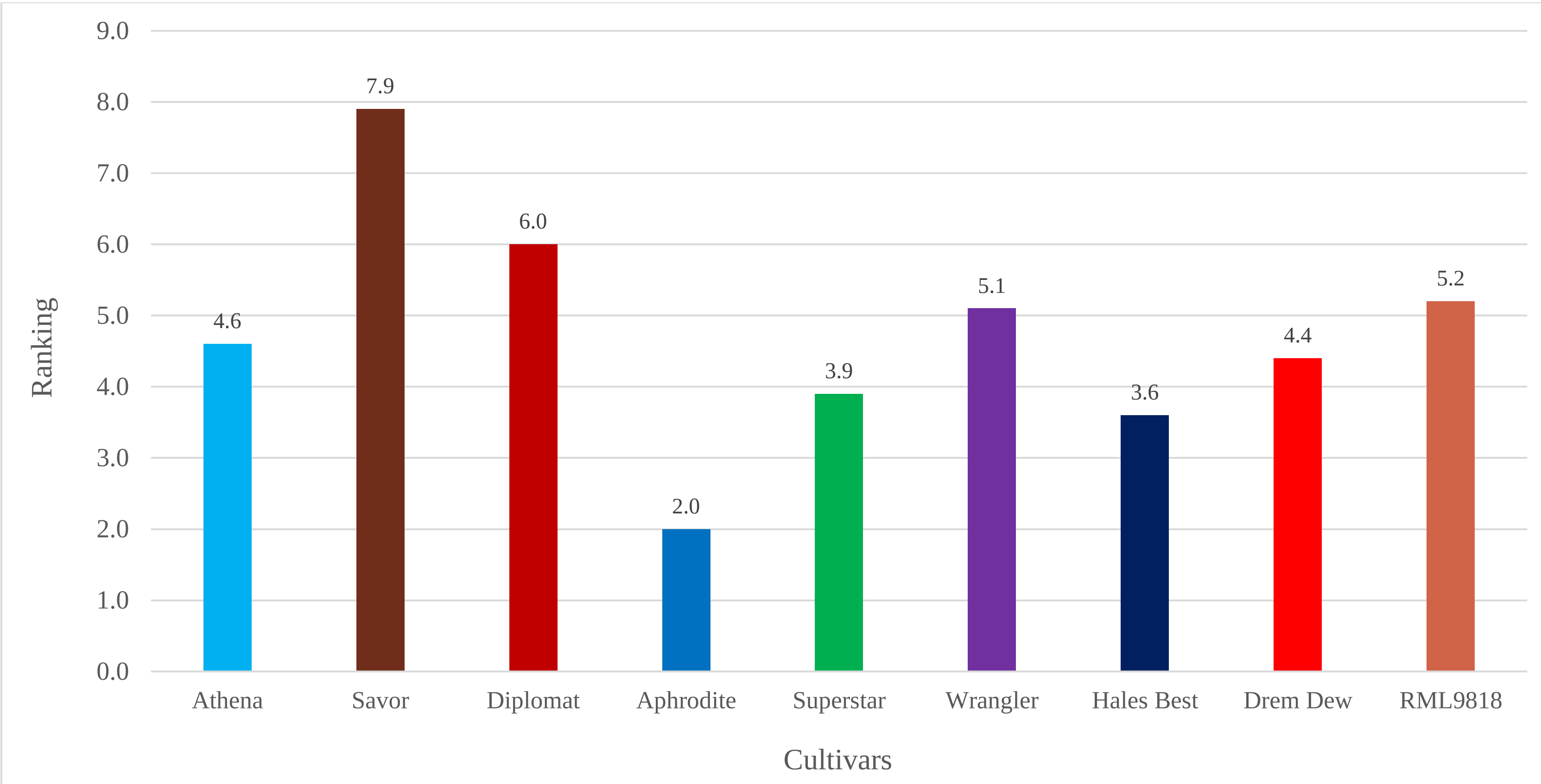

Figure 3.4 Muskmelon cultivars ranking based on beetle days. P= 0.002

Table 3.10 Cucurbitacin E, A, B and I response ratio in leaves and stems of twelve muskmelon cultivars

Cultivars	Response Ratio in Leaf			Response Ratio in Stem		
	A	B	I	E	B	I
Athena	0.014	0.0	0.008	0.0	0.0	0.042
Savor	0.0	0.0	0.028	0.0	0.0	0.024
Diplomat	0.0	0.0	0.022	0.010	0.0	0.083
Aphrodite	0.0	0.0	0.026	0.0	0.0	0.039
Superstar	0.0	0.0	0.038	0.0	0.0	0.064
Tirreno	0.0	0.0	0.025	0.0	0.0	0.028
Wrangler	0.0	0.0	0.021	0.0	0.0	0.022
Hales Best	0.0	0.0	0.050	0.009	0.0	0.058
Dream Dew	0.0	0.060	0.014	0.0	0.056	0.060
RML9818	0.045	0.016	0.021	0.0	0.061	0.017
Afg1	0.0	0.0	0.042	0.0	0.0	0.014
Afg2	0.014	0.0	0.013	0.012	0.0	0.049

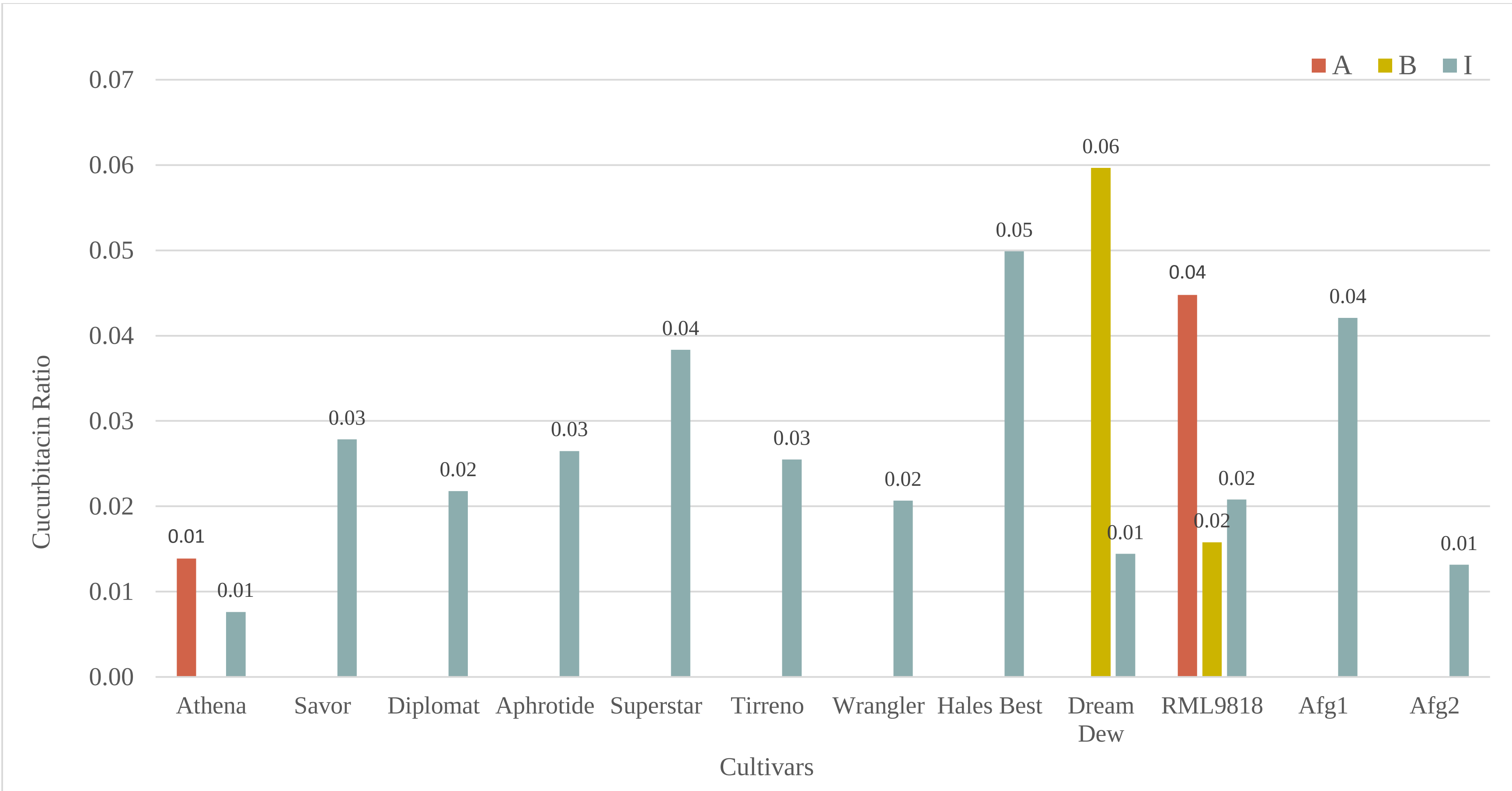

Figure 3.5 Cucurbitacin A, B and I response ratio in leaf of muskmelon cultivars. P=0.001

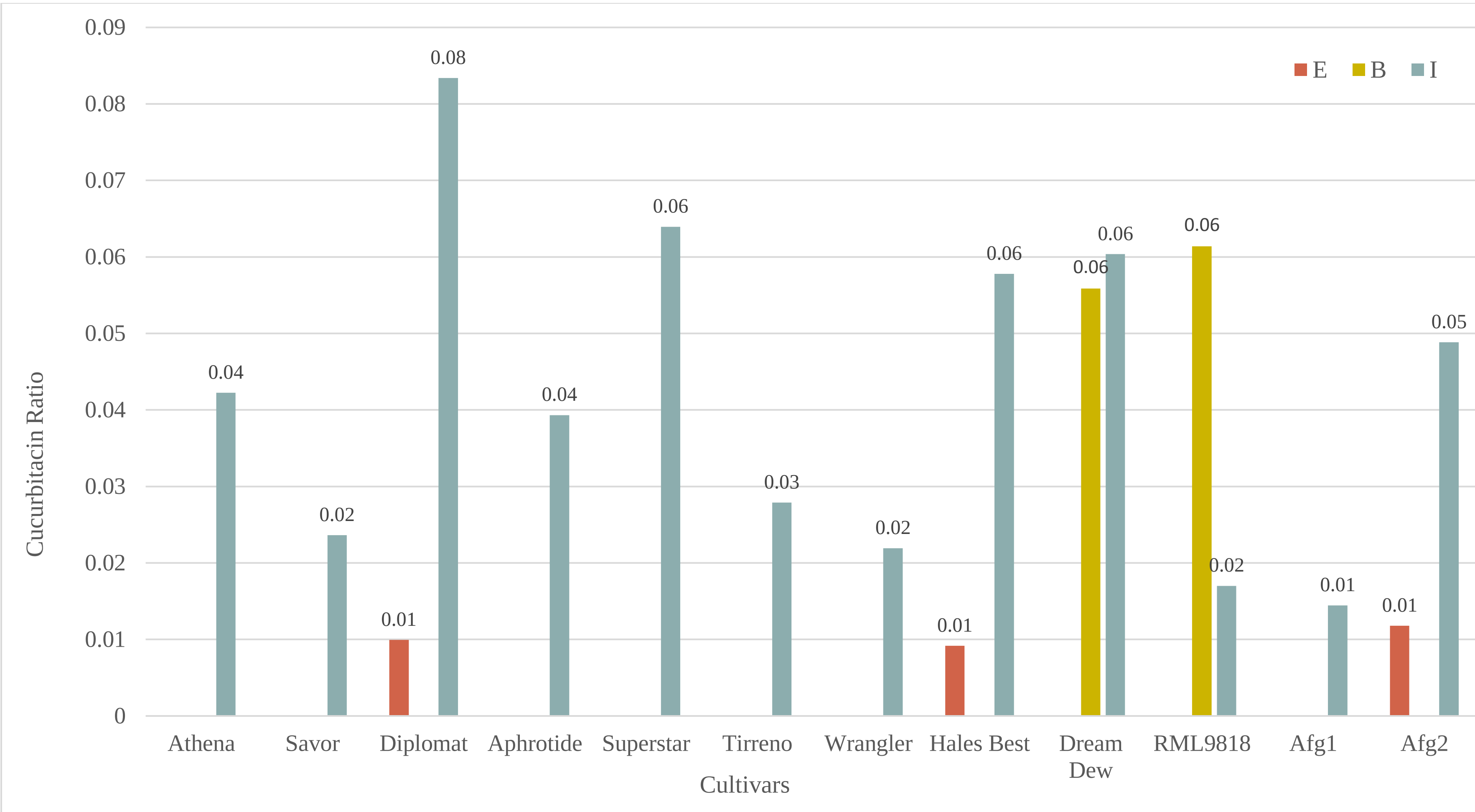

Figure 3.6 Cucurbitacin E, B and I response ratio in stem of muskmelon cultivars. P= 0.02

Table 3.11 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for ten muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2015.

Treatments	Bacterial Wilt Severity in Percent [z]							
	22 Jun	29 Jun	6 Jul	10 Jul	17 Jul	24 Jul	3 Aug	AUDPC [y]
Athena	0.6	2.3 c	11.3 bcd	15.8 c	32.0 cde	68.0 cd	90.6 abc	157.5 c
Savor	1.2	3.5 c	18.8 abc	27.0 bc	49.0 bcd	73.0 cd	88.7 abc	213.2 bc
Diplomat	0.0	4.1b c	43.0 ab	73.0 ab	77.5 ab	95.3 ab	95.9 ab	408.7 b
Aphrodite	0.0	2.9 c	6.4 cd	15.8 c	43.0 bcd	55.0 d	62.5b c	125.8 c
Superstar	0.6	0.6 c	3.5 d	7.7 c	11.3 e	49.0 d	55.0 c	49.6 c
Majus	0.0	2.3 c	7.7 cd	13.4 c	18.8 cde	55.0 d	55.0 c	106.4 c
Wrangler	0.0	4.7b c	15.8 bc	11.3 c	15.8 de	49.0 d	49.0 c	186.7 bc
Hales Best	0.6	3.5 c	7.7 cd	22.5 bc	32.0 cde	68.0 cd	88.7 abc	178.6 bc
Dream Dew	3.5	22.5 a	62.5 a	81.3 a	88.7 a	97.1 a	97.7 a	702.3 a
RML 9818	1.7	13.4 ab	43.0 abc	37.5 abc	55.0 bcd	92.3 bc	94.6 abc	415.0 b
P	0.11	0.003	0.002	0.01	0.001	0.001	0.001	0.001

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.

[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.12 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for twelve muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2016.

Treatments	Bacterial Wilt Severity in Percent [z]							
	24 Jun	27 Jun	1 Jul	8 Jul	14 Jul	22 Jul	29 Jul	AUDPC [y]
Athena	2.9 bcd	6.4 bc d	5.4 cd	13.4 bc	18.8 c	27.0 bc	27.0 cd	117.6 bc
Savor	4.1 bcd	3.5 cd	7.7 cd	22.5 bc	37.5 bc	62.5 b	68.0 bcd	150.0 bc
Diplomat	37.5 a	43.0 ab	43.0 ab	49.0 ab	93.6 a	97.1 a	97.7 a	607.5 b
Aphrodite	2.9 bcd	3.5 cd	7.7 cd	15.8 bc	9.4 d	22.5 bc	37.5 bcd	133.4 bc
Superstar	2.9 bcd	4.1 cd	5.4 d	7.7 c	7.7 d	13.8 c	18.8 d	69.8 d
Tirreno	6.4 bcd	5.4 bcd	7.7 cd	9.37 c	11.3 c	49.0 bc	81.3 bc	106.5 bc
Wrangler	18.8 abc	18.8 abc	22.5 bc	22.5 bc	27.0 c	62.5 b	88.7 bcd	306.4 c
Hales Best	1.2 de	2.9 cd	4.1 cd	6.4 c	27.0 c	32.0 bc	68.0 bcd	66.9 d
Dream Dew	22.5 abc	62.5 a	77.5 a	90.6 a	93.6 a	100.0 a	100.0 a	898.3 a
RML 9818	9.4 abcd	13.4 abc	49.0 ab	84.2 a	94.6 a	98.3 a	98.8 a	641.8 b
Afg 1	0.0 e	0.0 d	2.3 d	13.4 bc	15.83 c	55.0 bc	84.2 b	66.6 d
Afg 2	4.7 bcd	6.4 bcd	6.4 cd	7.7 c	18.75 c	22.5 bc	84.2 b	146.2 bc
P	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.
[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.13 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for ten muskmelon cultivars exposed to 5 cucumber beetles per plant under row covers for 21 days after transplanting and after that to natural populations. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2015.

Treatments	Bacterial Wilt Severity in Percent [z]				
	10 Jul	17 Jul	24 Jul	3 Aug	AUDPC [y]
Athena	0.0	2.5 c	4.8 c	25.0	177.9 de
Savor	0.3	22.5 a	31.3 a	36.3	675.4 a
Diplomat	0.0	10.0 abc	32.5 a	31.3	525.4 ab
Aphrodite	0.0	12.5 c	18.0 abc	30.0	441.4 bcd
Superstar	0.8	3.8 c	8.8 c	18.8	210.1 cde
Majus	0.0	10.0 abc	29.5 a	35.0	498.0 bc
Wrangler	0.0	7.5 bc	14.5 abc	26.3	332.9 bcd
Hales Best	0.0	1.3 c	15.0abc	22.5	303.4 bcde
Dream Dew	0.5	21.3 ab	25.5 ab	42.5	720.5 a
RML 9818	0.3	13.8 abc	21.3 abc	30.0	538.9 ab
P	0.51	0.03	0.02	0.30	0.001

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.
[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.14 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for twelve muskmelon cultivars exposed to 5 cucumber beetles per plant under row covers for 21 days after transplanting and after that to natural populations. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2016.

Treatments	Bacterial Wilt Severity in Percent [z]				
	17 Jun	14 Jul	25 Jul	3 Aug	AUDPC [y]
Athena	0.0	0.0	0.0 c	2.9	49.2
Savor	0.0	0.0	5.4 c	5.4	336.4
Diplomat	0.0	0.0	22.5 ab	68.0	564.3
Aphrodite	1.2	1.2	2.3 bc	5.4	117.8
Superstar	0.0	0.0	0.0 c	0.0	29.9
Tirreno	0.0	0.0	2.9 bc	3.5	179.1
Wrangler	0.0	0.0	2.9 bc	15.8	193.7
Hales Best	0.0	0.0	3.5 bc	4.1	250.8
Dream Dew	1.0	7.7	55.0 a	93.6	1270.4
RML 9818	0.0	13.4	13.4 ab	32.0	1285.4
Afg 1	0.0	0.0	0.0 c	3.5	801.2
Afg 2	0.0	0.0	0.0 c	7.7	128.6
P	0.53	0.16	0.005	0.09	0.13

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.

[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.15 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for eleven muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2015.

Treatments	Bacterial Wilt Severity in Percent [z]						
	10 Jun	17 Jun	24 Jun	1 Jul	8 Jul	15 Jul	AUDPC [y]
Athena	1.2	1.2 b	1.7 b	3.5 bc	6.4 bc	11.3 c	40.5 c
Savor	0.0	0.0 b	1.2 b	2.9 c	2.9 c	27.0 abc	25.8 c
Diplomat	2.3	2.9 b	5.4 b	15.8 abc	27.0 ab	77.5 ab	158.6 b
Aphrodite	0.0	0.0 b	0.0 b	2.9 c	9.4 abc	15.8 abc	19.0 c
Superstar	0.0	0.0 b	0.0 b	2.3 c	4.1 bc	18.8 abc	21.9 c
Majus	0.0	0.0 b	2.3 b	4.1 bc	7.7 bc	13.4 bc	66.8 c
Wrangler	0.0	0.0 b	0.6 b	2.9 c	5.4 bc	15.8 abc	20.6 c
Hales Best	0.0	0.0 b	0.0 b	4.7 bc	9.4 abc	27.0 abc	27.5 c
Dream Dew	1.2	15.8 a	15.8 ab	37.5 a	55.0 a	81.3 a	406.6 a
RML 9818	1.7	3.5 b	4.1 b	11.3 abc	18.8 abc	49.0 abc	137.1 b
Green	0.0	1.2 b	18.8 a	27.0 ab	27.0 ab	37.5 abc	327.5 ab
P	0.40	0.001	0.001	0.001	0.001	0.003	0.001

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.
[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.16 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for twelve muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2016.

Treatments	Bacterial Wilt Severity in Percent [z]					
	21 Jun	29 Jun	5 Jul	13 Jul	20 Jul	AUDPC [y]
Athena	0.0 b	1.2	4.7 ab	6.4 bc	9.4 bc	82.8 c
Savor	7.7 a	1.7	1.2 b	11.3 ab	13.4 ab	120.8 bc
Diplomat	1.7 b	1.7	15.8 a	27.0 a	27.0 a	277.4 a
Aphrodite	1.7 b	4.1	1.2 b	9.4 abc	7.7 bc	99.2 bc
Superstar	0.0 b	1.2	1.2 b	4.7 bc	5.4 bc	42.9 c
Tirreno	2.3 b	4.1	4.1 b	6.4 bc	11.3 ab	98.1 bc
Wrangler	0.0 b	1.7	4.1 b	11.3 abc	13.4 ab	106.6 bc
Hales Best	0.6 b	2.3	2.9 b	13.4 abc	13.4 ab	108.0 bc
Dream Dew	2.3 b	3.5	4.7 ab	15.8 abc	27.0 a	189.3 ab
Green	2.9 b	1.2	3.5 b	13.4 abc	22.5 a	116.9 bc
Afg1	0.0 b	0.0	1.7 b	4.1 c	4.7 c	44.0 c
Afg2	0.0 b	2.9	4.1 b	9.4 abc	11.3 ab	104.8 bc
P	0.01	0.57	0.02	0.05	0.001	0.001

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.

[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.17 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for ten muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2015.

Treatments	Bacterial Wilt Severity in Percent [z]						
	16 Jul	23 Jul	29 Jul	6 Aug	14 Aug	28 Aug	AUDPC [y]
Athena	0.6 ab	1.7	4.7	5.4 b	27.0 bc	43.0 cd	93.6
Savor	0.6 ab	3.5	4.7	6.4 b	43.0 bc	81.3 bc	125.7
Diplomat	4.7 a	5.4	32.0	32.0 a	86.6 ab	84.2 bc	494.2
Aphrodite	0.0 b	4.7	6.4	6.4 b	13.4 c	15.8 d	132.0
Superstar	0.6 ab	1.7	1.7	2.9 b	11.3 c	15.8 d	34.7
Majus	0.0 b	4.1	7.7	7.7 b	49.0 bc	62.5 bcd	189.9
Wrangler	0.6 ab	4.7	6.4	13.4 ab	49.0 bc	81.3 bc	197.1
Hales Best	0.0 b	2.9	4.7	5.4 b	27.0 bc	73.0 bcd	162.3
Dream Dew	0.6 ab	3.5	9.4	15.8 ab	68.0 abc	93.6 ab	265.9
RML 9818	2.9 ab	9.4	32.0	49.0 a	95.3 a	100.0 a	611.9
P	0.02	0.74	0.15	0.21	0.004	0.001	0.24

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.

[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.18 Severity of bacterial wilt disease reported as percent of foliage affected on different dates and Area Under the Disease Progress Curve (AUDPC) over the entire season for twelve muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2016.

Treatments	Bacterial Wilt Severity in Percent [z]						
	23 Jun	30 Jun	7 Jul	14 Jul	22 Jul	28 Jul	AUDPC [y]
Athena	0.0	1.7 cd	5.4 bc	9.4 de	9.4 ef	18.8 d	99.9 d
Savor	0.0	3.5bcd	6.4 abc	9.4 de	18.8 de	43.0 cd	132.4 c
Diplomat	2.3	7.7 ab	13.4 ab	37.5 ab	77.5 b	95.9 a	337.4 ab
Aphrodite	0.0	0.6 cd	5.4 bc	11.3 cde	13.4 de	18.8 d	91.3 d
Superstar	0.0	1.2 cd	2.3 c	4.7 e	5.4 f	13.4 d	39.6 d
Tirreno	1.2	1.7 cd	9.4 ab	32.0 abc	49.0 c	84.17 b	218.2 bc
Wrangler	0.0	2.3 bcd	6.4 abc	18.8 bcd	15.8 de	37.5 cd	147.7 bc
Hales Best	0.0	0.0 d	2.3 c	9.4 de	13.4 de	27.0 cd	52.2 d
Dream Dew	1.2	13.4 a	18.8 a	43.0 a	93.6 a	97.1 a	455.2 a
RML 9818	0.0	4.7 abc	11.3 ab	43.0 a	81.3 b	97.1 a	317.6 ab
Afg1	0.0	3.5 bcd	6.4 abc	22.5 bcd	22.5 de	77.5 bc	175.2 bc
Afg2	0.0	1.2 cd	6.4 abc	22.5 bcd	27.0 cd	43.0 cd	153.1 bc
P	0.07	0.002	0.003	0.001	0.001	0.001	0.001

[z] Severity values were estimated using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945) and converted to percent using the ELANCO tables.
[y] The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt ratings using trapezoid integration (Shaner and Finney, 1977).
Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

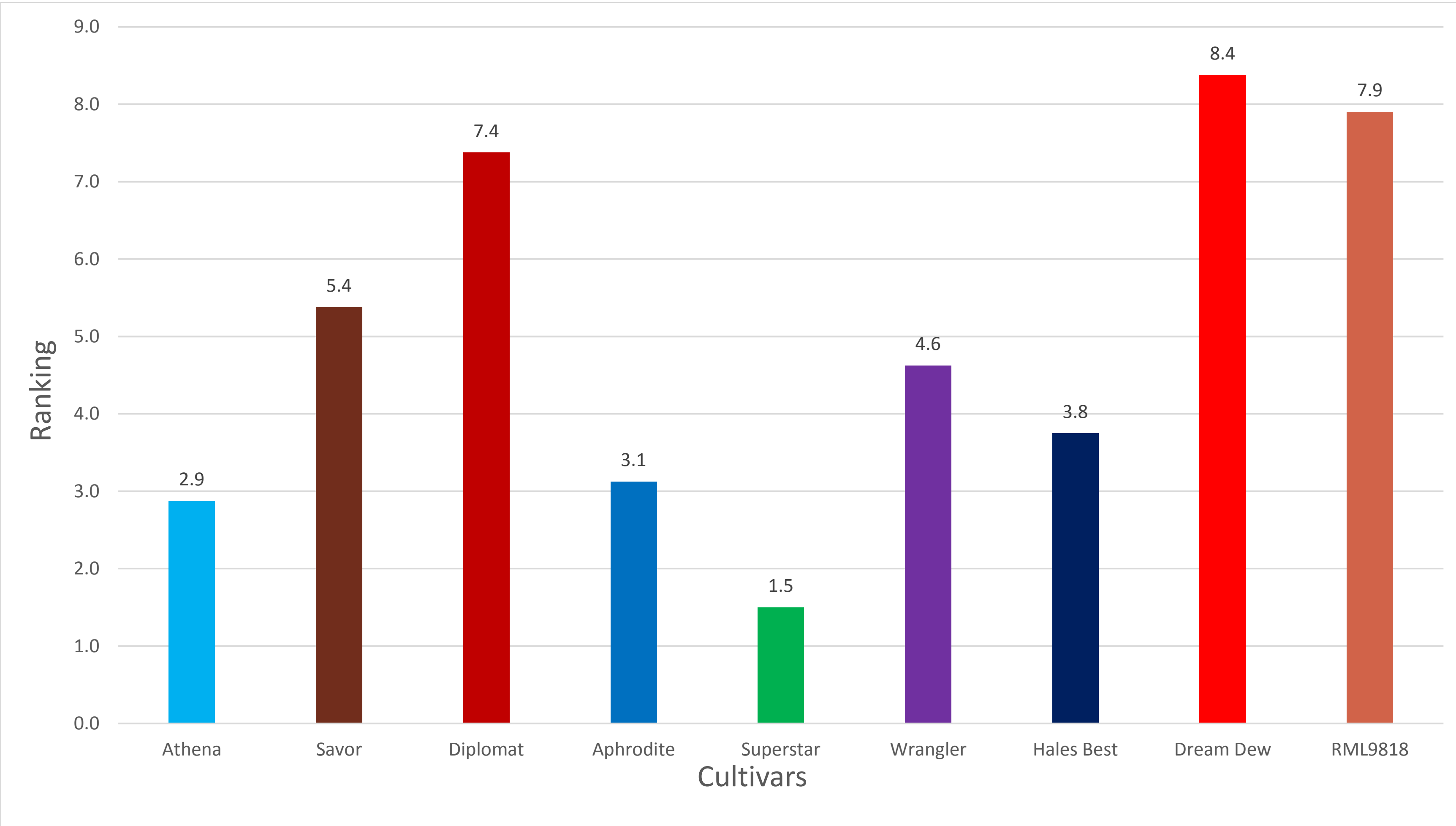

Figure 3.7 Muskmelon cultivars ranking based on the AUDPC for bacterial wilt severity from 4 experiments at three locations (TPAC1 and TPAC 2, SWPAC and PPAC), 2015 and 2016. P= 0.02

Table 3.19 Plant vigor (%) per observation for ten muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2015.

Treatments	22 Jun	29 Jun	6 Jul	10 Jul	17 Jul	24 Jul	3 Aug
Athena	82.5 ab	82.5 ab	65.0 ab	67.5 ab	57.5 ab	45.0 ab	17.5 cd
Savor	87.5 a	87.5 ab	65.0 ab	65.0 abc	52.5 abc	40.0 ab	20.0 bcd
Diplomat	75.0 abc	75.0 bc	50.0 c	45.0 cd	32.5 cd	10.0 a	7.5 c
Aphrodite	87.5 a	80.0 ab	67.5 ab	62.5 ab	60.0 ab	50.0 ab	50.0 a
Superstar	90.0 a	87.5 a	80.0 a	75.0 a	75.0 a	55.0 a	47.5 ab
Majus	90.0 a	85.0 a	70.0 ab	67.5ab	62.5 ab	45.0 ab	42.5 abc
Wrangler	87.5 a	85.0 a	75.0 a	72.5 a	70.0 a	52.5 a	45.0 abc
Hales Best	75.0 abc	77.5 a	72.5 ab	70.0 ab	62.5 ab	40.0 ab	27.5 abcd
Dream Dew	57.5 c	52.5 c	40.0 c	40.0 d	25.0 d	7.5 b	2.5 c
RML 9818	65.0 bc	62.5 c	50.0 bc	55.0 bcd	42.5 bcd	30.0 ab	10.0 c
P	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.20 Plant vigor (%) per observation for twelve muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2016.

Treatments	20 Jun	24 Jun	27 Jun	1 Jul	8 Jul	14 Jul	22 Jul
Athena	47.5 ab	62.5 bc	67.5 ab	62.5 b	62.5 abc	60.0 a	45.0 ab
Savor	47.5 ab	60.0 bc	65.0 ab	60.0 b	57.5 c	47.5 ab	42.5 abc
Diplomat	32.5 bc	40.0 de	35.0 b	32.5 c	12.5 e	12.5 c	10.0 e
Aphrodite	62.5 a	77.5 ab	75.0 ab	70.0 ab	60.0 abc	55.0 ab	55.0 a
Superstar	70.0 a	90.0 a	87.5 a	85.0 a	67.5 a	60.0 a	62.5 a
Tirreno	47.5 ab	52.5 cd	82.5 ab	57.5 b	52.5 c	52.5 ab	42.5 abc
Wrangler	47.5 ab	52.5 cd	50.0 ab	57.5 b	55.0 bc	20.0 b	40.0 abc
Hales Best	65.0 a	77.5 ab	80.0 ab	82.5 s	60.0 ab	20.0 b	50.0 a
Dream Dew	5.0 c	5.0 g	7.5 b	10.0 d	2.5 e	2.0 c	1.0 e
RML 9818	12.5 c	17.5 fg	22.5 b	15.0 cd	20.0 de	20.0 b	20.0 cd
Afg 1	17.5 c	22.5 fg	22.5 b	22.5 cd	20.0 d	20.0 b	25.0 bcd
Afg 2	22.5 bc	30.0 dfg	32.5 b	27.5 cd	25.0 d	25.0 b	25.0 bcd
P	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.21 Plant vigor (%) per observation for ten muskmelon cultivars. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2015.

Treatments	22-Jun	29-Jun	10-Jul	17-Jul	24-Jul	3-Aug
Athena	90.0 ab	87.5 a	80.0 a	70.0 a	60.0 a	47.5 a
Savor	77.5 bc	70.0 bcd	57.5 bc	45.0 c	15.0 c	0.0 c
Diplomat	95.0 a	87.5 a	60.0 abc	50.0 ab	10.0 bc	7.5 c
Aphrodite	90.0 ab	85.0 ab	67.5 abc	52.5 ab	47.5 ab	40.0 a
Superstar	100.0 a	92.5 a	77.5 a	70.0 a	60.0 a	37.5 ab
Majus	87.5 ab	92.5 a	77.5 a	67.5 ab	27.5 ab	10.0 bc
Wrangler	90.0 ab	80.0 abc	75.0 ab	60.0 ab	37.5 ab	25.0 abc
Hales Best	85.0 ab	87.5 a	85.0 a	77.5 a	57.5 a	40.0 a
Dream Dew	67.5 c	55.0 d	55.0 c	42.5 c	22.5 c	0.0 c
RML 9818	77.5 bc	65.0cd	57.5 bc	50.0 ab	32.5 bc	27.5 abc
P	0.01	0.001	0.003	0.002	0.001	0.002

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.22 Plant vigor (%) per observation for twelve muskmelon cultivars. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2016.

Treatments	20 Jun	24 Jun	27 Jun	1 Jul	8 Jul
Athena	97.5	100.0 a	100.0 a	100.0 a	92.5 abc
Savor	80.0	97.5 a	97.5 a	97.5 ab	100.0 a
Diplomat	75.0	82.5 bc	80.0 abc	75.0 abcd	77.5 bc
Aphrodite	77.5	82.5 bc	85.0 abc	72.5 bcd	77.5 bc
Superstar	82.5	82.5 bc	90.0 a	92.5 abc	100.0 a
Tirreno	92.5	97.5 a	90.0 a	90.0 abcd	100.0 a
Wrangler	67.5	82.5 bc	90.0 a	82.5 abcd	87.5 abc
Hales Best	77.5	67.5 bc	77.5 abc	75.0 abcd	82.5 abc
Dream Dew	60.0	60.0 bc	62.5 bc	65.0 d	72.5 c
RML 9818	47.5	52.5 c	60.0 c	67.5 cd	72.5 c
Afg 1	82.8	82.5 bc	87.5 ab	85.0 abcd	87.5 abc
Afg 2	75.5	70.0 bc	77.5 abc	85.0 abcd	95.5 ab
P	0.06	0.01	0.02	0.05	0.01

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.23 Plant vigor (%) per observation for eleven muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2015

Treatments	10 Jun	17 Jun	24 Jun	1 Jul	8 Jul	15 Jul
Athena	82.5 abc	90.0 ab	95.0 ab	85.0 a	77.5 abc	67.5 a
Savor	95.0 a	97.5 a	100.0 a	92.5 a	95.0 a	70.0 a
Diplomat	77.5 abc	77.5 bc	72.5 c	62.5 bc	55.0 cd	37.5 b
Aphrodite	87.5 ab	95.0 a	97.5 a	82.5 ab	72.5 abcd	70.0 a
Superstar	92.5 a	90.0 ab	90.0 ab	85.0 a	85.0 ab	72.5 a
Majus	95.0 a	95.0 a	80.0 bc	72.5 abc	70.0 bcd	60.0 a
Wrangler	85.0 ab	95.0 a	95.0 ab	87.5 a	80.0ab	67.5 a
Hales Best	90.0 a	97.5 a	97.5 a	85.0 a	75.0 abcd	70.0 a
Dream Dew	77.5 abc	72.5 cd	65.0 c	57.5 c	52.5 d	37.5 b
RML 9818	70.0 bc	77.5 bc	80.0 bc	72.5 abc	67.5bcd	52.5 ab
Green	65.0 c	62.5 d	67.5 c	60.0 c	62.5 d	55.0 b
P	0.01	0.001	0.001	0.003	0.005	0.002

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.24 Plant vigor (%) per observation for twelve muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2016

Treatments	15 Jun	21 Jun	29 Jun	5 Jul	13 Jul
Athena	62.5 a	87.5 ab	95.0 ab	90.0 ab	75.0 a
Savor	65.0 a	95.0 ab	100.0 a	100.0 a	75.0 a
Diplomat	55.0 abc	82.5 abc	82.5 c	75.0 c	55.0 b
Aphrodite	57.5 ab	92.5 ab	95.0 ab	92.5 ab	72.5 a
Superstar	65.0 a	97.5 ab	100.0 a	100.0 a	72.5 a
Tirreno	62.5 a	92.5 ab	97.5 ab	90.0 ab	70.0 a
Wrangler	65.0 a	100.0 a	100.0 a	100.0 a	70.0 a
Hales Best	60.0 ab	87.5 ab	97.5 ab	97.5 a	75.0 a
Dream Dew	47.5 bc	80.0 bc	95.0 ab	95.0 ab	72.5 a
Green	42.5 cd	65.0 cd	87.5 bc	90.0 ab	80.0 a
Afg1	30.0 d	47.5 d	67.5 d	82.5 bc	77.5 a
Afg2	42.5 cd	60.0 d	90.0 bc	90.0 ab	72.5 a
P	0.001	0.001	0.001	0.005	0.002

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.25 Plant vigor (%) per observation for ten muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2015.

Treatments	16 Jul	23 Jul	29 Jul	6 Aug	14 Aug	28 Aug
Athena	92.5 abc	87.5	82.5	82.5	62.5 ab	50.0 abc
Savor	97.5 a	95.0	82.5	82.5	52.5 ab	35.0 bc
Diplomat	82.5 c	77.5	52.5	60.0	30.0 bc	27.5 bcd
Aphrodite	95.0 ab	82.5	72.5	85.0	67.5 ab	57.5 ab
Superstar	90.0 abc	97.5	92.5	90.0	75.0 a	70.0 a
Majus	97.5 a	85.0	80.0	75.0	52.5 abc	42.5 abc
Wrangler	95.0 ab	87.5	82.5	60.0	50.0 abc	40.0 abc
Hales Best	95.0 ab	90.0	85.0	82.5	60.0 ab	45.0 abc
Dream Dew	92.5 abc	90.0	85.0	70.0	45.0 abc	22.5 cd
RML 9818	80.0 c	70.0	50.0	40.0	17.5 c	0.0 d
P	0.04	0.09	0.07	0.15	0.005	0.002

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.26 Plant vigor (%) per observation for twelve muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2016.

Treatments	23 Jun	30 Jun	7 Jul	14 Jul
Athena	45.0 ab	77.5 abcd	82.5 ab	67.5 abcd
Savor	62.5 ab	90.0 a	77.5 ab	75.0 ab
Diplomat	42.5 ab	62.5 bcd	67.5 c	55.0 cde
Aphrodite	67.5 a	92.5 a	82.5 ab	72.5 abc
Superstar	62.5 ab	87.5 ab	92.5 a	82.5 a
Tirreno	62.5 ab	85.0 abc	72.5 ab	57.5 bcde
Wrangler	65.0 a	85.0 abc	80.0 ab	67.5 abcd
Hales Best	57.5 ab	77.5 bcd	90.0 ab	70.0 abc
Dream Dew	47.5 ab	70.0 bcd	62.5 c	45.0 e
RML 9818	42.5 ab	67.5 bcd	70.0 b	50.0 de
Afg1	35.0 b	52.5 d	67.5 c	57.5 bcde
Afg2	35.0 b	57.5 d	67.5 c	62.5 bcde
P	0.001	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.27 Number and yield per plot of marketable fruits at early, mid, late and all harvests for ten muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2015.

Treatments	Early harvest No. of fruits 31 Jul–3 Aug (2 harvests)	Early harvest yield (kg) 31 Jul–3 Aug (2 harvests)	Mid harvest No. of fruits 7-10 Aug (2 harvests)	Mid harvest yield (kg) 7-10 Aug (2 harvests)	Late harvest No. of fruits 13 Aug (1 harvests)	Late harvest yield (kg) 13 Aug (1 harvests)	Total No. of marketable fruits	Total marketable yield (kg)	Individual fruit weight (kg)
Athena	2.8 abc	11.7 bc	0.8	3.3	0.0 b	0.0	3.5 bc	15.0 bc	3.5
Savor	0.3 bc	0.3 c	0.3	1.5	0.0 b	0.0	0.5 cd	1.8 c	1.8
Diplomat	0.3 bc	0.9 c	0.3	1.5	0.0 b	0.0	0.5 cd	2.3 c	2.3
Aphrodite	5.3 a	31.6 a	2.5	16.2	1.8 a	4.7	9.5 a	52.5 a	5.3
Superstar	4.0 ab	22.6 ab	1.5	9.3	0.0 b	0.0	5.5 ab	31.8 ab	5.8
Majus	3.0 abc	12.9 bc	2.3	9.5	0.5 ab	1.3	5.8 ab	23.7 bc	4.1
Wrangler	5.5 a	19.0 ab	2.0	8.5	1.0 ab	3.2	8.5 ab	30.7 ab	3.6
Hales Best	0.0 c	0.0 c	1.3	4.9	0.0 b	0.0	1.3 bc	4.9 b	1.0
Dream Dew	0.0 c	0.0 c	0.3	0.8	0.0 b	0.0	0.3 c	0.8 c	0.8
RML 9818	0.3 bc	1.1 c	0.0	0.0	0.0 b	0.0	0.3 c	1.1 c	1.1
P	0.003	0.001	0.22	0.20	0.05	0.18	0.001	0.001	0.08

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.28 Number and yield per plot of marketable fruits at early, mid, late and all harvests for twelve muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2016.

Treatments	Early harvest No. of fruits 25 Jul-1 Aug (3 harvests)	Early harvest yield (kg) 25 Jul-1 Aug (3 harvests)	Mid harvest No. of fruits 3-8 Aug (3 harvests)	Mid harvest yield (kg) 3-8 Aug (3 harvests)	Late harvest No. of fruits 10-17 Aug (3 harvests)	Late harvest yield (kg) 10-17 Aug (3 harvests)	Total No. of marketable fruits	Total marketable yield (kg)	Individual fruit weight (kg)
Athena	1.5 abc	5.3 abc	3.3 abc	8.3 bc	0.8	2.2 bc	5.5 abc	15.7 abc	1.7 bc
Savor	0.0 c	0.0 c	0.0 c	0.0 c	0.0	0.0 c	0.0 c	0.0 c	0.0 d
Diplomat	0.8 abc	1.7 bc	0.0 c	0.0 c	0.5	1.3 bc	1.3 c	3.0 c	0.3 d
Aphrodite	3.0 ab	12.6 a	6.5 a	21.2 a	1.0	4.6 ab	10.5 a	38.3 a	3.5 a
Superstar	3.5 a	11.6 ab	4.3 ab	14.8 ab	1.5	6.1 a	9.3 ab	32.4 ab	2.8 ab
Tirreno	0.0 c	0.0 c	0.5 c	1.5 c	0.0	0.0 c	0.5 c	1.5 c	0.1 cd
Wrangler	0.3 bc	0.6 c	2.5 bc	5.0 bc	2.0	5.1 ab	4.8 bc	10.7 bc	0.9 cd
Hales Best	0.0 c	0.0 c	2.3 bc	4.0 bc	1.0	1.4 bc	3.3 c	5.3 c	0.9 cd
Dream Dew	0.0 c	0.0 c	0.0 c	0.0 c	0.0	0.0 c	0.0 c	0.0 c	0.0 d
RML 9818	0.0 c	0.0 c	1.5 bc	1.9 c	0.0	0.0 c	1.5 c	1.9 c	0.2 d
Afg 1	0.0 c	0.0 c	0.0 c	0.0 c	0.8	2.3 bc	0.8 c	2.3 c	0.1 d
Afg 2	0.0 c	0.0 c	0.0 c	0.0 c	0.0	0.0 c	0.0 c	0.0 c	0.0 d
P	0.001	0.002	0.003	0.001	0.57	0.002	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.29 Number and yield per plot of marketable fruits at early, mid, late and all harvests for ten muskmelon cultivars. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2015.

Treatments	Early harvest No. of fruits 31 Jul (1 harvests)	Early harvest yield (kg) 31 Jul (1 harvests)	Mid harvest No. of fruits 3-7 Aug (2 harvests)	Mid harvest yield (kg) 3-7 Aug (2 harvests)	Late harvest No. of fruits 10 Aug (1 harvests)	Late harvest yield (kg) 10 Aug (1 harvests)	Total No. of marketable fruits	Total marketable yield (kg)	Individual fruit weight (kg)
Athena	0.0	0.0 b	4.5 a	19.6 a	0.8	3.7	5.3 a	23.3 a	4.5 ab
Savor	0.0	0.0 b	0.0 b	0.0 b	0.0	0.0	0.0 c	0.0 b	0.0 d
Diplomat	0.5	2.6 ab	0.5 b	2.0 b	0.0	0.0	1.0 c	4.6 b	1.1 cd
Aphrodite	0.0	0.0 b	1.3 ab	7.1 b	0.0	0.0	1.3 c	7.1 b	3.8 ab
Superstar	1.5	8.4 a	2.3 ab	12.8 ab	0.0	0.0	3.8 ab	21.2 a	5.9 a
Tirreno	0.8	3.3 ab	0.5 b	3.1 b	0.0	0.0	1.3 c	6.4 b	2.7 bcd
Wrangler	0.0	0.0 b	2.0 ab	6.4 b	0.3	0.9	2.3 bc	7.3 b	2.4 bcd
Hales Best	0.0	0.0 b	0.5 b	1.7 b	0.0	0.0	0.5 c	1.7 b	1.7 cd
Dream Dew	0.0	0.0 b	0.0 b	0.0 b	0.0	0.0	0.0 c	0.0 b	0.0 d
RML 9818	0.0	0.0 b	0.0 b	0.0 b	0.0	0.0	0.0 c	0.0 b	0.0 d
P	0.06	0.03	0.01	0.02	0.51	0.50	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table 3.30 Number and yield per plot of marketable fruits at early, mid, late and all harvests for twelve muskmelon cultivars. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette, IN, in 2016.

Treatments	Early harvest No. of fruits 25 Jul-1 Aug (3 harvests)	Early harvest yield (kg) 25 Jul-1 Aug (3 harvests)	Mid harvest No. of fruits 3-8 Aug (3 harvests)	Mid harvest yield (kg) 3-8 Aug (3 harvests)	Late harvest No. of fruits 10-17 Aug (3 harvests)	Late harvest yield (kg) 10-17 Aug (3 harvests)	Total No. of marketable fruits	Total marketable yield (kg)	Individual fruit weight (kg)
Athena	5.0 a	14.1 a	1.8 ab	4.1 bc	0.3	0.8	7.0 a	19.0 a	2.7 abc
Savor	0.5 cd	2.0 cd	0.0 b	0.0 c	0.0	0.0	0.5 d	2.0 c	0.4 d
Diplomat	1.8 bcd	4.0 bcd	0.3 b	0.3 bc	0.3	0.5	2.3 cd	4.8 bc	1.5 cd
Aphrodite	1.5 bcd	6.5 bcd	0.5 b	1.3 bc	1.0	4.2	3.0 cd	11.9 ab	3.5 ab
Superstar	2.3 bcd	9.0 abc	2.0 ab	6.0 b	1.0	4.6	5.3 ab	19.5 a	3.9 a
Tirreno	0.3 cd	0.7 d	4.5 a	11.6 a	0.8	1.2	5.5 ab	13.6 ab	2.5 abc
Wrangler	2.8 abc	7.0 abcd	2.0 ab	3.8 bc	1.5	4.2	6.3 ab	15.0 ab	2.3 abcd
Hales Best	0.5 cd	0.6 d	2.0 ab	4.5 bc	0.0	0.0	2.5 cd	5.1 bc	1.7 bcd
Dream Dew	2.3 bcd	10.0 ab	0.3 b	1.1 bc	0.5	2.0	3.0 bcd	13.1 ab	2.9 abc
RML 9818	3.5 ab	4.2 bcd	0.3 b	0.3 bc	0.5	0.7	4.3 abc	5.2 bc	1.0 cd
Afg1	0.5 cd	1.8 cd	1.0 b	3.0 bc	1.3	3.1	2.8 bcd	7.9 bc	2.6 abc
Afg2	0.0 d	0.0 d	0.5 b	1.4 bc	0.0	0.0	0.5 d	1.4 c	1.4 cd
P	0.001	0.002	0.003	0.002	0.50	0.25	0.001	0.001	0.01

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.31 Number and yield per plot of marketable fruits at early, mid, late and all harvest, and individual fruit weight (kg) for eleven muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2015.

Treatments	Early harvest No. of fruits 13-17 Jul (3 harvests)	Early harvest yield (kg) 13-17 Jul (3 harvests)	Mid harvest No. of fruits 20-24 Jul (3 harvests)	Mid harvest yield (kg) 20-24 Jul (3 harvests)	Late harvest No. of fruits 27-31 Jul (3 harvests)	Late harvest yield (kg) 27-31 Jul (3 harvests)	Total No. of marketable Fruits	Total marketable yield (kg)	Individual fruit weight (kg)
Athena	2.8 b	5.4 b	4.8 b	17.7 bcd	5.3 b	11.5	12.8 bc	34.6 abc	2.5 bc
Savor	0.0 b	0.0 b	1.3 c	1.4 d	3.8 c	4.7	5.0 c	6.2 d	1.2 e
Diplomat	8.3 a	16.0 a	1.8 c	4.2 de	1.5 c	3.9	11.5 bc	24.1 bcd	2.0 cd
Aphrodite	2.0 b	4.6 b	9.0 a	28.8 ab	5.3 bc	16.6	16.3 b	50.0 a	3.1 a
Superstar	1.3 b	3.6 b	11.5 a	39.9 a	3.5 c	10.6	16.3 b	54.2 a	3.3 a
Majus	3.0 ab	5.5 b	4.8 b	10.7 cde	5.0 bc	10.1	12.8 bc	26.3 bcd	2.0 cd
Wrangler	3.3 ab	4.8 b	12.5 a	20.4 bc	11.5 ab	18.8	27.3 a	44.1 ab	1.6 de
Hales Best	0.3 b	0.2 b	3.0 bc	4.4 de	14.0 a	21.9	17.3 b	26.5 bcd	1.5 de
Dream Dew	1.5 b	2.9 b	2.5 bc	10.4 cde	1.8 c	5.0	5.8 c	18.2 cd	3.0 ab
Green	1.3 b	1.5 b	0.3 c	0.3 e	6.8 bc	13.0	8.3 c	14.8 cd	1.8 d
P	0.001	0.001	0.001	0.001	0.01	0.14	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.32 Number and yield per plot of marketable fruits at early, mid, late and all harvests for twelve muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2016.

Treatments	Early harvest No. of Fruits 11-18 Jul (4 harvests)	Early harvest yield (kg) 11-18 Jul (4 harvests)	Mid harvest No. of Fruits 20-25 Jul (3 harvests)	Mid harvest yield (kg) 20-25 Jul (3 harvests)	Late harvest No. of Fruits 27 Jul 5 Aug (3 harvests)	Late harvest yield (kg) 27 Jul 5 Aug (3 harvests)	Total No. of Marketable Fruits	Total Marketable yield (kg)	Individual Fruit weight (kg)
Athena	6.3 b	9.5 bc	9.3 a	22.9 ab	9.3 ab	26.8 ab	24.8 ab	59.3 ab	2.4 b
Savor	0.0 c	0.0 d	1.8 cd	2.2 d	2.8 cd	1.7 e	4.5 de	3.8 f	1.0 c
Diplomat	11.3 a	20.9 a	4.0 bcd	9.1 c	1.8 cd	3.0 de	17.0 bc	33.1 bcde	1.9 b
Aphrodite	1.3 c	3.0 cd	7.8 ab	25.2 ab	4.8 bcd	23.6 abc	13.8 c	51.8 abc	3.9 a
Superstar	2.8 c	10.4 b	7.8 ab	32.4 a	2.0 cd	6.6 de	12.5 cd	49.4 abc	4.0 a
Tirreno	1.0 c	1.1 d	3.0 bcd	7.4 c	6.0 abc	18.7 bcd	10.0 cd	27.2 cde	2.7 b
Wrangler	10.5 a	13.9 b	9.5 a	20.9 b	6.8 abc	10.5 cde	26.8 a	45.3 abc	1.7 bc
Hales Best	0.0 c	0.0 d	4.5 bcd	9.5 c	6.8 abc	12.8 bcd	11.3 cd	22.3 cde	2.4 b
Dream Dew	3.0 c	11.7 b	6.0 ab	19.9 b	9.3 ab	37.6 a	18.3 abc	69.1 a	3.8 a
Green	0.3 c	0.6 d	0.5 d	1.9 d	10.0 a	35.9 a	10.8 cd	38.4 bcd	3.6 ab
Afg1	0.8 c	1.9 d	0.8 d	1.8 d	2.3 d	5.9 de	3.8 e	9.6 ef	2.9 b
Afg2	0.3 c	0.4 d	0.3 d	1.0 d	0.3 d	2.8 e	0.8 e	4.2 e	2.5 b
P	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.04

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.33 Number and yield per plot of marketable fruits at early, mid, late and all harvests for ten muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2015.

Treatments	Early harvest No. of fruits 10-17 Aug (3harvests)	Early harvest yield kg 10-17 Aug (3 harvests)	Mid harvest No. of fruits 21-28 Aug (3 harvests)	Mid harvest yield kg 21-28 Aug (3 harvests)	Late harvest No. of fruits 1-3 Sep (2 harvests)	Late harvest yield kg 1-3 Sep (2 harvests)	Total No. of marketable fruits	Total marketable yield (kg)	Individual fruit weight (kg)
Athena	14.8 a	26.2 a	11.3 ab	24.4 bcd	4.0	9.2 ab	30.0 ab	59.8 abc	3.0 abc
Savor	1.0 bc	1.7 bc	2.8 b	2.9 de	1.8	2.1 b	5.5 de	6.7 e	0.3 e
Diplomat	13.0 a	26.2 a	2.8 b	3.9 de	0.0	0.0 c	15.8 bcd	30.2 cde	1.5 cde
Aphrodite	10.8 a	28.3 a	11.3 ab	31.6 b	2.8	7.6 ab	24.8 abc	67.5 ab	3.4 ab
Superstar	7.8 ab	16.6 abc	25.5 a	57.9 a	3.3	8.2 ab	36.5 a	82.7 a	4.1 a
Majus	14.5 a	24.5 ab	7.0 b	14.3 bcde	3.0	6.4 ab	24.5 abc	45.1 bcd	2.3 bcd
Wrangler	11.8	16.9 abc	9.8 ab	15.8 bcde	8.0	11.6 a	29.5 b	44.2 bcd	2.2 bcd
Hales Best	1.0 bc	0.9 c	3.5 b	5.1 cde	4.8	7.8 ab	9.3 cde	13.7 de	0.7 de
Dream Dew	9.5 a	25.2 a	10.3 ab	26.4 bc	1.8	3.5 b	21.5 abc	55.2 abc	2.8 abc
RML 9818	0.0 c	0.0 c	0.0 c	0.0 e	0.0	0.0 c	0.0 e	0.0 e	0.0 e
P	0.001	0.001	0.001	0.001	0.19	0.001	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table 3.34 Number and yield per plot of marketable fruits at early, mid, late and all harvests twelve muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2016.

Treatments	Early harvest No. of fruits 28 Jul-4 Aug (2 harvests)	Early harvest yield (kg) 28 Jul-4 Aug (2 harvests)	Mid harvest No. of fruits 9 Aug (1 harvests)	Mid harvest yield (kg) 9 Aug (1 harvests)	Late harvest No. of fruits 13 Aug (1 harvests)	Late harvest yield (kg) 13 Aug (1 harvests)	Total No. of marketable fruits	Total marketable yield (kg)	Individual fruit weight (kg)
Athena	14.3 bc	28.9 b	3.0 a	5.9 ab	2.5	3.8	19.8 ab	38.6 ab	2.0 ab
Savor	0.5 d	1.3 e	0.0 b	0.0 b	0.0	0.0	0.5 d	1.3 e	0.7 d
Diplomat	4.0 d	6.8 cde	0.0 b	0.0 b	0.0	0.0	4.0 d	6.8 e	1.1 bcd
Aphrodite	7.8 cd	19.7 bcd	3.5 a	9.8 a	1.3	3.0	12.5 bc	32.4 bc	2.7 a
Superstar	24.8 a	50.2 a	0.5 b	1.3 b	0.5	0.6	25.8 a	52.0 a	2.0 ab
Tirreno	5.8 d	10.4 cde	0.0 b	0.0 b	0.0	0.0	5.8 cd	10.4 de	0.9 bcd
Wrangler	15.3 b	21.8 bc	0.0 b	0.0 b	0.5	0.9	15.8 b	22.6 cd	1.4 bc
Hales Best	3.5 d	5.5 de	0.0 b	0.0 b	0.8	1.1	4.3 d	6.6 e	1.1 bcd
Dream Dew	0.0 d	0.0 e	0.0 b	0.0 b	0.0	0.0	0.0 d	0.0 e	0.0 e
RML 9818	1.0 d	0.9 e	0.0 b	0.0 b	0.0	0.0	1.0 d	0.9 e	0.5 d
Afg1	1.8 d	4.1 de	0.0 b	0.0 b	0.0	0.0	1.8 d	4.1 e	1.3 bcd
Afg2	2.8 d	5.7 de	0.0 b	0.0 b	0.5	1.5	3.3 d	7.2 e	1.8 bc
P	0.001	0.001	0.03	0.05	0.26	0.18	0.001	0.01	0.005

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

CHAPTER 4. CONCLUSION

Muskmelon is one of the major horticulture crops all over the world, especially in Indiana, and the United States. Annual production of muskmelon depends on market demand, Cultivar selection, planting management, post-harvest management, and crop protection strategy. Bacterial wilt (*Erwinia tracheiphila*) is one of the serious diseases of muskmelon and is transmitted by striped cucumber beetle (*Acalymma vitattum* (F)). Thus, the only way of BW management is to control SCB. Integrated Pest Management (IPM) is an important and environmental friendly methods to eliminate or reduce insect pest damages and diseases. Combination of different methods such as row covers, seed treatment, date of planting, soil and foliar spray of insecticides for managing diseases and eliminated insect invasion, can improve crop production. The results of experiments at two locations, TPAC, SWPAC in 2013 and 2014 show that the length of time row covers were left on the plants (for 7, 14, or 21 days after transplanting, DAT), or the period beetles were permitted to feed on plants (0 - 7, 7 - 14, or 14 - 21 DAT), or the time when beetles began to feed on plants (0, 7, or 14 DAT) did not significantly influence disease or yield. Row covers with soil drench of Platinum® and weekly foliar spray of Warrior reduced beetle feeding and population throughout the season. Plants with row covers had higher plant vigor and produced more number of fruits and greater yield.

Also, cultivar selection is an important factor of crop production because cultivars must be selected based on market demand, environment adaptation, and resistance or maximum tolerance to insect feeding and diseases. The results of cultivar trials experiments at three locations in 2015 and 2016 indicate that Superstar is the most tolerant cultivar against beetle feeding and BW follow by Athena and Aphrodite. These cultivars had lowest BW and AUDPC, and greater number of marketable fruits and yield. In contrast, Dream Dew and Diplomat were recorded most susceptible cultivars with maximum number of beetles per plants, BW, AUDPC and lower yield. Cultivars with more damages and BW wilt produced the highest number of unmarketable fruits and yield per plot. Also, most of cultivars had high beetle feeding damage at 1 and 2 weeks after transplanting, especially green-fleshed cultivars such as Diplomat and Dream Dew. Higher beetle days were found on Savor, Diplomat and Dream Dew cultivars. The number of beetles per plant and level of cucurbitacin in leaves and stems of muskmelon cultivars indicate that there is no correlation between the level of cucurbitacin and number of beetles at each cultivar.

Over all the data of all experiments from 2013-2016 show that row covers improve plant growth and reduce beetle feeding, BW and AUDPC. Soil drench along with row covers and foliar spray also reduce beetle populations, which can decrease diseases and AUDPC severity, but it is necessary to apply insecticides at the proper time and amount to avoid environmental pollution and killing beneficial insects. Also the results indicate that orange-fleshed cultivars have more tolerance and green-fleshed cultivars are more susceptible to beetle feeding and BW. Also the first beetles were recorded on honeydew cultivars after 1-2 weeks after transplanting. There were some cultivars such as Savor, Hales Best and RML9818 that produced small fruits or fruits that cracked before maturity, and which were not marketable. Moreover, Afg1 and Afg2 cultivars were not adapted well to the Midwest climate because of rain and humidity, so they produced very few fruits through the season.

Figure 4.1 Overview of all experiments; 1) Experiment 1 (TPAC 1), 2) Experiment 2 (TPAC 2), 3) Experiment 3 (SWPAC), 4) Experiment 4 (PPAC).

Figure 4.2 Transplanting seedlings (1), Replacing row covers (2), Harvesting (3) Weighing fruits (4).

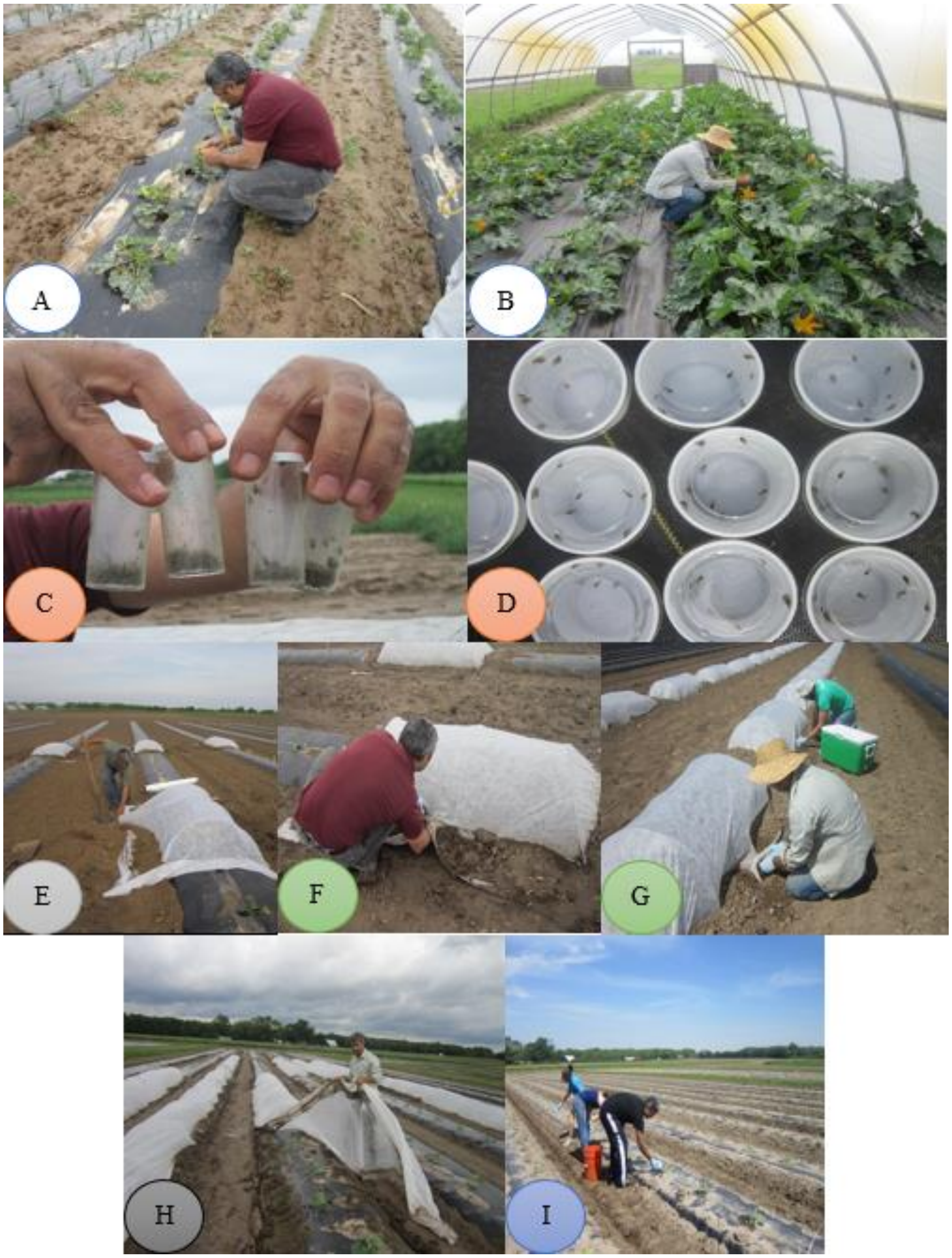

Figure 4.3 Sucking beetles with aspirator (A and B), Collected beetles in vial and boxes (C and D), Placing row covers (E), Releasing beetles under row covers (F and G), Removing row covers after three weeks (H), Soil drench application (I).

Figure 4.4 Striped cucumber beetles and their feeding damages on different parts of muskmelon plant.

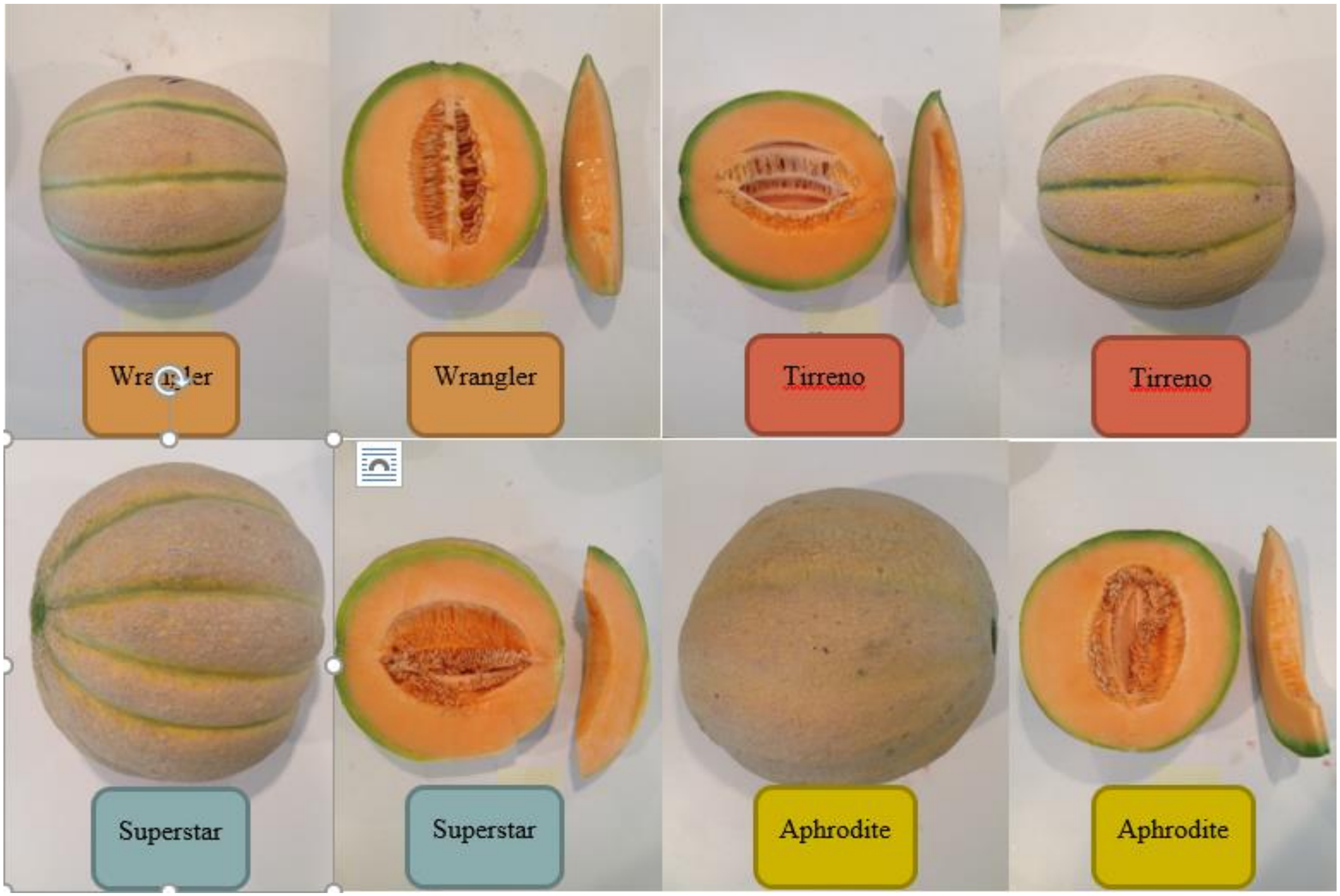

Figure 4.5 Muskmelon Cultivars

Figure 4.6 Muskmelon Cultivars

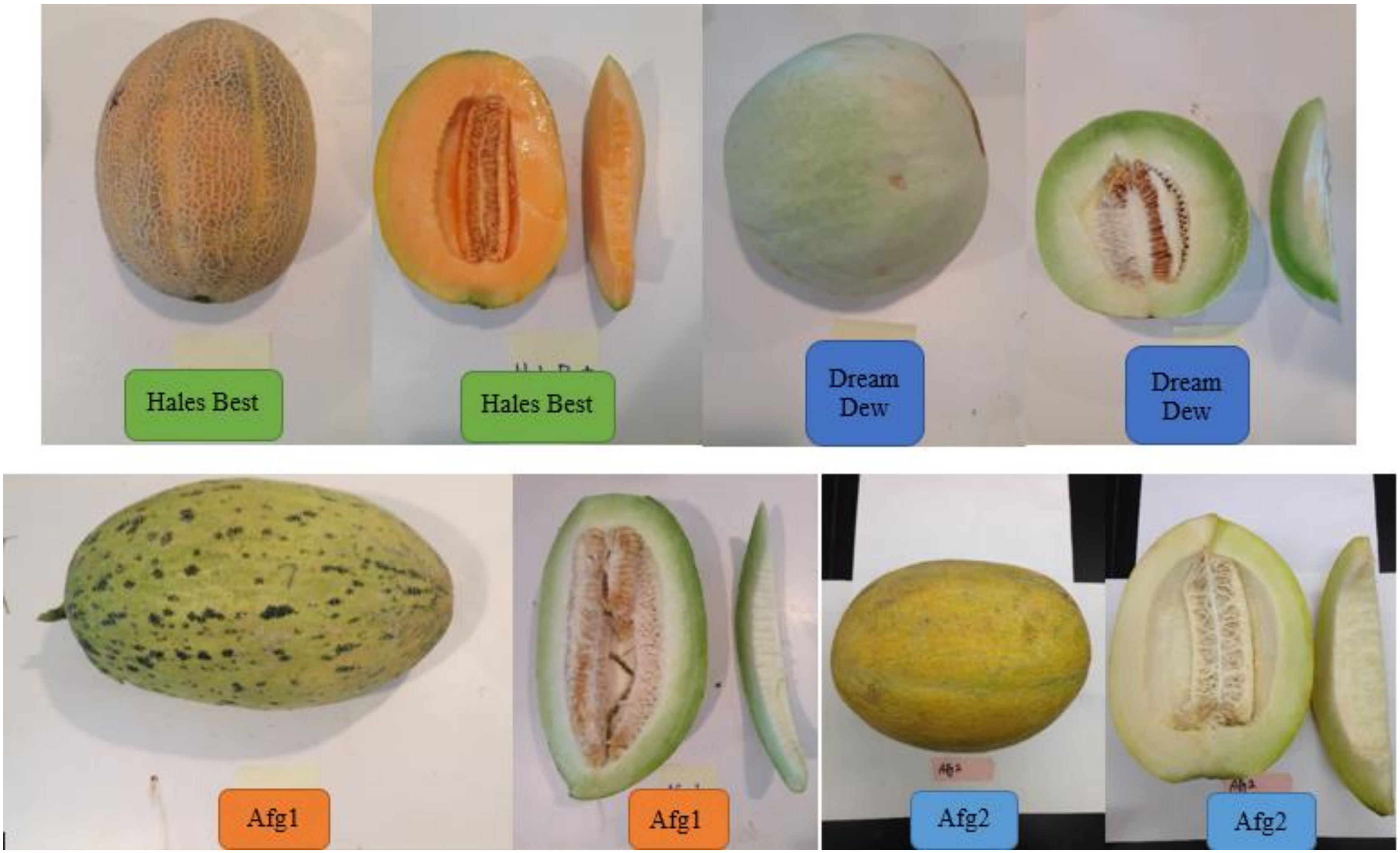

Figure 4.7 Muskmelon Cultivars

Figure 4.8 Bacterial wilt symptoms on muskmelon plants at different stage of growth

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APPENDICES

Appendix A

Muskmelon Cultivars Taste Test, and Total Soluble Solid (TSS)

A muskmelon taste test was conducted at the Department of Entomology, Purdue University, West Lafayette, Indiana. The main goal of this experiment was to understand people's demand and favor among different cultivars. Ten cultivars were used for this test and there were different questions such as: taste, sweetness and texture. Around 45 people participated in this experiment. There was a number from 1 (slightly good), 2 (good), 3(very good) and 4 (excellent) for each option based on participant's interest. The results show that most people rated cultivar Hales Best 1 for taste (Figure A.1), sweetness (Figure A.2) and texture (Figure A.3). Total soluble solid (TSS) percentage content in each cultivar was measured with a refractometer in 2016. The results show that Afg1, Diplomat and Hales Best had lower TSS than other cultivars and the highest TSS were found RML9818 and Savor followed by Tirreno, Wrangler and Athena cultivars (Figure A.4).

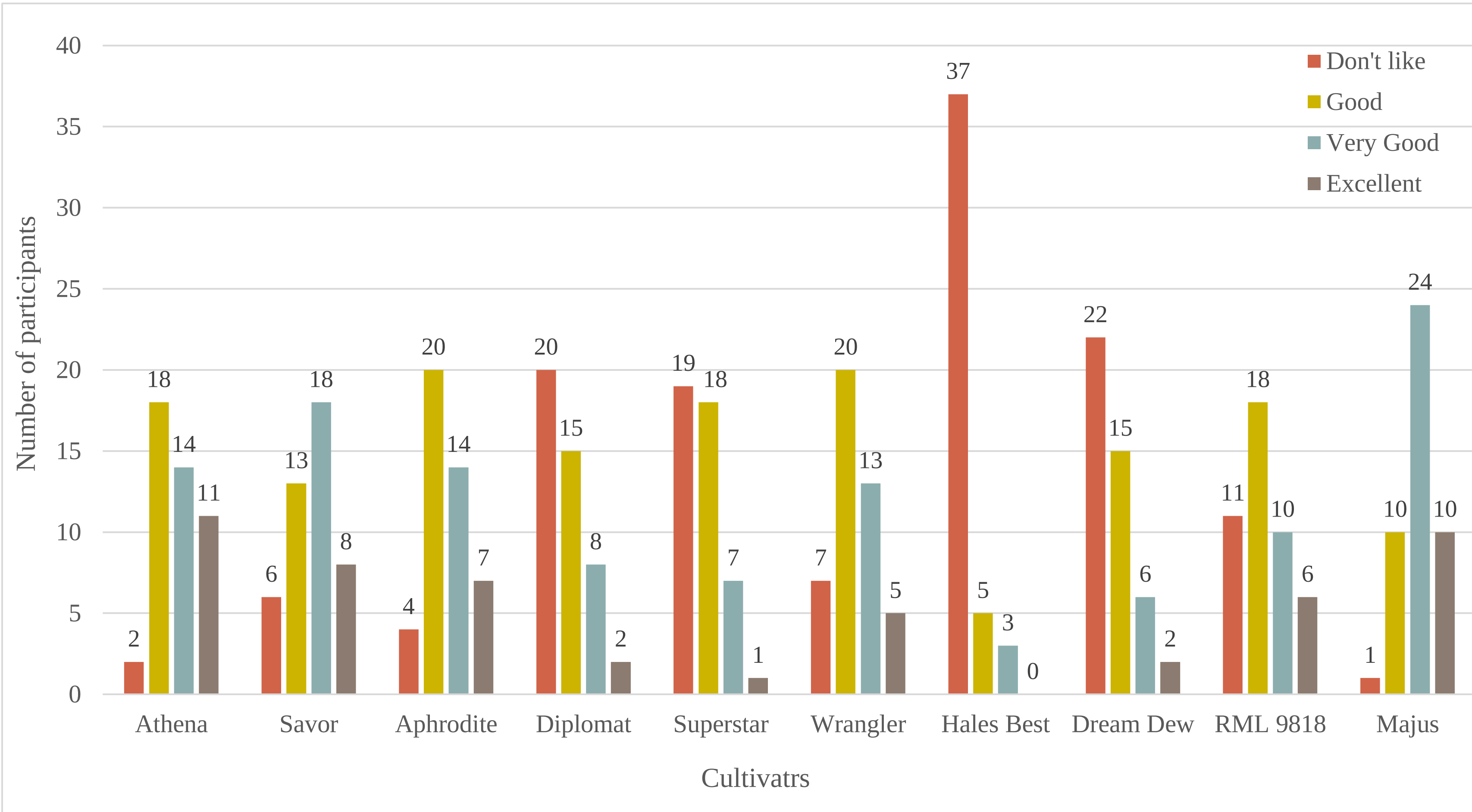

Figure A.1 Number of participants (total 45 participants) responding to the muskmelons taste. They gave a number from 1-4 for taste (1= slightly good, 2 = good, 3= very good and 4= excellent), P= 0.02

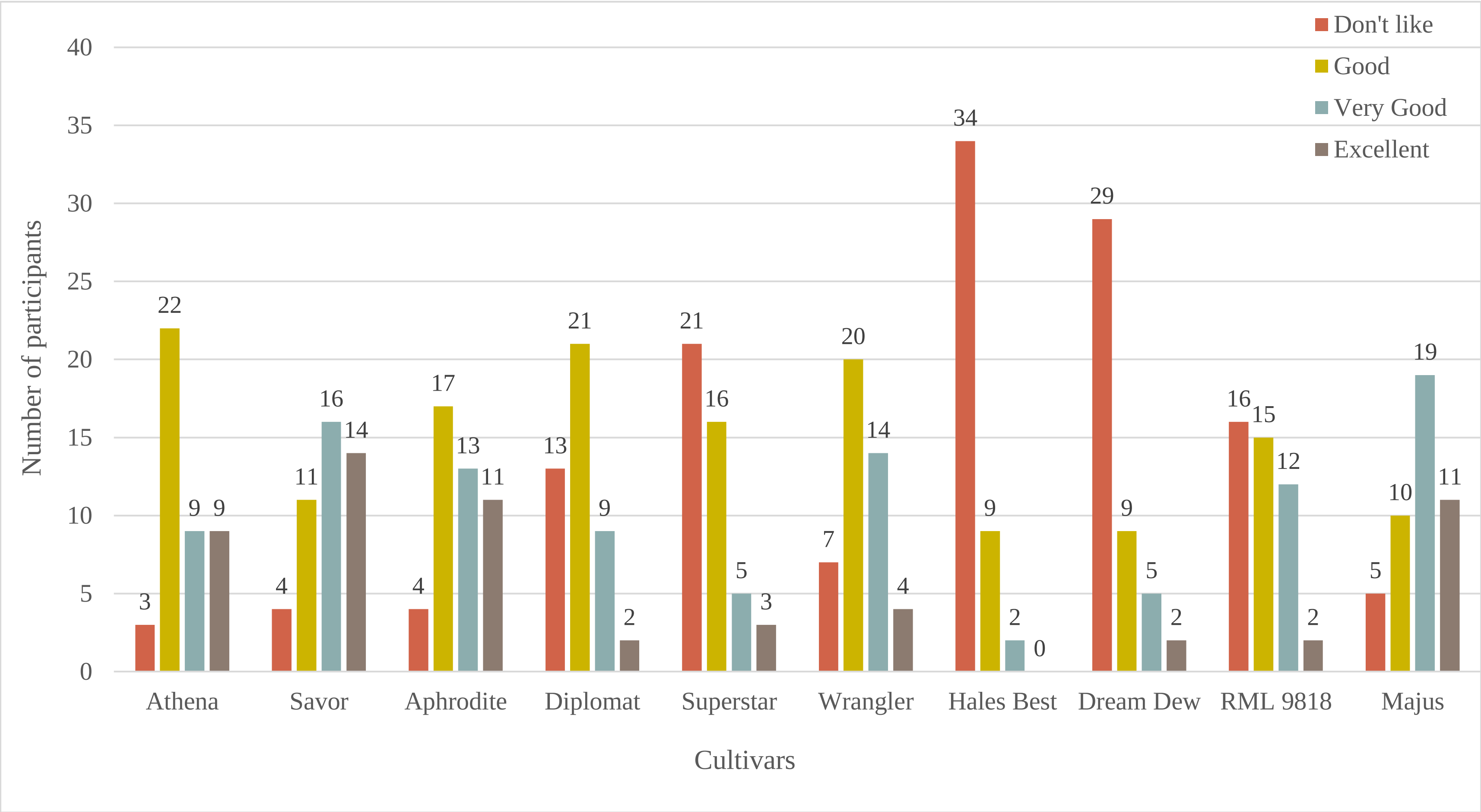

Figure A.2 Number of participants (total 45 participants) responding to the muskmelon sweetness. They gave a number from 1-4 for sweetness (1= slightly good, 2 = good, 3= very good and 4= excellent), P=0.03

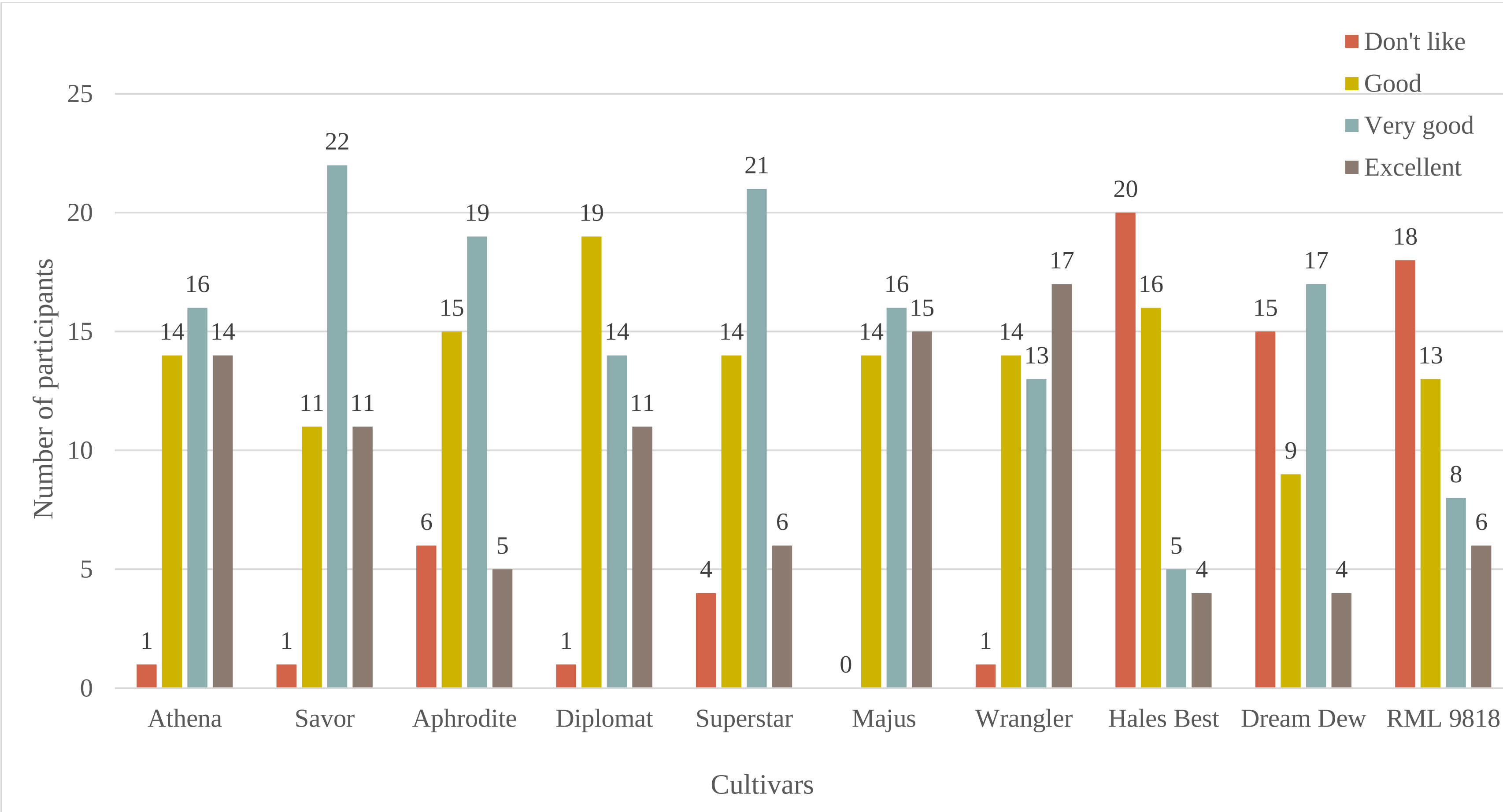

Figure A.3 Number of participants (total 45 participants) responding to the muskmelon texture. They gave a number from 1-4 for texture (1= slightly good, 2 = good, 3= very good and 4= excellent), P= 0.005

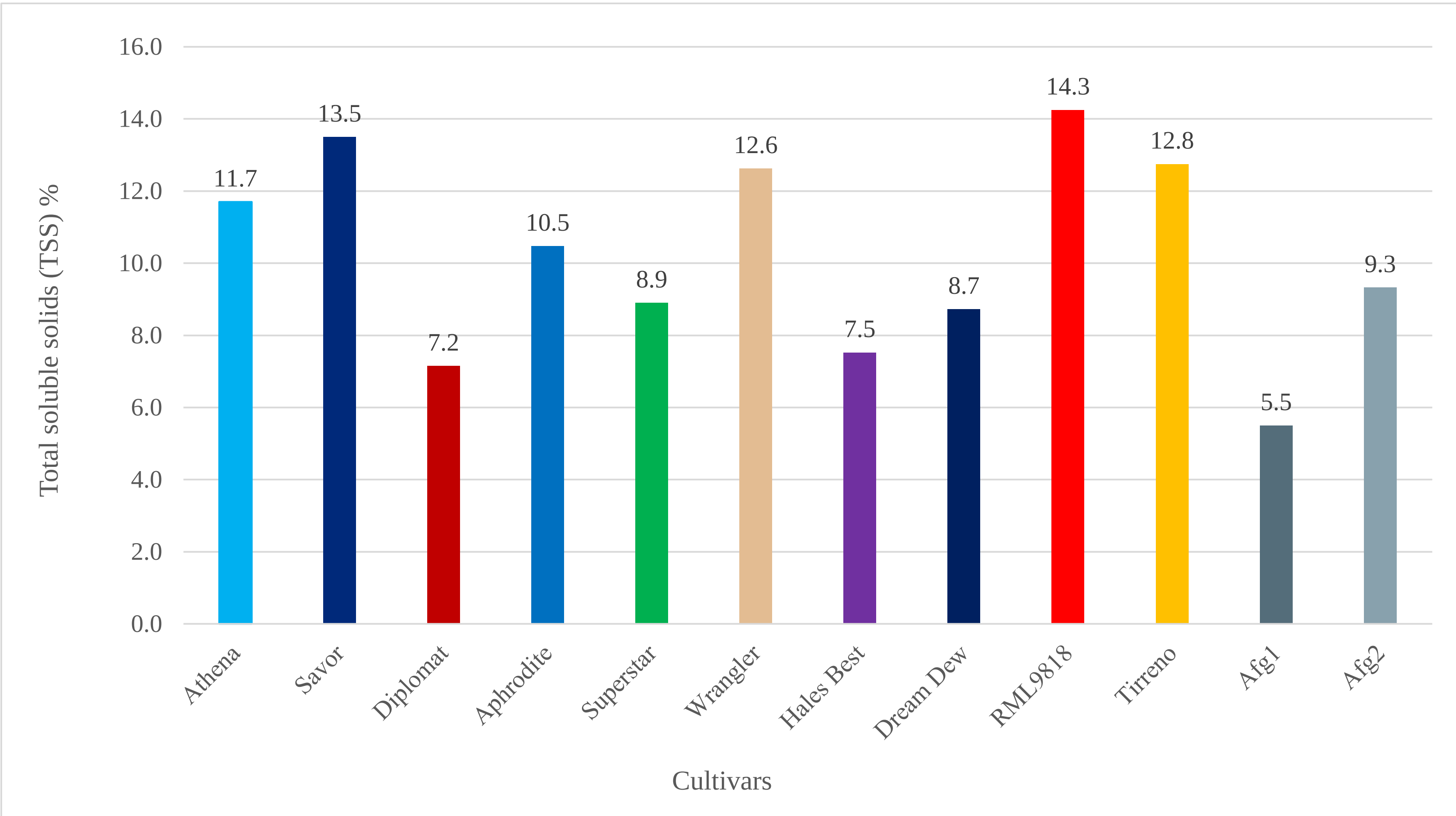

Figure A.4 Total soluble solids percentage (TSS) in 12 muskmelon cultivars. The experiment was conducted at SWPAC, Vincennes, Indiana in 2016. P= 0.001

Appendix B

B 1. Inoculation of Muskmelon Seedlings with Bacterium Pathogen under Controlled Environment

Muskmelon seeds (12 cultivars) were planted in separate round "azalea" (tall) pots of diameter 20.3 cm and 16.5 cm high, on 10 July 2016, and grown in the Horticulture greenhouse at Purdue University, West Lafayette, Indiana. Prior to planting bacterium strains were isolated from wilted plants which were collected from Melon-Acres Farm, Vincennes, Indiana and SCR3 strain was obtained from the Department of Plant Pathology and Microbiology, Iowa State University, Ames, Iowa, United States. The strain from Melon-Acres muskmelon was separated by cutting a small portion of the stem, and squeezing onto the agar medium (Distilled water 500 ml; Difco nutrient agar 11.5 g; Difco agar 2.5 g; Difco Bacto-peptone 2.5 g) in a petri dish, and keeping in an incubator at 27 $^{\circ}$C for few days to produce more colonies. Then three colonies of each strain (SCR3 and Melon-Acres strains) were mixed with 10 mm distilled water in 15 ml tube and vortexed for 5 minutes. Two week-old seedlings were inoculated with SCR3 and Melon Acres Farm strains by using a core (leaf piercer) and cotton tipped applicator. A small hole was made on one leaf per each seedling and bacterium pathogen was applied around the leaf hole on 26 July 2016. One plant of each cultivar was inoculated with each strain and one left un-inoculated as a control. After inoculation a small amount of water was sprayed on the surfaces of leaves to help the pathogen enter into the plant. The seedlings were monitored every day for any bacterial wilt symptoms. Seedlings of cultivars Hale Best, Diplomat, Afg1, Tirreno, Dream Dew and RML9818 inoculated with SCR3 strain showed wilting symptoms 3 weeks after inoculation. The remaining cultivars did not show any symptoms, nor did any cultivars inoculated with Melon-Acres strain (Figures B 1 and 2). At the end of the study growing medium was washed off of the roots and root systems we photographed to document size and structure (Figure B 3).

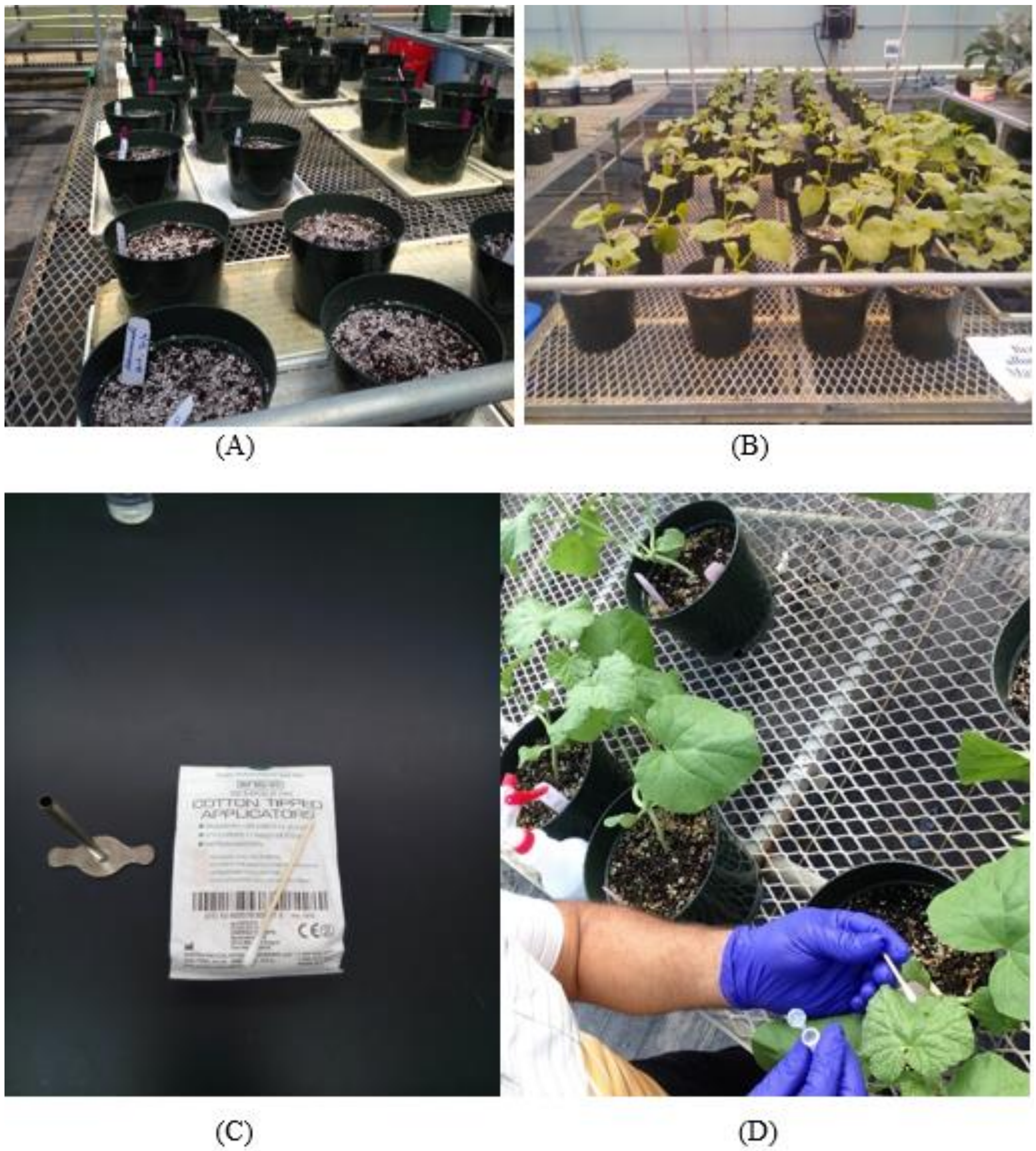

Figure B.1 Overview of greenhouse experiment from seeding of 12 muskmelon cultivars to inoculation (Horticulture Greenhouse, Purdue University, West Lafayette, Indiana). (A) Initial seeding of muskmelons seeds in separate pots. (B) Muskmelon seedlings a few weeks after planting. (C) Cotton tipped applicator and leaf piercer. (D) Inoculation of leaf surface with bacterium

Figure B.2 Bacterial wilt symptoms on different cultivars inoculated with SCRS strain under controlled condition. The symptoms appeared three weeks after inoculation under controlled environment (Horticulture Greenhouse, Purdue University, West Lafayette, Indiana). 12 muskmelon cultivars (Athena, Savor, Diplomat, Aphrodite, Superstar, Tirreno, Wrangler, Hales Best, Dream Dew, RML9818, Afg1 and Afg2) were used in this experiment.

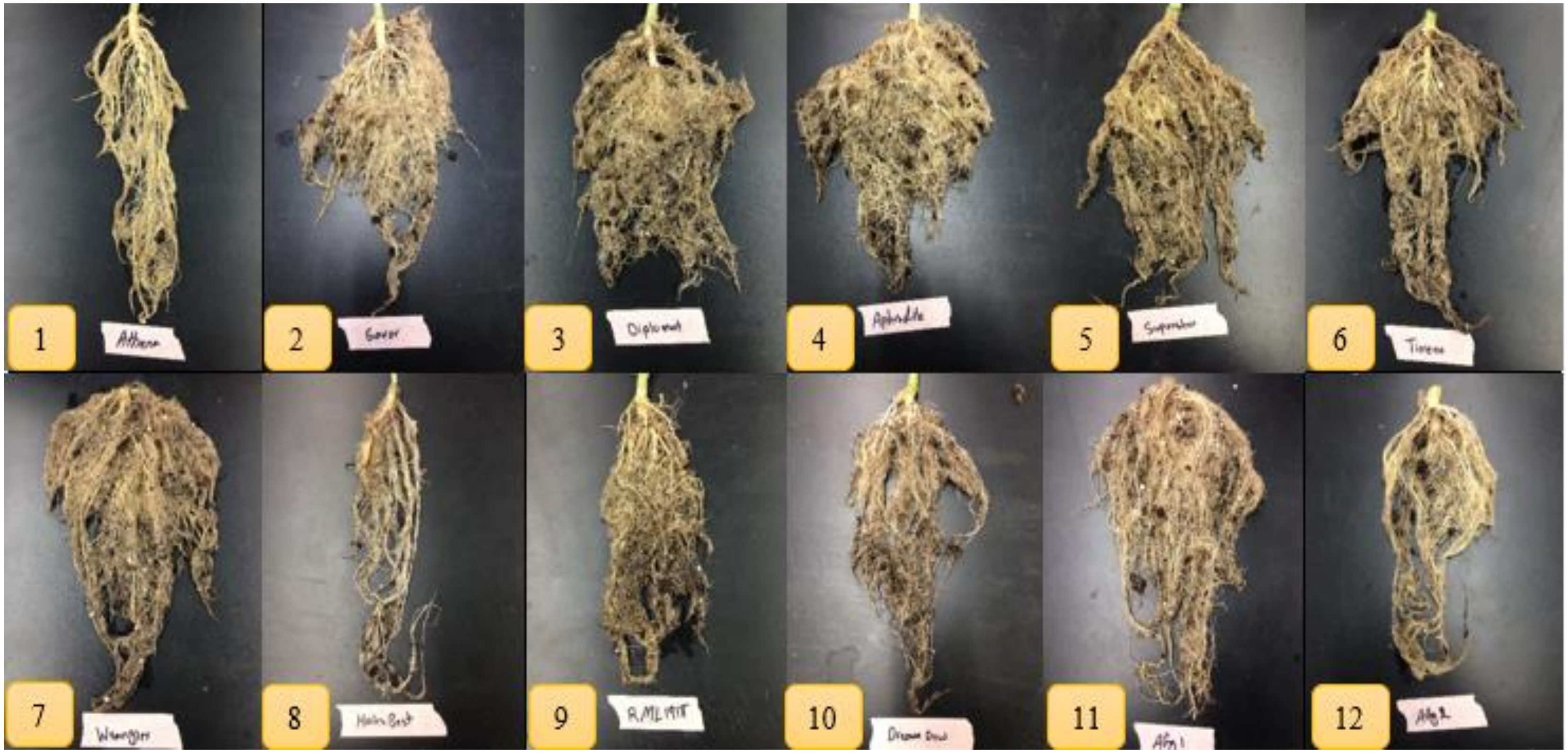

Figure B.3 Root growth and structure of 5-week old seedlings of 12 different muskmelon cultivars; (1) Athena, (2) Savor, (3) Diplomat, (4) Aphrodite, (5) Superstar, (6) Tirreno, (7) Wrangler, (8) Hales Best, (9) Dream Dew, (10) RML9818, (11) Afg1, (12) Afg2.

B 2. Number of Fruits, Yield (kg) of Unmarketable (Cull) Fruits

In 2015, experiment 1 (TPAC), Savor had the fewest cull fruits and lowest cull yield at early harvests, but not significantly fewer fruit or lower yield than Dream Dew, and RML9818, and not significantly fewer fruit than Aphrodite or Majus (Table B 2.1). There was not significant difference among cultivars at mid-harvests or for cull yield at late harvest, but Hales Best produced more cull fruits at late harvests than any other cultivar except Savor (Table B 2.1). Total cull fruits were significantly greater for Hales Best than for other cultivars except Wrangler and Athena. Total cull yield was significantly lower for Dream Dew, RML9818 and Savor than for Hales Best, Superstar and Athena (Table B 2.1).

As in 2015 (TPAC 1), there was no significant difference in number of cull fruits and cull yield at mid harvest in 2016 (Table B 2.2). Hales Best was the top producer of cull fruits at all harvests, although Tirreno and Wrangler were not significantly different at early harvests, and several cultivars were not significantly different later in the season (Table B 2.2).

In experiment 2 (TPAC) in 2015, there was no significant differences between treatments at mid and late harvests, or for total number of cull fruits, $p>0.05$ (Table B 2.3). Tirreno followed by Athena, Diplomat, Aphrodite and Superstar produced the highest cull fruit number and yield at the early harvest. These same cultivars plus Hales Best produced the most culls (Table B 2.3).

In experiment 2 (TPAC) in 2016, at early harvests, the fewest number of cull fruits were harvested from Savor, Aphrodite, Tirreno and Wrangler, and the most cull yield was harvested from Diplomat and Afg1 (Table B 2.4). Savor produced the most cull fruits and yield at mid and late harvests, and the most total cull fruits and yield, although not significantly more than all other cultivars. Hales Best had the second highest cull yield at mid harvests. Tirreno and Afg2 produced the second and third highest cull yields at late harvests (Table B 2.4). Total cull yield was very low for Athena, Aphrodite, Superstar, Dream Dew and RML9818 in experiment 2. The results of two years show that Superstar, Aphrodite and Dream Dew had lowest cull fruits and yield (Table B 2.4).

In experiment 3 (SWPAC) IN 2015, Diplomat produced significantly more cull fruits at early harvest than any other cultivar (Table B 2.5). Cull yield was not significantly different at early harvest. Superstar and Athena had the highest cull fruit numbers and yield at mid harvests, when the fewest cull fruits were produced by Diplomat and Dream Dew Diplomat and Dream Dew also produced significantly fewer cull fruit at late harvests than Hales Best, which produced the most. Diplomat had the lowest cull yield at late harvests, significantly lower than Hales Best, Superstar and Athena (Table B 2.5). Total number of cull fruits was significantly lower for Dream Dew than for Athena or Superstar. Dream Dew and Diplomat produced less total cull yield than Superstar, Athena, Aphrodite, or Hales Best. (Table B 2.5).

As in 2015 experiment 3 (SWPAC), Diplomat produced more cull fruits than other cultivars at early harvests in 2016, but also produced but higher cull yield at early harvests in 2016 (Table B 2.6). At mid harvests, this cultivar and Superstar had significantly more cull fruits than other cultivars except Hales Best. Superstar produced greater cull yield than any other cultivar at mid harvests (Table B 2.6). Greater numbers of cull fruits were also recorded for Diplomat and Green at late harvests. Aphrodite, Wrangler, Hales Best and Afg1 produced significantly lower cull yield at late harvests than Green and Dream Dew (Table B 2.6). Higher total numbers of cull fruits were harvested from Diplomat than any other cultivar. Superstar had greater total cull yield than all other cultivars except Diplomat (Table B 2.6). Results of experiment 3 show that some green-fleshed cultivars produced high cull fruits and yield at early and late harvests followed by some orange-fleshed cultivars in general.

In experiment 4 (PPAC). in 2015, cull fruit number and yield did not differ among cultivars at early harvests (Table B 2.7). At mid and late harvests Hales Best produced more cull fruits and greater cull yield than all cultivars except Savor. Hales Best produced more total number of cull fruits than all other cultivars except Savor and Diplomat, and more total cull yield than all except Savor (Table B 2.7).

In experiment 4 (PPAC), in 2016, Tirreno along with Savor and Diplomat had the most cull fruits and yield at early harvests (Table B 2.8). At mid harvests greater number of cull fruits and yield were collected from Hales Best, Aphrodite and Athena, and Superstar also had high cull yield. Cull fruits and yield were lower and did not differ at late harvests. Savor and Hales Best produced more total cull fruits than other cultivars. These two, plus Diplomat, Aphrodite, and Tirreno did not differ in total cull yield. The lowest total cull yields by weight were from Dream Dew, RML9818, Afg1 and Afg2 (Table B 2.8).

Table B 2.1 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests ten muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette IN, in 2015.

Treatments	Early harvest No. of fruits 31 Jul –3 Aug (2 harvests)	Early harvest yield (kg) 31 Jul – 3 Aug (2 harvests)	Mid harvest No. of fruits 7-10 Aug (2 harvests)	Mid harvest yield (kg) 7-10 Aug (2 harvests)	Late harvest No. of fruits 13 Aug (1 harvests)	Late harvest yield (kg) 13 Aug (1 harvests)	Total No. of cull fruits	Total cull yield (kg)
Athena	9.3 a	26.0 a	1.3	1.8	0.0 b	0.0	10.5 ab	27.8 a
Savor	0.8 c	1.3 c	0.8	1.1	2.5 ab	4.5	4.0 bc	6.9 bc
Diplomat	7.3 ab	15.9 ab	0.8	1.4	0.0b	0.0	8.0 bc	17.3 abc
Aphrodite	5.3 abc	18.9 a	1.0	2.7	0.3 b	0.9	6.5 bc	22.5 abc
Superstar	7.5 ab	25.2 a	1.5	3.3	0.0 b	0.0	9.0 bc	28.5 a
Majus	6.0 abc	16.1 ab	0.8	1.2	0.3 b	0.7	7.0 bc	18.0 abc
Wrangler	10.3 a	23.1 a	0.8	1.2	0.3 b	0.6	11.3 ab	24.9 ab
Hales Best	10.8 a	15.6 ab	0.0	0.0	6.5 a	13.5	17.3 a	29.1 a
Dream Dew	2.0 bc	4.7 bc	0.0	0.0	0.0 b	0.0	2.0 c	4.7 c
RML 9818	1.0 c	2.8 bc	0.5	0.8	0.0 b	0.0	1.5 c	3.6 c
P	0.001	0.001	0.65	0.38	0.05	0.07	0.01	0.01

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table B 2.2 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests twelve muskmelon cultivars. The experiment (1) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette IN, in 2016.

Treatments	Early harvest No. of fruits 25-1 Aug (3 harvests)	Early harvest yield (kg) 25-1 Aug (3 harvests)	Mid harvest No. of fruits 3-8 Aug (3 harvests)	Mid harvest yield (kg) 3-8 Aug (3 harvests)	Late harvest No. of fruits 10-17 Aug (3 harvests)	Late harvest yield (kg) 10-17 Aug (3 harvests)	Total No. of cull fruits	Total cull yield (kg)
Athena	2.5 b	3.8 abc	2.3	4.1	3.8 bc	6.8 ab	8.5 bc	14.6 abc
Savor	1.5 b	1.0 bc	9.3	7.4	4.8 ab	5.7 ab	15.5 ab	14.1 abc
Diplomat	3.3 b	4.8 abc	0.8	1.5	1.0 bc	0.4 b	5.0 bc	6.7 bc
Aphrodite	3.3 b	6.8 ab	1.8	4.6	4.0 bc	5.9 ab	9.0 abc	17.3 abc
Superstar	3.3 b	6.0 abc	5.0	11.6	3.3 abc	7.3 ab	11.5 abc	24.8 a
Tirreno	5.5 ab	8.1 a	4.5	7.4	4.5 ab	4.8 ab	14.5 ab	20.3 ab
Wrangler	5.0 ab	6.2 abc	2.5	2.1	2.3 bc	2.4 ab	9.8 abc	10.8 abc
Hales Best	10.0 a	6.9 ab	4.3	4.6	8.0 a	9.8 a	22.3 a	21.3 ab
Dream Dew	0.0 b	0.0 c	0.0	0.0	0.0 c	0.0 b	0.0 c	0.0 c
RML 9818	0.0 b	0.0 c	0.8	1.0	0.0 c	0.3 b	0.8 c	1.3 c
Afg1	0.0 b	0.0	0.0	0.0	0.0 c	0.0 b	0.0 c	0.0 c
Afg2	0.3 b	0.5 c	0.3	0.5	1.5 bc	2.6 ab	2.0 bc	3.6 bc
P	0.001	0.01	0.12	0.09	0.003	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table B 2.3 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests ten muskmelon cultivars. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette IN, in 2015.

Treatments	Early harvest No. of fruits 31 Jul (1 harvests)	Early harvest yield (kg) 31 Jul (1 harvests)	Mid harvest No. of fruits 3-8 Aug (2 harvests)	Mid harvest yield (kg) 3-8 Aug (2 harvests)	Late harvest No. of fruits 10-13 Aug (2 harvests)	Late harvest yield (kg) 10-13 Aug (2 harvests)	Total No. of cull fruits	Total cull yield (kg)
Athena	1.0 ab	3.2 ab	0.8	1.9	1.0	2.6	2.8 ab	7.8 a
Savor	0.0 b	0.0 b	0.0	0.0	0.0	0.0	0.0 b	0.0 b
Diplomat	2.0 ab	5.2 a	0.0	0.0	0.0	0.0	2.0 ab	5.2 ab
Aphrodite	1.3 ab	2.3 ab	0.5	1.4	0.0	0.0	1.8 ab	3.7 ab
Superstar	1.7 ab	4.3 ab	0.5	0.9	0.0	0.0	2.2 ab	0.9 b
Tirreno	3.3 a	6.5 a	0.3	0.7	0.0	0.0	3.5 a	7.3 a
Wrangler	0.0 b	0.0 b	0.3	0.4	0.0	0.0	0.3 b	0.4 b
Hales Best	0.0 b	0.0 b	0.8	1.3	0.8	2.0	1.5 ab	3.3 ab
Dream Dew	0.0 b	0.0 b	0.0	0.0	0.0	0.0	0.0 b	0.0 b
RML 9818	0.0 b	0.0 b	0.0	0.0	0.0	0.0	0.0 b	0.0 b
P	0.05	0.02	0.66	0.75	0.37	0.36	0.07	0.03

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table B 2.4 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests twelve muskmelon cultivars. The experiment (2) was conducted at Throckmorton/Meigs Purdue Agricultural Center (TPAC), Lafayette IN, in 2016.

Treatments	Early harvest No. of fruits 25 Jul-1 Aug (3 harvests)	Early harvest yield (kg) 25 Jul-1 Aug (3 harvests)	Mid harvest No. of fruits 3-8 Aug (3 harvests)	Mid harvest yield (kg) 3-8 Aug (3 harvests)	Late harvest No. of fruits 10-17 Aug (3 harvests)	Late harvest yield (kg) 10-17 Aug (3 harvests)	Total No. of cull fruits	Total cull yield (kg)
Athena	0.3 bc	1.0 b	0.3 c	0.4 bc	0.8 b	2.2 b	1.3 b	3.5 b
Savor	0.0 c	0.0 b	3.8 a	4.2 a	7.8 a	9.3 a	11.5 a	13.5 a
Diplomat	2.8 a	6.3 a	0.0 c	0.0 c	2.0 b	2.2 b	4.8 b	8.5 ab
Aphrodite	0.0 c	0.0 b	0.8 bc	1.3 abc	0.8 b	1.8 b	1.5 b	3.0 b
Superstar	0.3 bc	1.0 b	0.0 c	0.7 bc	0.3 b	1.0 b	0.5 b	2.6 b
Tirreno	0.0 c	0.0 b	0.5 c	1.4 abc	2.0 b	6.1 ab	2.5 b	7.5 ab
Wrangler	0.0 c	0.0 b	1.5 bc	3.2 abc	2.5 b	3.8 b	4.0 b	7.0 ab
Hales Best	0.5 bc	0.6 b	2.3 b	3.7 ab	3.3 b	3.8 b	6.0 ab	8.0 ab
Dream Dew	0.5 bc	0.5 b	0.0 c	0.0 c	0.8 b	1.4 b	1.3 b	1.8 b
RML 9818	1.5 b	1.2 b	0.0 c	0.0 c	1.0 b	1.0 b	2.5 b	2.2 b
Afg1	1.3 bc	2.8 ab	0.5 c	1.5 abc	0.8 b	1.5 b	2.5 b	5.8 ab
Afg2	0.3 bc	0.6 b	0.3 c	0.7 bc	2.0 b	4.5 ab	2.5 b	5.7 ab
P	0.001	0.001	0.001	0.04	0.002	0.05	0.001	0.01

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table B 2.5 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests for eleven muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2015.

Treatments	Early harvest No. of fruits 13-17 Jul (3 harvests)	Early harvest yield (kg) 13-17 Jul (3 harvests)	Mid harvest No. of fruits 20-24 Jul (3 harvests)	Mid harvest yield (kg) 20-24 Jul (3 harvests)	Late harvest No. of fruits 27-31 Jul (3 harvests)	Late harvest yield (kg) 27-31 Jul (3 harvests)	Total No. of cull fruits	Total cull yield (kg)
Athena	0.3 b	1.2	6.0 ab	7.7 ab	4.5 ab	7.3 abc	10.8 a	16.3 ab
Savor	0.0 b	0.0	2.5 bc	1.6 c	3.5 ab	4.7 abcd	6.0 ab	6.2 cd
Diplomat	4.3 a	3.0	1.8 c	0.5 c	0.5 b	0.7 d	6.5 ab	4.2 d
Aphrodite	0.3 b	3.2	3.8 abc	4.9 bc	2.8 ab	6.0 abcd	6.8 ab	14.1 abc
Superstar	0.5 b	2.8	7.0 a	10.6 a	3.3 ab	7.9 ab	10.8 a	21.3 a
Majus	0.3 b	2.0	2.0 bc	1.5 c	3.0 ab	5.6 abcd	5.3 ab	9.1 bcd
Wrangler	0.5 b	1.9	4.3 abc	1.0 c	3.3 ab	4.9 abcd	8.0 ab	7.8 bcd
Hales Best	0.0 b	0.2	2.3 bc	4.1 bc	7.8 a	10.0 a	10.0 ab	14.3 abc
Dream Dew	0.0 b	2.9	1.0 c	0.4 c	1.0 b	1.5 bcd	2.0 b	4.8 d
Green	0.0 b	1.5	2.0 bc	1.6 c	2.5 ab	3.1 bcd	4.5 ab	6.3 cd
P	0.001	0.20	0.02	0.001	0.03	0.03	0.01	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table B 2.6 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests twelve muskmelon cultivars. The experiment (3) was conducted at the Southwest Purdue Agricultural Center (SWPAC), Vincennes, IN, in 2016.

Treatments	Early harvest No. of Fruits 13-18 Jul (3 harvests)	Early harvest yield (kg) 13-18 Jul (3 harvests)	Mid harvest No. of Fruits 20-25 Jul (3 harvests)	Mid harvest yield (kg) 20-25 Jul (3 harvests)	Late harvest No. of Fruits 27 Jul 5 Aug (3 harvests)	Late harvest yield (kg) 27 Jul 5 Aug (3 harvests)	Total No. of Cull Fruits	Total Cull yield (kg)
Athena	0.3 b	0.4 b	0.8 c	1.3 c	2.5 bcd	5.6 bc	3.5 c	7.4 c
Savor	0.3 b	0.2 b	1.8 bc	2.5 c	3.8 abc	5.4 bc	5.8 c	8.1 c
Diplomat	6.3 a	10.6 a	6.5 a	13.7 b	5.5 a	9.6 abc	18.3 a	33.8 ab
Aphrodite	0.0 b	0.0 b	0.8 c	2.4 c	2.0 cd	4.5 c	2.8 c	6.9 c
Superstar	0.8 b	1.4 b	7.0 a	27.9 a	4.0 abc	12.4 abc	11.8 b	41.6 a
Tirreno	0.8 b	0.8 b	1.5 bc	3.9 c	3.5 abc	8.9 abc	5.8 c	13.6 c
Wrangler	0.8 b	1.4 b	1.8 bc	3.6 c	0.5 d	3.9 c	3.0 c	8.8 c
Hales Best	0.0 b	0.0 b	4.8 ab	6.5 bc	2.3 cd	4.5 c	7.0 c	11.0 c
Dream Dew	0.0 b	0.0 b	1.5 bc	5.3 bc	3.8 abc	13.4 ab	5.3 c	18.7 bc
Green	0.0 b	0.0 b	0.5 c	0.4 c	5.3 ab	15.6 a	5.8 c	16.0 bc
Afg1	0.5 b	1.0 b	1.0 c	3.4 c	2.3 cd	4.5 c	3.8 c	8.9 c
Afg2	0.5 b	0.9 b	1.5 bc	5.4 bc	1.8 cd	5.5 bc	3.8 c	11.8 c
P	0.001	0.001	0.001	0.001	0.01	0.02	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher’s LSD.

Table B 2.7 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests ten muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2015.

Treatments	Early harvest No. of fruits 10-17 Aug (3harvests)	Early harvest yield kg 10-17 Aug (3 harvests)	Mid harvest No. of fruits 21-28 Aug (3 harvests)	Mid harvest yield kg 21-28 Aug (3 harvests)	Late harvest No. of fruits 1-3 Sep (2 harvests)	Late harvest yield kg 1-3 Sep (2 harvests)	Total No. of cull fruits	Total cull yield (kg)
Athena	6.5	7.7	2.8 bc	4.3 b	1.3 bc	2.3 b	10.5 b	14.2 cd
Savor	18.0	12.0	16.0 ab	14.7 a	15.3 ab	14.4 ab	49.3 a	41.1 ab
Diplomat	21.3	29.4	2.3 bc	2.7 b	0.0 c	0.0 b	23.5 ab	32.0 bc
Aphrodite	2.8	4.5	1.3 b	2.3 b	1.3 bc	2.7 b	5.3 b	9.5 d
Superstar	2.0	4.7	3.5 bc	5.1 b	2.3 bc	4.1 b	7.8 b	14.0 cd
Majus	10.5	14.1	0.5 b	0.4 b	2.5 bc	5.3 b	13.5 b	19.8 cd
Wrangler	13.3	13.2	4.3 bc	3.3 b	4.0 bc	2.4 b	21.5 b	18.8 cd
Hales Best	8.3	6.0	20.3 a	22.1 a	21.8 a	26.2 a	50.3 a	54.3 a
Dream Dew	10.8	11.4	3.3 bc	5.3 b	1.3 bc	1.8 b	15.3 b	18.5 cd
RML 9818	18.5	11.5	1.5 b	0.9 b	0.0 c	0.7 b	20.8 b	13.1 cd
P	0.11	0.06	0.001	0.001	0.001	0.001	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

Table B 2.8 Number and yield per plot of unmarketable (cull) fruits at early, mid, late and all harvests twelve muskmelon cultivars. The experiment (4) was conducted at the Purdue Pinney Agricultural Center (PPAC), Wanatah, IN, in 2016.

Treatments	Early harvest No. of fruits 28 Jul-4 Aug (2 harvests)	Early harvest yield (kg) 28 Jul-4 Aug (2 harvests)	Mid harvest No. of fruits 9 Aug (1 harvests)	Mid harvest yield (kg) 9 Aug (1 harvests)	Late harvest No. of fruits 13 Aug (1 harvests)	Late harvest yield (kg) 13 Aug (1 harvests)	Total No. of cull fruits	Total cull yield (kg)
Athena	5.0 e	4.4 e	10.8 ab	15.9 ab	0.8	1.1	16.5 cef	21.3 bc
Savor	37.0 a	26.0 abc	9.0 bc	6.3 cd	1.0	0.8	47.0 a	33.0 ab
Diplomat	29.0 ab	32.6 ab	0.5 e	0.3 d	0.0	0.0	29.5 b	32.9 ab
Aphrodite	13.5 de	21.1 cd	10.5 ab	20.2 a	1.3	2.3	25.3 bcd	43.6 a
Superstar	6.3 e	10.0 de	8.5 bcd	12.3 abc	0.0	0.3	14.8 ef	22.6 bc
Tirreno	30.8 ab	34.5 a	2.8 cde	5.0 cd	0.5	0.5	34.0 b	40.0 a
Wrangler	18.3 cd	17.9 cd	8.5 bcd	8.5 bcd	0.3	0.5	27.0 bc	26.9 bc
Hales Best	26.0 bc	23.4 bc	16.5 a	20.5 a	1.5	1.1	44.0 a	44.9 a
Dream Dew	12.5 de	20.3 cd	0.0 e	0.0 d	0.0	0.0	12.5 ef	20.3 c
RML 9818	16.5 d	12.3 de	3.3 cde	3.6 cd	0.0	0.0	19.8 cde	15.9 c
Afg1	7.3 e	10.1 de	2.3 de	4.8 cd	0.8	1.2	10.3 f	16.1 c
Afg2	6.0 e	5.9 e	5.3 cde	8.6 bcd	2.3	2.0	13.5 ef	16.4 c
P	0.001	0.001	0.001	0.001	0.20	0.13	0.001	0.001

Values in a column followed by the same letters are not significantly different at P=0.05 as determined by Fisher's LSD.

VITA

VITA

Ahmad Shah Mohammadi

Education:

B.Sc. (Agronomy)	Herat University, Afghanistan	2001-2004
M.Sc. (Horticulture)	University of Agricultural Sciences, Bangalore India	2006-2008
Ph.D. (Horticulture)	Purdue University, IN, US.	2012-2016

Appointments:

2004-2006	Assistant Professor of Horticulture Department, Agriculture Faculty, Herat University, Afghanistan.
2006-2008	Master Degree Period. Bangalore, India.
2008-2012	Assistant Professor and Department Head, Department of Horticulture, Agriculture Faculty, Herat University, Afghanistan.
2012-2016	Ph.D. Degree Period. West Lafayette, IN, US.

Professional Activities; From 2005-2016

1- Poster presentation in title of Timing Early Season Cucumber Beetle Control to Manage Bacterial Wilt in Muskmelon, at American Society of Horticulture Sciences, New Orleans, Louisiana, US, August 3-8/2015.

2- Poster presentation in title of Timing Early Season Cucumber Beetle Control to Manage Bacterial Wilt in Muskmelon, at The 9th Annual Ecological Sciences and Engineering Symposium, West Lafayette, IN. September, 2015.

3- Poster presentation in title of Variation among Muskmelon Cultivars in Attractiveness to Striped Cucumber Beetle and Severity of Bacterial Wilt, at

4- Department of Horticulture and Landscape Architecture annual retreat. West Lafayette IN. May, 2016.

5- Poster presentation in title of Variation among Muskmelon Cultivars in Attractiveness to Striped Cucumber Beetle and Severity of Bacterial Wilt, at American Society of Horticulture Sciences, Atlanta, Georgia, US, August 7-12/2016.

6- Participating in International Congress of Entomology, Orlando, Florida, US, September 25 August- 1st October/2016.

7- I served 4 years as a Head of Horticulture Department, Agriculture Faculty, Herat University (2009-2012).

8- I taught 5 Courses: Principle of Vegetable Production, Vegetable Production Technology, Evergreen Fruits production, Forestry, Tropical Fruit Production.

9- Agricultural Consultant to Italian provincial reconstruction team (PRT), 2010.

10- I hold and taught different workshops regarding:

    a- Environmental protection and safety awareness for elementary and high school's students Herat Afghanistan, and a group of high school teachers (women and men) Afghanistan, Funding US Embassy in Herat Province. 2009.

    b- Kitchen Garden establishment techniques for a group of farmers (women and men) of Badghis Province, Afghanistan, 2010.

    c- Vegetable production techniques for a group of farmers of Kohsan District, Herat province Afghanistan, 2009.

    d- Saffron planting, protection and production techniques for a group of farmers (women and men) of Herat Afghanistan, 2008.

Certificates

1- Training on Soybean Production Education and Training Session at the Ministry of Agriculture Irrigation and Livestock, MAAHF/NEI, Kabul, Afghanistan, 2-4 April/2005.

2- Training workshop on Environmental production in Afghanistan) UNEP, Herat, Afghanistan June 25/ 2006.

3- Training workshop on postharvest management of Horticulture products A4-Kabul. Afghanistan.
4- Training on curriculum development policy in Afghanistan Universities, Kabul, Afghanistan.
5- Training on experimental design and data analyzing. Kabul, Afghanistan.
6- Training on Nursery management of forestry, Kabul, Afghanistan.
7- Training workshop on Saffron Production Education and training Session, DACAAR – RDP-Herat office, Afghanistan, March 2005.
8- Training on Postharvest technology and marketing of Horticulture crops.

Publications

Mohammadi, A. S., Foster, R. E., Maynard, E. T., & Egel, D. S. (2015). Comparison of Attractiveness and Reaction of Melon Cultivars to the Striped Cucumber Beetle and Bacterial Wilt, 2015 Midwest Vegetable Trial Report for 2015.

Mohammadi, A. S., Foster, R. E., Maynard, E. T., & Egel, D. S. (2015). (Abstract) Timing Early Season Cucumber Beetle Control to Manage Bacterial Wilt in Muskmelon. Hort. Science, Vol 50(9).

Mohammadi, A. S., Foster, R. E., Maynard, E. T., & Egel, D. S. (2016). (Abstract). Variation among Muskmelon Cultivars in Attractiveness to Striped Cucumber Beetle and Severity of Bacterial Wilt. ASHS 2016 Annual Conference. https://ashs.confex.com/ashs/2016/webprogram/Paper23994.html

Unpublished Researches

1- Mohammadi, A. S. (2011). Effect of different methods of planting on yield of garlic. Herat, Afghanistan.
2- Mohammadi, A. S. (2010). Yield evaluation of 5 cultivars of cabbage under Herat Province climate condition. Herat, Afghanistan.
3- Mohammadi, A. S. (2009). Effect of different spaces on yield of saffron. Herat, Afghanistan.

4- Mohammadi, A. S. (2009). Effect of different levels of NPK fertilizers on yield of garlic. Herat, Afghanistan.

5- Mohammadi, A. S. (2007). Effect of different amount of NPK fertilizers and levels of fertigation on yield, quality and shelf life of tomato under greenhouse and field condition. Bangalore, India.