POPULATION DYNAMICS FOR KEY PESTS IN ORGANIC SOYBEAN FIELDS IN OHIO AND SUCCEPIBILITY DIFFERENCES BETWEEN ORGANIC AND CONVENTIONAL SOYBEAN.

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of the Ohio State University

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ABSTRACT

With reports of pest problems in organic soybean fields in Ohio, a group of studies were designed to look at what was happening. Three main insect pests were studied, the bean leaf beetle, Mexican bean beetle and soybean aphid. To study bean leaf beetle populations and dynamics, sampling was done in organic soybean fields. The data from this sampling study showed an economic population of bean leaf beetle in organic soybeans. This economic population and high levels of pod injury makes bean leaf beetle a major concern in organic soybean. The next study was designed to determine if there were decreases in plant susceptibility due to organic growing methods using Mexican bean beetle. No difference was found between organically and conventionally grown soybean. The last study looked at the soybean aphid. Samples were taken in organic fields to examine aphid populations and dynamics throughout the seasons. Although hampered due to weather, there were still economic populations of aphids present in organic soybeans.
Dedicated to my parents.
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CHAPTER 1

INTRODUCTION

Organic farming is one of the fastest growing branches of agriculture today. The market for organic products is steadily increasing as consumer demand grows. Despite the market potential for organic products little or no research has been conducted to look at the pest problems that occur within the organic growing system (Zehnder et al., 2007). Much of the research conducted concentrates mainly on the benefits of the organic farming system and not on potential problems farmers are actually experiencing. Currently there is little research available showing what the population dynamics are for specific pests present in organic fields.

In organic farming there has always been an emphasis placed on utilizing a variety of tactics in order to prevent general pest problems from occurring. An integrated pest management (IPM) strategy is used to establish more permanent solutions to pest problems rather than relying solely on curative solutions. With a limited number of curative solutions available, organic farmers must utilize more cultural and biological controls than conventional farmers.

In organic soybean production farmers are faced with a number of weed, fungi, viral, and insect pests with few curative methods available to suppress them once they have reached economic injury levels. This lack of such tactics makes the cultural...
practices involved in the process more important. For soybeans these practices include tillage, multiple year rotation, planting location, and variety selection (Steffey et al., 1994; Pedigo and Rice, 2006). Tillage serves to help control weeds and to reduce the arthropod pests associated with the soil such as bean leaf beetle (BLB) larvae, *Cerotoma trifurcata*, and wireworms, Elateridae (Lorenz, et al., 2006). Multiple year rotation and planting location are useful to help soybeans to avoid certain pests all together, such as soybean severe stunt, *Soybean severe stunt virus* and the dagger nematode, *Xiphinema americanum* that vectors it (Evans et al., 2007). With most insect pests many organic farmers tend to hold the belief that their soil management system will control the insect pests that arise during the season (Howard, 1940; Phelan et al., 1996). The thought that when the ecosystem is in balance belowground with both biotic and abiotic components there will be no pest problems aboveground, is a commonly held belief in organic farming. Despite the attempts by organic farmers to improve their soil quality, they are still experiencing pest problems (Dean McIlvaine, Ohio organic farmer, personal communication). For soybeans the most critical times for pest injury are during the early growing stages and then reproductive stages, from bloom to pod fill (Gouge et al., 1999). Injury from pests during these stages may cause decreases in yield and seed quality. Soybean injury can result from any number of pests including weeds, fungi, viruses, and insects.

One major pest in organic fields is weeds. There are no curative herbicides available for use on organic farms. The lack of organic herbicides means using a combination of different management strategies, such as using a rotation schedule that incorporates an autumn planted cover crop that helps to prevent weed seeds from
germinating. Studies have also shown that organic surface mulches can help reduce the number of weeds (Bond and Grundy, 2001). Many times these initial management strategies are not sufficient enough to control weeds throughout the season, which often results in tillage being the only strategy left. When weeds are not controlled through tillage, they may be observed completely overgrowing the soybeans, resulting in significant crop loss (personal observation). Weed control in organic fields often requires intensive tillage before planting as well as additional tillage after the seedlings have sprouted to keep the weeds below the top of the soybean canopy. As a result of this intensive tillage, planting dates are often much later in the planting season than in conventional fields (personal observation). Organic farmers in Ohio have reported planting dates as late as the first week of July. A search of literature indicates that no studies have been done to look at the effects later planting dates have on specific pest populations in organic soybean fields. By using tillage as a cultural control for one type of pest, organic farmers may in fact be allowing another, different pest problem later on.

Ohio soybean growers experience many problems with foliage feeding arthropod pests in regards to yield and seed quality. A few of the more important defoliators are the BLB, Japanese beetle, *Popillia japonica*, and Mexican bean beetle (MBB), *Epilachna varivestis* (Kogan and Kuhlman, 1982; Hammond, 1994). More recently farmers have also reported problems with the soybean aphid, *Aphis glycines*, that pierces the leaves and sucks the sap (Ragsdale et al., 2004).

With reports of pest problems in many organic soybean fields across Ohio, a group of studies were designed to better understand what was occurring within these fields. Three main insect pests were studied, the BLB, MBB and soybean aphid. To study
BLB populations and dynamics sweep sampling was done for two seasons in organic soybean fields. The sampling data will be used to confirm the number of generations of BLB, as well as to determine if economic populations are occurring in organic fields. The next study was designed to determine if there was a decrease in plant susceptibility due to the organic growing system, as most organic growers believe, using MBB bioassays. Data will be analyzed comparing organically and conventionally fed larvae for percent mortality, average pupal weight and egg-to-pupae developmental time. The last study looked at a new, invasive pest to North America, the soybean aphid. Here field samples were taken in organic soybean fields to get a better understanding of aphid populations and dynamics throughout the seasons. The data will be examined to find population dynamics, as well as to determine if economic populations are occurring in organic fields. This series of studies was designed to see what types of pest problems were occurring in organic soybean fields and if they were economically important.
The demand for organically grown products in the United States as well as worldwide has motivated a large increase in the amount of certified organic farmland. In 2005 U.S. producers dedicated over 4.0 million acres of farmland for organic crop production; 1.7 million acres for cropland and 2.3 million acres for rangeland and pasture (Greene, 2007). By 2006 certified organic land reached 75 million acres, up by 4.4 million acres in 2006 alone. The market for organic crops had increased by 5 billion U. S. dollars in 2006 worldwide, reaching 40 billion, with consumption mainly in Europe and North America (Willer and Yussefi, 2007). Despite the growth in organic agriculture, the body of scientific research conducted on certified organic farmland has been limited. The need for information on specific mechanisms and practices used in organic farming in regards to how they affect various pests in the field has not been widely addressed.

Producing a certified organic crop does not only mean avoiding the use of synthetic chemicals or the substitution of natural chemicals. Organic crop production must be managed according to the regulations listed in the National Organic Program (NOP) regulations and have had no prohibited substances applied to it for at least 3 years prior to harvest (USDA NOP, 2000). Fields must also have distinct boundaries with
buffer zones to prevent contact with any prohibited substances. Production of organic crops includes a variety of practices designed to achieve goals of improved biological diversity and improved soil quality. These practices include utilizing multiple cultural, mechanical, ecological, biological and chemical tactics.

In organic systems, pest management involves the use of ecologically sound production that promotes and enhances biological diversity, cycles and soil activity by minimizing the use of off-farm inputs and using practices that restore, maintain and enhance ecological balance (USDA NAL, 2007). These organic practices are designed to be incorporated into the cropping system in order to prevent economic pest populations from occurring, thus reducing the use of curative solutions (Zehnder et al., 2007). Many of these same practices are now being labeled as an integrated pest management (IPM) program. The underlying practice of utilizing a variety of tactics to suppress multiple pests including arthropods, weeds, and pathogens, has served as a guideline for organic and sustainable crop production for many years. Kogan traces the roots of IPM ecological concepts back to the late 1800s with its concepts and ideas running parallel to the practices found in low-input sustainable agriculture systems (1998).

When developing an organic farming pest management system the indirect, preventative measures hold the highest priority and should be utilized early on during production, while more direct, curative measures should be considered much later and only when necessary (Wyss et al., 2005). Using Wyss’s model, pest management tactics in organic systems can be divided into the four phases described below. In an organic farming IPM program more of an emphasis is placed on first and second phase tactics to
prevent a pest problem from occurring. By using the correct combination of tactics it is possible to manage pests that occur throughout the growing season.

2.1 FIRST PHASE

First Phase tactics are designed to be implemented in a long-term organic production system to reduce the likelihood of pest infestation and damage and include cultural practices such as crop rotation, soil management, tillage, non-transgenic host plant resistance, and farm and field location. These cultural practices are some of the oldest pest management techniques and serve to suppress pest populations in various ways. When utilizing cultural control practices organic farmers must be aware that certain practices can increase the risk of attack by some pests while contributing to the control of another pest (Glen, 2000).

The first thing that needs to be considered is farm location. Selecting an ideal environment for the crop to grow involves a few considerations. A site where conditions are favorable for crops and natural enemies while remaining unfavorable to primary pest outbreaks is ideal. In some cases a certain crop may not be grown in a particular geographic area due to consistent pest pressures such as lygus bug, _Lygus hesperus_ in fresh market bean fields located in the San Joaquin Valley, where it is not possible to stop losses with certified organic materials (Fouche et al., 2000). On a more local level this means planting a crop in a field that is best suited for its growing needs or selecting a cultivar that is adapted for growing in their chosen geographic area (Zehnder et al., 2007).
Crop rotation involves growing a series of crops in succession on a regional or individual field basis in order to increase fertility, soil organic matter, improve soil structure, decrease soil erosion, increase soil microorganisms, and decrease pests (Bullock, 1992, Helenius, 1997). While these effects may not be evident in conventional growing systems like the 2-year corn-soybean system, organic farming involves using an extended crop rotation including crops such as sod, pasture and hay crops (USDA NOP, 2000). Incorporating a wider variety of crops through space and time helps to break pest life cycles, provide complimentary fertilization to crops in sequence as well as prevent the build up of pest insects and weeds (Sullivan, 2003, Zinati, 2002, and Kopke, 1995). This becomes especially important to reduce variety of weed species as well as total weed biomass during the season by varying the nutrient utilization of the crops in succession (Teasdale et al., 2004, Liebman and Dyck, 1993).

Soil management strategies have been in use within the organic farming community for quite some time. By managing the abiotic and biotic components in the soil, it is believed that a balance is achieved capable of warding off various pests that arise during the season (Howard, 1940 and Phelan et al., 1996). This reduction in pests may be achieved through habitat manipulation and soil fertility management (Alteri et al., 2005). Although there have been many studies conducted to demonstrate the connection between soil management and pest management, it is extremely difficult to show how management effects various pests (Bardgett et al., 1998). Studies have shown that by increasing the soil organic matter in a field may help increase the soil biota diversity (Mader et al., 2002, Bengtsson et al., 2005). This enhancement of soil fertility provides an environment that enhances plant health, allowing for increased pest resistance (Phelan,
et al., 1995 and Alteri and Nicholls, 2003). On the other hand, one study has shown that too large of an increase in nitrogen may be causing certain pest problems in the field (Stockdale et al., 1992).

The increase of soil fertility in organic farming is accomplished by a number of strategies including rotation, cover crops, and the addition of organic plant and animal materials (USDA NOP, 2000). Using cover crops and manures is an important part of the organic farming cycle. Cover crops are grown mainly to provide soil cover in order to prevent soil erosion from wind and water throughout the winter although they also have the ability to increase soil fertility (Sullivan, 2003). Livestock manures are a key source for the fertilization needed to stimulate the biological processes in the soil that help build fertility within organic and sustainable farming systems (Kuepper, 2003). The use of these manures is highly regulated especially with application of raw manures (USDA NOP, 2000). Organic mulches and composts may also be used to add organic matter to the soil, increase soil fertility and soil-moisture-holding capacity and reduce soil temperature along with suppressing weeds and other pests (Zehnder et al., 2007 and Bond and Grundy, 2001). The use of vermicompost has also been shown to significantly reduce pest damage in the field (Arancon et al., 2003).

The use of conservation tillage has been practiced in organic farming for a number of reasons. It is used to reduce soil erosion, nutrient leaching, and temperature fluctuations and increase biological diversity and organic matter (Kuepper, 2001). By increasing soil moisture and stabilizing temperatures, species that are sensitive to physical disturbances in the soil layers are able to create a more complex ecosystem (Kladivko, 2001). For example, tillage operations have been reported to reduce the
overall populations of generalist arthropod predators found in the field (Thorbek and Bilde, 2004). Despite the benefits of conservation tillage problems arise with regards to weed control within this type of system. Often times tillage is the best and only effective tactics against weeds. Without the use of synthetic herbicides fewer economically feasible options are available for use in organic farming (Stopes and Millington, 1991).

Host plant resistance in organic farming has been centered on disease management rather than the insect pest management applications seen in conventional fields (Zehnder et al., 2007). In organic farming partial plant resistance is more useful when combined with other control measures in an IPM program than higher level resistance used in conventional farming (Van Emden, 1991). When using this type of resistance a lower level of pest populations are maintained in the field which allows the natural enemy populations to stay present throughout the season (Sharma and Ortiz, 2002). This allows biological control agents a chance to suppress an insect outbreak before it occurs.

### 2.2 SECOND PHASE

This group of tactics is designed to alter the ecological structure of the area after the first phase tactics have been put in place. It includes conservation biological control, intercropping and trap cropping aimed at enhancing natural enemy impacts as well as direct effects on pest populations (Zehnder et al., 2007). These tactics are useful in that they may be initiated once one or more of the first phase tactics was not successful such
as poor farm location or poor soil fertility. By modifying the environment in which the crop is grown pest problems may be avoided before insecticides need to be used.

Increasing the natural enemy populations in the field is an integral part of an IPM program in organic farming. The enhancement of natural enemies through conservation biological control is especially important during the transition phase from conventional to organic during the certification process (Zinati, 2002). This may be accomplished in two ways, habitat modification and the minimized use of pesticides with lethal and sublethal effects (Desneux et al., 2007). Contrary to older beliefs this does not mean completely stopping all pesticide use, but rather using pesticides that are better incorporated into an IPM management program (van Emden and Peakall, 1996). While in the past there was more of an emphasis on the importation of biological control agents, there is beginning to be more interest in developing in situ conservation of agents already established in the field (van Emden, 2003).

Intercropping with alternative crops or even weeds is one method to help decrease pest populations. This is made possible by reducing the concentration of host plants that attract the pests to the area (Root, 1973). With a larger variety of crops in the field it makes finding host plants more difficult. The use of intercropping may also serve to help increase crop yields as is the case with field bean and wheat (Bulson, 1997). Although not always effective, intercropping may be a useful IPM component.

Trap cropping is another method used for pest management, usually with pesticides in conventional farming (Zehnder et al., 2007). It utilizes pull components of the push-pull strategy to reduce pest populations in the field (Cook et al., 2007). By planting a crop more attractive to pest species they will be pulled away from the main
crop. Once the pest has established itself in the trap crop an insecticide may be sprayed, killing the pests. In organic farming this may be used in combination with approved botanical insecticides (USDA NOP, 2000). With the recent interest in trap cropping methods by organic farmers, there have been more applications of trap cropping applied in the field, including its use in combination with biological control and semiochemicals (Shelton and Badenes-Perez, 2006). These two in particular have the best potential for use in organic farming.

### 2.3. THIRD PHASE

After first and second phase tactics are in place or utilized there still may be an economic pest problem. Once a pest problem has occurred, inundative and inoculative biological control strategies may be used. Both strategies involve the release of mass-reared agents into the field to help control the pests (Eilenberg et al., 2001). These are considered direct control strategies against a given pest. When releasing these agents into the field it is important to check with the certifying agency Organic Materials Review Institute (OMRI) to see if in fact they are allowed (2008). They include a list of approved predators, parasitoids, bacteria, fungi, and viruses, excluding any genetically modified organisms. It has been shown that the release of multiple biological control species is more effective against some pests than the release of a single species (Stiling and Cornelissen, 2005). Also this study shows that generalist predators have the best potential to control pest populations in the field. With the use of low-risk pesticides and organic
farming practices, there are newer opportunities for this type of biological control to be applied (Collier and Van Steenwyk, 2003).

2.4. FOURTH PHASE

Fourth phase tactics are designed to be used after all other strategies have been unsuccessful at keeping pest populations below thresholds including pheromones for mating disruption, repellent agents and insecticides of biological and mineral origin (Zehnder et al., 2007). The compounds allowed for use in organic farming systems are listed in the IFOAM Basic Standards for Production and Processing (2005) as well as by OMRI online (2008) for the U. S. Except for pheromones used in traps, all of these substances must be non-synthetic in origin. Pheromones are allowed to be synthetic because they are contained inside of a mating disruption trap and do not come in contact with the crop. Despite the growth of research on botanical insecticides very few are being used commercially, with only 2 new sources of botanicals discovered within the last 20 years (Isman, 2006,). A list of approved insecticides may be found at the USDA NOP website. A few of the more common insecticides are neem, pyrethrum and essential oils. With the limited number of approved insecticides, the previously explained tactics become more important to prevent economic populations from occurring.
CHAPTER 3

BEAN LEAF BEETLE SAMPLING

3.1 INTRODUCTION

One of the more important insect pests present in Ohio is the bean leaf beetle (BLB), *Certoma trifurcata*, a native species and mainly a pest in the eastern United States (Pedigo, 1994). It has been reported to feed on a number of host plants but it is mainly a pest on soybeans (Kogan et al., 1980; Koch et al., 2004). The adults are about 5 mm in length and can vary in coloration. The three variations are pale yellow elytra with 4 black spots and marginal stripes, crimson elytra with spots and stripes and pale yellow without spots and stripes (Horn, 1893). A black triangle is always present behind the prothorax on all the adult color variations. BLB adults and larvae both have chewing mouthparts that are able to consume any part of the soybean plant including roots, root hairs, nodules, stems, leaves, and pods (Kogan et al., 1980; Pedigo, 1994). Adult feeding is the most recognizable damage and is characterized by small round holes on the leaves between the veins. The soybean plant can withstand a large amount of defoliation before it reaches reproductive stages, making management usually unnecessary at this stage. Later in the season however the adults begin feeding on the developing pods (Smelser and Pedigo, 1992). This is the damage that causes the largest reductions in both yield and seed
quality. These damaged pods leave the seed open to moisture and secondary infections by bacteria and fungi, such as *Phomopsis* sp. and *Alternaria* sp., which may cause rotting and discoloration (Obopile and Hammond, 2001). These disease pathogens enter the pods from the feeding sites, causing seeds to appear shrunken, discolored, and moldy, which can result in reduced yield and dockage for poor seed quality (Crop Watch, 2001). BLB is also able to transmit bean pod mottle virus, cowpea mosaic virus and southern bean mosaic virus by feeding on healthy soybean plants after being infected (Pedigo et al., 1990). With bean pod mottle virus and the soybean mosaic virus together soybean fields can experience more than an 80% yield loss (Krell et al., 2004). Depending upon the soybean stage the BLB is feeding on, management decisions need to be made based on potential yield losses.

The BLB life cycle begins with the overwintering adults emerging in spring from habitats like wood lots, clumps of grass and leaf litter (Smelser and Pedigo, 1991). They first move to alfalfa fields in early to late April before soybean emerges (Waldbauer, 1976). Upon migrating to soybeans, they begin feeding and lay eggs in the field. Larvae emerge after 5-7 days and feed on the roots and nodules of the soybean plant (McConnell, 1915; Boyd and Bailey, 2000). They then pupate in the soil before moving to the leaves and pods as adults. The BLB has one generation in more northern states and as many as three in some southern states. Studies show that there is only one generation per year in Minnesota (Loughran and Ragsdale, 1986) while North Carolina (Boiteau et al., 1979), Illinois (Waldbauer, 1976) and Iowa (Smelser and Pedigo, 1991; Lam et al., 2001) all have two generations per year. All of these studies have been done in
conventional soybean fields. There has been no similar studies conducted that examine BLB population dynamics specifically in organic fields.

For control of BLB in organic soybeans there is a limited amount of control measures available. When considering planting location, it is recommended that soybean fields are as far away from alfalfa as possible in order to reduce the initial BLB immigration (Pedigo and Rice, 2006). Other cultural tactics used to control pests in the organic system may in fact be leading to more severe pest problems with the BLB during the growing season. As mentioned earlier, tillage for weeds often results in organic farmers planting later than most conventional growers. For BLB management in conventional fields there are various studies that show later plantings may reduce the amount of damage from over-wintering beetles (Witkowski and Echtenkamp, 1996 and Zeiss and Pedigo, 1996). In another study however it was noted that in some later plantings a large BLB migration later in the season was experienced that lead to an increase in overall pod injury when compared to the earlier planting dates (Pedigo and Zeiss, 1996). After soybeans are mature and development has stopped the seeds may still be at risk if left in the field. A study in Ohio showed that when BLB damage is high during the growing season, immediate harvest at maturity is important to prevent further seed germination losses and increases in fungal pathogens (Obopile and Hammond, 2001). Delayed harvesting is also something that may occur in organic farming due to time constraints in the fall with increased cover crop and organic mulch usage. With the organic farmers planting and harvesting later, they may actually be allowing the BLB more time to cause damage to the soybean fields.
The primary objective of this study was to determine the population dynamics of BLB in organic soybean fields in Ohio, in part, to confirm the number of BLB generations present. A secondary objective was to record the level of pod injury that occurs at the end of the season in organic systems. BLB population and pod injury data from organic fields will be examined to determine if planting date has a role on impacting pod damage. Thus, a two year study was conducted where organic fields were sampled in two locations in Ohio, in northwest Ohio where insect pressure is known to occur in conventionally grown fields, and in northeast Ohio where soybean insect pressure tends to be less.

3.2 MATERIALS AND METHODS

Field sampling for the BLB was conducted in Wood County, located in northwest Ohio, and in Wayne County, located in the northeast during the 2006 and 2007 growing seasons. Five certified organic soybean fields were chosen in each county during both seasons by contacting local organic farmers through Ohio State. Fields were labeled O1 to O5, and O6 to O10, in Wood and Wayne Counties, respectively. Sampling was done weekly using a 38 cm diameter sweep net with 10 sweeps per sample. Samples were taken at least 50 ft into the field to eliminate edge effects. Sweeping began in each of the fields when the plants reached growth stage V5 (5 nodes with fully developed leaves) and were tall enough to sweep without damaging the plants. A total of 10 random samples were taken weekly in each field for both years. The samples were bagged and then taken back to the laboratory and stored in a freezer for later sorting. Sampling continued until
the soybeans reached R7 (beginning of maturity), when leaves began turning yellow and pods began to turn brown. Samples were sorted and BLB numbers were recorded.

Pod injury data were collected weekly in the same fields once the soybean plants reached R5 (beginning seed) in both 2006 and 2007. Ten soybean plants were randomly selected in each field. Percentage pod injury was calculated by counting the number of pods with BLB damage out of the total number of pods on each plant. Mean number of BLB was plotted against time during each growing season to delineate population trends for both 2006 and 2007. The mean percent pod injury was also plotted against time to show levels of damage incurred throughout the season.

Surveys were sent to the various farmers whose fields were used for sampling in both counties. This survey was used to obtain information regarding plant variety, planting date, harvest date and any treatments applied.

3.3 RESULTS

3.3.1 FIELD DATA

Field information obtained from the farmer surveys for each of the sampled fields is given in Tables 3.1 and 3.2 in 2006 and 2007, respectively. The planting dates and harvest dates varied as much as one month. The earliest plantings were May 2nd and May 5th in 2006 and 2007, respectively, and the latest plantings were June 9th and June 8th in 2006 and 2007, respectively. Most fields were planted late May or June, which is late compared to many of the conventional fields in the same areas which were planted in late April or early May (personal observations). Harvest dates ranged from October 2nd to
December 1st during the study which was well passed the September harvests in most conventional soybean. In Wayne County organic field O10 was lost during the season due to weeds. The last sample was collected in each organic field when the beans reached R7, yellowing of most of the leaves and a few pods at maturity color. As with planting and harvest dates, the organic soybean fields tended to stay greener well into September, whereas most of the conventional fields in the areas were at harvest maturity.

There were three varieties being grown, Blue River 2A71 and Ohio FG1 and Iowa 2020. Blue River 2A71 and Iowa 2020 are both in maturity group II, while Ohio FG1 is in maturity group III (St. Martin, et al., 1996, Blue River Hybrids Organic Seed, 2007 and Committee for Agricultural Development, 2007). While Ohio FG1 and Iowa 2020 are food grade soybeans Blue River 2A71 is feed grade. Despite the difference in grades and varieties there were no trends in the BLB sampling data. When comparing BLB populations and pod injury percentages, there were no trends among the data in regards to planting or harvest dates. In both the 2006 and 2007 seasons there were no organic sprays applied to the crops for BLB during the season by the farmers.
Table 3.1 Field data from farmer surveys in 2006.

<table>
<thead>
<tr>
<th>Field</th>
<th>Location</th>
<th>Variety</th>
<th>Plant Date</th>
<th>Harvest Date</th>
<th>Maturity Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic 1</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>6/6</td>
<td>11/4</td>
<td>II</td>
</tr>
<tr>
<td>Organic 2</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/31</td>
<td>11/4</td>
<td>II</td>
</tr>
<tr>
<td>Organic 3</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/13</td>
<td>10/15</td>
<td>II</td>
</tr>
<tr>
<td>Organic 4</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/2</td>
<td>10/14</td>
<td>II</td>
</tr>
<tr>
<td>Organic 5</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/25</td>
<td>10/2</td>
<td>II</td>
</tr>
<tr>
<td>Organic 6</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>5/30</td>
<td>10/28</td>
<td>III</td>
</tr>
<tr>
<td>Organic 7</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/8</td>
<td>10/29</td>
<td>III</td>
</tr>
<tr>
<td>Organic 8</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/8</td>
<td>10/28</td>
<td>III</td>
</tr>
<tr>
<td>Organic 9</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/9</td>
<td>10/30</td>
<td>III</td>
</tr>
<tr>
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<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/3</td>
<td>lost to weeds</td>
<td>III</td>
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</tbody>
</table>

Table 3.2 Field data from farmer surveys in 2007.

<table>
<thead>
<tr>
<th>Field</th>
<th>Location</th>
<th>Variety</th>
<th>Plant Date</th>
<th>Harvest Date</th>
<th>Maturity Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic 1</td>
<td>Wood Co</td>
<td>Iowa 2020</td>
<td>6/1</td>
<td>10/30</td>
<td>II</td>
</tr>
<tr>
<td>Organic 2</td>
<td>Wood Co</td>
<td>Iowa 2020</td>
<td>6/2</td>
<td>10/31</td>
<td>II</td>
</tr>
<tr>
<td>Organic 3</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>6/2</td>
<td>10/31</td>
<td>II</td>
</tr>
<tr>
<td>Organic 4</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/16</td>
<td>11/1</td>
<td>II</td>
</tr>
<tr>
<td>Organic 5</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/20</td>
<td>10/24</td>
<td>II</td>
</tr>
<tr>
<td>Organic 6</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>5/18</td>
<td>10/20</td>
<td>III</td>
</tr>
<tr>
<td>Organic 7</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>5/5</td>
<td>12/1</td>
<td>III</td>
</tr>
<tr>
<td>Organic 8</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>5/20</td>
<td>10/23</td>
<td>III</td>
</tr>
<tr>
<td>Organic 9</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/5</td>
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<tr>
<td>Organic 10</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/8</td>
<td>11/1</td>
<td>III</td>
</tr>
</tbody>
</table>

3.3.2 BEAN LEAF BEETLE POPULATIONS AND POD INJURY

Adult BLB population trends are shown in Figure 3.1 for the 2006 season in Wood County. These data show that there was a small peak of BLB adults toward the end of July and the beginning of August, presumably the first generation of adults. There was
a second and much larger peak in BLB adults corresponding to a second generation, occurring during the pod development and maturity stages of soybean growth. The number of BLB adults ranged from 35 to over 80 adults per sample in early September.

**Figure 3.1 Wood County 2006 average BLB adult densities per sweep sample throughout the growing season.**

Adult BLB populations in Wayne County for 2006 are shown in Figure 3.2. The initial peak, assumed to be first generation, of BLB adults was smaller in Wayne County than in Wood County but occurred around the same time in late July/early August. The second peak of BLB adults in late August early September was also smaller compared
with that in Wood. Adult densities ranged from 10 to 40 adults per sample. However, population peaks also suggest the presence of two generations.

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**Figure 3.2 Wayne County 2006 average BLB adult densities per sweep sample throughout the growing season.**

Percent pod injuries for Wood and Wayne Counties for 2006 are shown in Figures 3.3 and 3.4, respectively. By the end of the season pod injury in Wood County ranged from 20% to a maximum of 40%. In Wayne County pod injury ranged from 20% to a maximum of 30%, remaining slightly lower than in Wood County. These levels of pod injury correspond well with the BLB densities observed in these same fields (Figs. 3.1 and 3.2).
Figure 3.3 Average percent pod injury for 2006 in Wood County.

Figure 3.4 Average percent pod injury for 2006 in Wayne County.
BLB data from 2007 for Wood County are shown in Figure 3.5. Two peaks again appear to have occurred, being the first and second generation, respectively. However, the second generation peak was overall lower in 2007, ranging from 0 to 25 adults in four of the fields, although one field, O1, peaked at over 90 adults per sample.

![Figure 3.5 Wood County 2007 average BLB adult densities per sweep sample throughout the growing season.](image)

BLB data from Wayne County in 2007 is shown in Figure 3.6. The first generation was mostly non-existent in four of the fields, although field O6 had a considerable population peaking at 50 adults per sample. However, the second generation remained low in all five fields.
Figure 3.6 Wayne County 2007 average BLB adult densities per sweep sample throughout the growing season.

Figures 3.7 and 3.8 show the corresponding pod injury from Wood and Wayne Counties in 2007, respectively. During this season pod injury ranged from 30% to a maximum of 60% in Wood County, while from 20% to a maximum of 45% in Wayne County.
Figure 3.7 Average percent pod injury for 2007 in Wood County.

Figure 3.8 Average percent pod injury for 2007 in Wayne County.
3.4 DISCUSSION

Results from sampling organic soybean fields indicated that there was a significant BLB problem in Ohio. In conventional soybeans, 2 or more adult beetles per sweep (20 adults per 10 sweep samples) along with 15% defoliation is the economic threshold for BLB during reproductive stages prior to pod set (Willson, 1992). For growth stages from pod set to maturity, R3-R8, 15% pod injury is the economic threshold for applying a rescue treatment. With these extension guidelines, every organic soybean field was well over thresholds during both seasons. The more northwestern location, Wood County, had a greater problem with higher densities of BLB and greater levels of pod injury, at 90 adults and 60% pod injury compared with the northeastern location, Wayne County, at 50 adults and 45% pod injury. With these high numbers, economic levels of adult BLB and pod injury are being observed in organic fields.

There appeared to be two generations of adult BLB in the Ohio organic fields in both counties based on the peaks observed, the same as observed in Ohio conventional fields (Hammond et al., 2001; Bulletin 827-05). The first occurs late July to early August and is assumed to be the first adult generation, while the second is seen in late August to early September and is the second adult generation that will overwinter.

The second BLB generation that peaks in September occurs when soybean is most vulnerable to yield reductions and loss in seed quality, the time when pods are being formed and seeds are maturing in the plant’s reproductive stages, R5-R7. By the end of the growing season, pod injury ranged between 20% and 60% in these fields, well over the 15% threshold. With the plants continuing to grow and remaining green in the field
later in the season, these organic soybeans were exposed to the second generation of BLB adults for a longer time compared to conventional fields. While not sampling conventional fields, it was observed that the vast majority of them in the surrounding landscape were being harvested, or had reached either plant harvest or maturity, no longer making them attractive to this BLB generation. When comparing planting dates, the organic soybeans were generally planted much later than conventional soybeans. Conventional soybeans in Ohio are typically being planted between the last week in April and the first week in May if possible to maximize yields (Beuerlein and Dorrance, 2005). Maturing by the end of August often results in conventional soybeans being removed from the field before the second adult BLB generation peak occurs. Indeed, the incidence of BLB pod injury is becoming less in conventional soybean because of earlier maturity dates (Hammond, personal communication). With the conventional fields maturing, the BLB adults leave seeking additional feeding sites before overwintering. Thus, it appears that these organic fields are serving as trap crops late in the season, attracting second generation BLB adults, resulting in very large adult densities in September and significant pod injury. With as much as 60% pod injury occurring in the organic fields, more effective management strategies will be needed to minimize yield losses.

Although many organic farmers believe that their insect problems in soybean are lower compared with conventionally-grown soybean, it is obvious from this study that BLB can be a severe problem depending on location and year. Without any biopesticides being available to effectively and economically manage BLB, very few tactics are available. The first tactic may be to plant earlier, preferable in earlier May when most of the conventional beans are also being planted. Changing to earlier plantings would also
allow their soybeans to mature prior to the occurrence of the second adult BLB generation in September. This would help to reduce the pod feeding from pod set to maturity. These earlier planting dates may be accomplished by reducing the amount of tillage and overall field preparation required in the spring. A system of conservation tillage would allow for more flexible timing of field operations, like planting dates (Kuepper, 2001). However this may not always be possible depending upon necessary weed control. Another option for organic farmers may be to use soybean varieties from earlier maturity groups, such as Group I, to achieve earlier harvest dates in late August/early September, before the second generation BLB peaks. If organic soybeans could be harvested closer to the conventional ones, they perhaps would no longer act as trap crops for the BLB adults and possibly escape the severe pod injury levels seen here during their most vulnerable growth stages. When BLB populations are high during the growing season, immediate harvest at maturity is recommended to reduce further yield losses, which has been found useful in conventional fields (Obopile and Hammond, 2001). Changing the cultural controls in organic soybeans may be successful in reducing BLB below economic injury levels.
CHAPTER 4

MEXICAN BEAN BEETLE BIOASSAY

4.1 INTRODUCTION

Ohio soybean growers experience many problems with foliage feeding pests in regards to yield and seed quality. A few of the more important defoliators are the bean leaf beetle (BLB), *Certoma trifurcata*, Japanese beetle (JB), *Popillia japonica*, and Mexican bean beetle (MBB), *Epilachna varivestis* (Kogan and Kuhlman, 1982; Hammond, 1994). More recently farmers have also reported problems with the soybean aphid, *Aphis glycines*, a pest that pierces the leaves and sucks the sap out (Ragsdale et al., 2004). Currently, organic farmers in Ohio have also begun experiencing severe problems with these same pests. However, compared with conventional growers, organic farmers have no curative measures available for these insects. Organic farmers tend to believe that their soil management system will control the insect pests that arise during the season (Howard, 1940; Phelan et al., 1996). The thought that when the ecosystem is in balance belowground with both biotic and abiotic components, then there will be no pest problems aboveground is a commonly held belief in organic farming.
From personal observation, the idea that organic systems can ward off pests due to a decrease in susceptibility is a commonly held belief amongst organic farmers in Ohio. This decrease has been attributed to the organic soils in which the crops are being grown (Merrill, 1983), which organic farmers attempt to achieve through field habitat management and soil fertility management (Altieri et al., 2005). Various techniques need to be applied to maximize soil organic matter naturally, including an intensified regime of cultural methods that includes multiple year crop rotations, cover cropping, and the addition of organic mulches to the soil (USDA NOP). With ideal levels of soil organic matter and nutrients available, the plant is thought to be better equipped to resist insect pests by obtaining an optimal nutrient balance (Beanland et al., 2003). Phelan et al. 1995, reported higher pest fecundity rates on plants grown in conventional soils when compared to plants grown in organic soils. Besides insect pests, soil organic matter management is also reported to keep diseases below economic levels (Phelan, 2004).

Although it is hypothesized that optimal nutrient balance has the ability to ward off pests (Phelan et al. 1996, 1997), our data from organic soybean fields in Ohio suggest that it does not appear to offer adequate pest control measure. Observations over the past five years (Hammond, per. obs.) indicate that organic fields are still faced with similar pest problems as conventional fields. For soybeans in particular these concerns comprise a variety of leaf and pod feeding insect pests including the MBB, BLB, JB, two-spotted spider mite, *Tetranychus urticae* and soybean aphids (E-85, 1999; Ragsdale, 2004). In addition to the insect pests there are also problems with weeds and diseases, including bean pod mottle virus, soybean rust, white mold and the perennial giant ragweed (Sinclair et al., 1997). Through field observations and accounts from farmers in the Ohio area there
are concerns about the same pests in both growing systems. Both systems are experiencing the same pests despite the differences in the two growing systems and differences in management practices.

The previous field sampling study (Chapter 1) demonstrated that BLB can be a significant problem in organic soybean fields in Ohio. To better determine whether there is a decrease in susceptibility in organic fields, a follow up study was conducted to compare development and survivorship on organically grown soybean compared to soybean that was conventionally grown. Mexican bean beetle was used as the test insect, having previously been used in numerous host plant resistance studies (Van Duyn et al., 1972, Hammond et al., 1995, 1998, Hammond and Cooper, 1999, Iverson et al., 2001). MBB is a significant pest of soybeans in certain growing regions of the United States (Edwards et al., 1992, 1994), and has been a major pest in Ohio (Hammond et al., 1995). Both the larvae and adults feed on leaves (Edwards and Turpin, 1989), which allows for easy use in developmental studies. Thus, bioassays were conducted to compare development and survivorship on soybean obtained from organic systems compared with conventional systems. The hypothesis is that there would be an increase in developmental times and in mortality when MBB were fed organically-grown soybean, suggesting that organically-grown soybean are less susceptible compared with conventionally-grown soybean. The null hypothesis was that there would be no differences.
4.2 MATERIALS AND METHODS

4.2.1 TRIALS USING FIELD GROWN LEAVES

Feeding trials were conducted using MBB larvae to compare developmental rates and survivorship between soybean grown organically and conventionally. The same five organic soybean fields in Wayne County that were sampled for BLB in Chapter 1 were used as a source of leaf material. Five conventionally grown fields that were either adjacent to or near the organic fields were used as a source of leaf material for the comparison. The matched pairs of fields were labeled as O1 and C1, O2 and C2, etc. Chapter 1 lists the specific varieties grown in these organic fields; for conventional fields the varieties were, Callahan 9366RR, for fields C1 and C3, AgriPro 3702RR, for field C2, LG Seeds 6393RR for field C4 and Dekalb CX 383RR for field C5. One additional source of plant material was green bean grown in a greenhouse at OARDC, used as a standard knowing that it is a preferred host of MBB (Kogan, 1972; Hammond et al., 1998).

Ten fully expanded leaves per field were selected from the 10 fields and brought to the laboratory. Collection of the plant material was done by walking into a field at least 50 feet to avoid any edge effects. Individual plants were chosen at random and the second or third fully open trifoliate from the top was collected, assuring uniformity of the plant. Each leaf was placed into a 9-cm petri dish along with a moistened filter paper disk to
keep the leaves fresh. New leaves were gathered from the field or greenhouse every few
days to ensure leaf freshness.

Six neonate larvae from egg masses hatched on the same day were placed on each
leaf. Eggs had been collected from a colony reared on green bean plants at OARDC. The
number of larvae in each petri dish was reduced or replenished to 5 larvae total on the
second day of the trial. It was believed that mortality on the first day was most likely
from natural causes and unrelated to the feeding trial.

Petri dishes were checked daily for mortality and larval pupation, and plant
material was replenished as needed. The dishes were stored in a dark growth chamber
maintained at a constant 24°C similar to previously reported MBB studies (Hammond et
al., 1998, 1999). Individual dishes were maintained until all larvae within a dish died or
pupated. Upon pupation, MBB pupae were removed and their weights recorded. Two
trials using field-grown leaves were conducted during the 2007 growing season.

4.2.2 TRIALS USING GREENHOUSE GROWN LEAVES

Because the soybean varieties in the organic and conventional fields were
different and could have possibly been the reason for any differences observed in MBB
development, rather than the production practice (organic compared to conventional),
trials were conducted during the following winter to examine any potential differences in
MBB development and mortality on specific varieties when grown in the same soil.
Seeds were randomly collected at harvest maturity from the 10 fields (organic and
conventional) and returned to the laboratory. Seeds were planted on January 4th in 20-cm
pots in the greenhouse. Each variety was planted in 6 pots for a total of 60 pots. The same source of silt loam greenhouse soil was used. As done in the summer, green bean was also planted for comparison. Planted pots were randomly arranged onto a greenhouse bench top, and received equal amounts of water. Two feeding bioassays were conducted similar to the summer trials, with dishes being checked daily for development and mortality.

Data collected included percent larval mortality, total developmental time period (egg-to-pupa), and pupal weight. Data were collected and analyzed in the same manner for each individual trial. Each pair of fields at one location was treated as a replication, for example O1 and C1. The treatments were organic and conventional with the dishes being the sub-samples. The inclusion of green bean in the study was for observation comparison purposes only, and to ensure that larval development was as expected; thus data from green bean were not included in the analysis. Mortality was calculated by determining the percentage of larvae that died before pupation in each petri dish. Percent mortality (x) was transformed before analysis by $\sqrt{x/100}$ to control for variability. Only data from those insects completing egg-to-pupa development were included in the analysis of developmental time period. Because there was 100% mortality in some of the Petri dishes, the remaining data of days to pupation and pupal weights were occasional unbalanced. Thus, data for mortality were analyzed using analysis of variance (ANOVA), while for the unbalanced data for developmental and pupal weight, data were analyzed using general linear models (GLM) procedures, ($P=0.05$) (SAS Institute, 1988). Larvae having longer larval development, increased mortality, or decreased pupal weight, would be considered to be less acceptable as host plants for MBB.
4.3 RESULTS

4.3.1 FIELD GROWN SOYBEAN

Percent mortality, egg-to-pupa development and pupal weights for the organic and conventional fields are shown in Table 4.1 for both field trials. There was no significant difference in either trial in the data for mortality and developmental time. (Trial 1- mortality: F = 0.03; df = 1; Pr > F = 0.8702; pupal weight: F = 0.06; df = 1; Pr > F = 0.8116; development time: F = 0.79; df = 1; Pr > F = 0.4231 Trial 2- mortality: F = 4.90; df = 1; Pr > F = 0.0912; pupal weight: F = 18.85; df = 1; Pr > F = 0.0122; developmental time: F = 2.98, df = 1; Pr > F = 0.1592). Overall means for trial 1 were: mortality – 26% and 28%; pupal weight – 0.03092 g and 0.03030 g; developmental time – 16 d and 17 d, for larvae on organic or conventional grown soybean, respectively. On green bean, larval mortality averaged 14.0%, pupal weight averaged 0.0418 g, and developmental time averaged 15 d. Overall means for trial 2 were: mortality - 32% and 42%; pupal weight – 0.02935 g and 0.03522 g; developmental time – 19 d and 19 d, for larvae on organic or conventional grown soybean, respectively. On green bean, mortality averaged 30%, pupal weight averaged 0.0391 and developmental time averaged 16 days. There was a significant difference in pupal weight for trial 2. The highest mortality recorded for both trials, 64% and 50%, was recorded in C2, a conventional field. When comparing the results to green beans, a preferred host, 8 of the 10 soybean fields showed
a higher average mortality. Each field in both trials showed a lower average pupal weight when compared to green beans, which was expected. Green beans have always been considered a more preferable host, and MBB always develop much quicker with less mortality and larger pupae (Hammond, 1984, Kogan, 1972). Results support the lack of a significant difference in susceptibility to MBB based on development and survivorship between organic and conventional soybean varieties when grown in the field.

<table>
<thead>
<tr>
<th>Field Identity</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% mortality</td>
<td>Egg-to-pupa development, d</td>
</tr>
<tr>
<td>GB</td>
<td>14.0%</td>
<td>15</td>
</tr>
<tr>
<td>O1</td>
<td>26.0%</td>
<td>17</td>
</tr>
<tr>
<td>C1</td>
<td>14.0%</td>
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<tr>
<td>O2</td>
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</tr>
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<td>17</td>
</tr>
<tr>
<td>O5</td>
<td>28.0%</td>
<td>17</td>
</tr>
<tr>
<td>C5</td>
<td>28.0%</td>
<td>17</td>
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</tbody>
</table>

Table 4.1 Mexican bean beetle percent mortality, egg-to-pupa development and pupal weights for Trials 1 and 2 for the field feeding trials.

4.3.2 GREENHOUSE GROWN SOYBEAN

Percent mortality, egg-to-pupa development and pupal weights for the organic and conventional fields for both green house trials are shown in Table 4.2. When using the same varieties as grown in the field there were no significant differences in the data.
between the organic and conventional soybeans in either trial. (Trial 1-mortality: F = 0.03; df = 1; Pr > F = 0.8794; pupal weight: F = 3.31; df = 1; Pr > F = 0.1428; developmental time: F = 1.44; df = 1; Pr > F = 0.2959; Trial 2- mortality: F = 2.30; df = 1; Pr > F = 0.2036; pupal weight: F = 5.42; df = 1; Pr > F = 0.0804; developmental time: F = 0.38; df = 1; Pr > F = 0.5686). Overall means for trial 1 were: mortality – 13% and 13%; pupal weight – 0.02852 g and 0.03170 g; developmental time – 21 d and 20 d, for larvae on organic or conventional grown soybean, respectively. On green bean, larval mortality averaged 16.0%, pupal weight averaged 0.0352 g and developmental time averaged 16 d. Overall means for trial 2 were: mortality – 46% and 65%; pupal weight – 0.02211 g and 0.01965 g; developmental time – 25 d and 26 d, for larvae on organic or conventional soybean, respectively. On green bean, larval mortality averaged 34%, pupal weight averaged 0.0361 and developmental time averaged 17 d. All 10 fields had higher mortality than that of the green beans. With the exception of one field (C2) in the 1st trial, each field showed a lower average pupal weight when compared to green beans. Developmental time was also longer in all 10 fields when compared to green beans. As with the field grown leaves, there were no differences in larval development or mortality between the conventional and organic soybean lines.
### Table 4.2 Mexican bean beetle average percent mortality, egg-to-pupa development and pupal weights for Trials 1 and 2 for the greenhouse feeding trials.

<table>
<thead>
<tr>
<th>Field Identity</th>
<th>% mortality</th>
<th>Egg-to-pupa development, d</th>
<th>Pupal wt, g</th>
<th>% mortality</th>
<th>Egg-to-pupa development, d</th>
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<td>GB</td>
<td>6.0%</td>
<td>16</td>
<td>0.0352</td>
<td>34.0%</td>
<td>17</td>
<td>0.0361</td>
</tr>
<tr>
<td>O1</td>
<td>8.0%</td>
<td>21</td>
<td>0.0279</td>
<td>24.0%</td>
<td>23</td>
<td>0.0232</td>
</tr>
<tr>
<td>C1</td>
<td>8.0%</td>
<td>20</td>
<td>0.0310</td>
<td>60.0%</td>
<td>25</td>
<td>0.0199</td>
</tr>
<tr>
<td>O2</td>
<td>10.0%</td>
<td>20</td>
<td>0.0296</td>
<td>38.0%</td>
<td>25</td>
<td>0.0225</td>
</tr>
<tr>
<td>C2</td>
<td>12.0%</td>
<td>20</td>
<td>0.0368</td>
<td>92.0%</td>
<td>27</td>
<td>0.0140</td>
</tr>
<tr>
<td>O3</td>
<td>12.0%</td>
<td>23</td>
<td>0.0290</td>
<td>54.0%</td>
<td>26</td>
<td>0.0197</td>
</tr>
<tr>
<td>C3</td>
<td>22.0%</td>
<td>21</td>
<td>0.0289</td>
<td>56.0%</td>
<td>26</td>
<td>0.0185</td>
</tr>
<tr>
<td>O4</td>
<td>10.0%</td>
<td>20</td>
<td>0.0298</td>
<td>58.0%</td>
<td>25</td>
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</tr>
<tr>
<td>O5</td>
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<td>20</td>
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<td>48.0%</td>
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</tr>
<tr>
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<td>0.0263</td>
<td>54.0%</td>
<td>26</td>
<td>0.0220</td>
</tr>
<tr>
<td>C5</td>
<td>12.0%</td>
<td>20</td>
<td>0.0328</td>
<td>70.0%</td>
<td>26</td>
<td>0.0202</td>
</tr>
</tbody>
</table>

#### 4.4 DISCUSSION

In Chapter 1 field data showed that BLB occurred in large populations in organic soybean fields. In order to determine any differences in plant susceptibility between organic and conventional soybean, MBB development was directly compared in feeding trials. There were no differences observed in egg-to-adult development, mortality, nor weight gain when MBB were reared on organically and conventionally grown soybean. These results suggest no difference in the susceptibility between organic and conventional soybean due to the differences in the management techniques and soil fertility. Realizing the concern that different varieties were grown in the fields,
greenhouse studies confirmed that there were no differences between larval growth on the various varieties when grown in the same soil.

Longer larval developmental times and higher mortality on soybeans suggests either more resistance, or less susceptibility, in the plant. Comparing development and mortality of larvae on soybean to those on green beans suggests a similar degree of less susceptibility present in both the organic and conventional varieties grown. By confirming this in the greenhouse it suggests that this reduction in susceptibility was not due to the different farming systems in which they were grown. Despite the intensified cultural practices employed, there appears to be no decrease in plant susceptibility unique to the organic fields. This lack of change in susceptibility is something that should be considered in organic farming with concerns for their pest management strategies.

Cultural controls continue to be the starting point for organic farming systems. While many farmers rely entirely on these tactics for their pest management, there is concern over their effectiveness. In this study, susceptibility was neither decreased nor increased due to the extensive use of these controls. The future of organic farming will need to contain more studies on the effectiveness of natural curative controls as well as studies that help to give a more accurate understanding about what is really happening in organic fields. Additional future research done on certified organic farms will reveal whether or not the common ideas within the organic system are in fact flawed and need to be adjusted.
CHAPTER 5

SOYBEAN APHID SAMPLING

5.1 INTRODUCTION

Ohio soybean growers experience many problems with foliage feeding pests in regards to yield and seed quality. A few of the more important defoliators are the bean leaf beetle (BLB), *Certoma trifurcata*, Japanese beetle, *Popillia japonica*, and Mexican bean beetle (MBB), *Epilachna varivestis* (Kogan and Kuhlman, 1982 and Hammond, 1994). More recently farmers have also reported problems with the soybean aphid, *Aphis glycines* Matsumura, that pierces the leaves and sucks the sap out (Ragsdale et al., 2004). While BLB pod feeding creates openings for secondary infections (Obopile and Hammond, 2001), the soybean aphid directly vectors viruses that further reduce soybean yield and seed quality.

Currently, organic farmers in Ohio have begun experiencing severe problems with insects such as the BLB and the soybean aphid. The previous field sampling study demonstrated that there is a significant problem with BLB in organic soybean fields in Ohio (Chapter 1). A follow-up feeding trial showed that there was no difference in susceptibility based on MBB larval development and survivorship when fed organic
soybean compared with conventional soybean (Chapter 2). Compared with conventional growers, organic farmers have no effective and economical curative measures available.

Being a relatively new pest, there is no research on soybean aphid population densities in organic fields. The soybean aphid is a native species in Asia where its primary summer host is soybean, *Glycine max* (Blackman and Easop, 2000). Throughout Asia the soybean aphid is widely spread from Russia to Thailand (Wu et al., 2004). For farmers in China the soybean aphid is considered the most serious threat to soybean productivity (Wang et al., 1996). In the United States, this invasive pest was first discovered in July 2000 in Wisconsin, and by the end of summer in 10 other northern states (Alleman et al., 2002, Venette and Ragsdale, 2004). The spread of soybean aphid south so far has relied mainly on the location of its overwintering host buckthorn, *Rhamnus* spp, found in large areas north of the 41st parallel (Ragsdale et al., 2004). Large soybean aphid populations spreading further north into northern Minnesota, northern Wisconsin, the upper peninsula of Michigan and northern Canada is not likely due to the extreme low winter air temperatures (McCornack et al., 2005). Larger soybean aphid populations have been observed in Illinois, Indiana, Ohio, Iowa, southern Minnesota, southern Wisconsin and the lower peninsula of Michigan. By 2003, Hammond (personal communication) reported finding thousands of aphids per plant across the state of Ohio (Pollock, 2003). It has been reported to have caused over $200 million dollars of crop loss in Minnesota during one season alone (Hodgson, 2004). With this level of damage the soybean aphid is a serious threat to all soybean, both organically and conventionally grown.
For conventional soybeans control has relied mainly on scouting to time insecticide sprays. An action threshold of 250 aphids per plant and 80% infested is a widely approved standard in conventional soybeans, with populations below 250 aphids per plant having little impact on soybean yield (Ragesdale et al. 2006, 2007, Olson and Badibanga, 2005, O’Neal and Johnson, 2004). This threshold provides the grower with a 7-day window to spray for the aphids. However, this threshold does not recognize the difference in damage to various growth stages of the soybean plant. The threshold before the R5 growth stage is 250 aphids per plant, while after R5 the threshold is thought to be nearer to 1000 aphids per plant (NCSRP, 2004). Unnecessary sprays later in the season may adversely affect natural enemies that follow the soybean aphid back to its overwintering host (Yoo et al., 2005). In the future, control of the soybean aphid may involve a number of tactics for conventional farmers, including chemical, cultural, and biological control and host plant resistance, although the primary control tactics as of now are foliar insecticides. Numerous synthetic foliar insecticides are available for the conventional grower, including Warrior® (lambda-cyhalothrin), Mustang Max® (zeta-cypermethrin), Asana® (esfenvalerate), Lorsban® (chlorpyrifos), and Orthene® (acephate), to name a few (Rice et al., 2003). Because of the inability to use synthetic insecticides, effective and economical control tactics in organic soybeans are limited. There has been little research to date in organic soybeans on effective control measures for the soybean aphid.

Despite the numerous studies on this invasive species and its possible management in conventional soybean, little information is available from organic systems. Indeed, organic farmers in Ohio are reporting significant problems with the
soybean aphid (Alan Sundermeier, personal communication). In a preliminary field study conducted at the Hirzel Research Farm in Ohio during the 2005 season economic populations of over 2500 aphids per plant were found in organic soybean fields (Appendix A).

The objective of this study was to determine the population dynamics and density of the soybean aphid in organic soybean fields in Ohio. Thus, a two year study was conducted where organic fields were sampled in two locations in Ohio, northwest Ohio and northeast Ohio.

5.2 MATERIALS AND METHODS

Field sampling for the soybean aphid was conducted in Wood County, located in northwest Ohio, and in Wayne County, located in the northeast during the 2006 and 2007 growing seasons. The same certified organic fields used for BLB sampling as detailed in Chapter 1 were used. Five organic soybean fields were chosen in each county each year by contacting local organic farmers through Ohio State and were labeled O1 to O5, and O6 to O10, in Wood and Wayne Counties, respectively. Sampling began in each of the fields when the soybeans reached the V2 growth stage. The fields were sampled once each week until the aphids declined in September. Sampling was done by walking into the field at least 50 feet to avoid edge effects, and selecting individual plants at random. Each week 20 samples were taken per field. For each plant the aphids were counted up to 100 then estimated above that. The data was averaged for each sample date to get the aphid populations throughout both growing seasons in each of the fields.
At the end of the summer surveys were sent to the various organic farmers that participated in the study. The survey obtained information on plant variety, treatments applied, planting date and harvest date. The information was used to help evaluate aphid data.

5.3 RESULTS

5.3.1 FIELD DATA

Field information obtained from the farmer surveys for each of the sampled fields is given in Tables 5.1 and 5.2 in 2006 and 2007, respectively. The planting dates and harvest dates varied as much as one month. The earliest plantings were May 2\textsuperscript{nd} and May 5\textsuperscript{th} in 2006 and 2007, respectively, and the latest plantings were June 9\textsuperscript{th} and June 8\textsuperscript{th} in 2006 and 2007, respectively. Most fields were planted late May or June, which is late compared to many of the conventional fields in the same areas which were planted in late April or early May (personal observations). Harvest dates ranged from October 2\textsuperscript{nd} to December 1\textsuperscript{st} during the study which was well passed the September harvests in most conventional soybean. In Wayne County organic field O10 was lost during the season due to weeds. As with planting and harvest dates, the organic soybean fields tended to stay greener well into September, whereas most the conventional fields in the areas were at harvest maturity.

There were three varieties being grown, Blue River 2A71 and Ohio FG1 and Iowa 2020. Blue River 2A71 and Iowa 2020 are both in maturity group II, while Ohio FG1 is
in maturity group III (St. Martin, et al., 1996, Blue River Hybrids Organic Seed, 2007 and Committee for Agricultural Development, 2007). While Ohio FG1 and Iowa 2020 are food grade soybeans Blue River 2A71 is feed grade. Despite the difference in grades and varieties there were no trends in the aphid sampling data. When comparing aphid populations there were no trends among the data in regards to planting or harvest dates. In both the 2006 and 2007 seasons there were no organic sprays applied to the crops for aphids during the season by the farmers.

<table>
<thead>
<tr>
<th>Field</th>
<th>Location</th>
<th>Variety</th>
<th>Plant Date</th>
<th>Harvest Date</th>
<th>Maturity Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic 1</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>6/6</td>
<td>11/4</td>
<td>II</td>
</tr>
<tr>
<td>Organic 2</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/31</td>
<td>11/4</td>
<td>II</td>
</tr>
<tr>
<td>Organic 3</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/13</td>
<td>10/15</td>
<td>II</td>
</tr>
<tr>
<td>Organic 4</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/2</td>
<td>10/14</td>
<td>II</td>
</tr>
<tr>
<td>Organic 5</td>
<td>Wood Co</td>
<td>Blue River 2A71</td>
<td>5/25</td>
<td>10/2</td>
<td>II</td>
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<tr>
<td>Organic 6</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>5/30</td>
<td>10/28</td>
<td>III</td>
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<td>Organic 7</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/8</td>
<td>10/29</td>
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<tr>
<td>Organic 8</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/8</td>
<td>10/28</td>
<td>III</td>
</tr>
<tr>
<td>Organic 9</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/9</td>
<td>10/30</td>
<td>III</td>
</tr>
<tr>
<td>Organic 10</td>
<td>Wayne Co</td>
<td>Ohio FG1</td>
<td>6/3</td>
<td>lost to weeds</td>
<td>III</td>
</tr>
</tbody>
</table>

Table 5.1 Field data from farmer surveys in 2006.
Table 5.2 Field data from farmer surveys in 2007.

<table>
<thead>
<tr>
<th>Field</th>
<th>Location</th>
<th>Variety</th>
<th>Plant Date</th>
<th>Harvest Date</th>
<th>Maturity Group</th>
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<td>Wood Co</td>
<td>Iowa 2020</td>
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<td>10/31</td>
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<td>Ohio FG1</td>
<td>6/8</td>
<td>11/1</td>
<td>III</td>
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</table>

5.3.2 APHID POPULATION DENSITIES

Soybean aphids were present in low numbers in all of the fields during 2006 in Wood County (Figure 5.1). The highest average density was 22 aphids per plant, well below the 250 aphids per plant threshold. Aphids did not begin to appear in noticeable densities until late August and were gone by the end of September.
Figure 5.1 Mean number of aphids per plant in each of the five organic fields in Wood County, Ohio in 2006 for sampling periods each week during the growing season.

Similar trends were observed in Wayne County that year (Figure 5.2). The highest average density was 43 aphids per plant, again well below threshold. In Wayne County, aphids did not become noticeable until the beginning of September and were gone by the beginning of October.
Figure 5.2 Mean number of aphids per plant in each of the five organic fields in Wayne County, Ohio in 2006 for sampling periods each week during the growing season.

Aphid populations were higher during 2007 in Wood County (Figure 5.3). The highest mean density was 130 aphids per plant, albeit that this was still well below threshold. Two peaks were observed in the population, one in the first week of August, the second in the last week of September.
Figure 5.3 Mean number of aphids per plant in each of the five organic fields in Wood County, Ohio in 2007 for sampling periods each week during the growing season.

Aphid populations were also larger in Wayne County in 2007 (Figure 5.4) compared with Wood County. In a single field (O6), the peak density was 1100 aphids per plant, which is above threshold. A second field (O7) in Wayne County also exceeded the established threshold. Only a single peak in soybean aphid population was observed, which occurred in mid September when fields were in R3 to R4 growth stages.
5.4 DISCUSSION

Overall trends in the sampling data show that there was a change in the aphid populations between the 2006 and 2007 growing seasons, with 2007 having substantially larger field populations present. For 2006 the aphid populations behaved as predicted for a low year, remaining well below the economic threshold (Hammond and Eisley, 2006). In 2007 despite predictions of high populations, the aphid densities remained lower than expected, which was also observed in conventional fields in Ohio. In early April, Ohio experienced an extreme cold spell that is believed to have been responsible for a reduction in survivorship of the soybean aphid on buckthorn (Hammond and Eisley, 2007a). With a smaller number of soybean aphids entering the fields, populations remained low in early summer. Later in the season however Wayne County aphid
populations exceeded the threshold in two fields, O6 and O7. This aphid activity is attributed to a storm front that passed over the heavy aphid populations in eastern Ontario, Quebec and New York, where aphid densities were much higher, and deposited them in northeast Ohio (Hammond and Eisley, 2007b). Indeed, many of the conventional soybean in extreme northeast experienced soybean outbreaks following this migration.

Results from sampling soybean aphids in organic fields in Ohio indicated that soybean aphid is a concern. For soybean aphids the economic threshold is 250 aphids per plant (NCSRP, 2004). With this guideline some of the fields sampled in 2007 had an aphid problem. This threshold also puts soybean aphid over threshold in the previously mentioned Hirzel Research Farm study in 2005, where aphid densities reached over 2500 aphids per plant. Economically damaging aphid populations were also mentioned by organic farmers in the northwest for the 2005 season (farmer surveys, 2006). It is clear that the soybean aphid is reaching economic threshold in Ohio organic soybean fields.

In order to manage the aphid populations in these organic fields the effects of the cultural practices involved need to be evaluated. One thing that may be having an effect on the soybean aphid is planting dates. With the plants growing and remaining green in the field later in the season, these organic soybeans are exposed to the migrant soybean aphids from other fields much later in the season allowing them to reach higher population numbers. When comparing planting dates, the organic soybeans are usually planted much later than conventional soybeans. Conventional soybeans in Ohio are normally planted between the last week in April and the first week in May to maximize yields (Beuerlein and Dorrance, 2005). In the southern part of the aphid distribution it has
been suggested that the late-planted and double-cropped soybean fields may be the primary source of gynoparae and males (Ragesdale et al., 2004).

This study along with observations from the Hirzel location in 2005 from organic soybeans has shown a 2 year cycle of aphid populations, where 2005 and 2007 had larger populations exceeding threshold and 2006 had lower populations below threshold. In 2005 organic soybean fields had reached 3100 aphids per plant. Although 2007 did not experience this level of aphid populations there were still larger populations than observed in 2006. As long as this 2 year cycle continues, control measures will be more important in odd numbered years than in even numbered years. A recommendation to organic farmers is to consider not planting soybean during these odd numbered years if rotation schedules allow for it. Without the use of insecticides there are no proven effective and economical controls for the soybean aphid in organic fields.
CHAPTER 6

SUMMARY

With reports of pest problems in many organic soybean fields across Ohio, a group of studies were designed to better understand what was happening within these fields. Three main insect pests were studied including the bean leaf beetle (BLB), *Certoma trifurcata*, Mexican bean beetle (MBB), *Epilachna varivestis*, and soybean aphid, *Aphis glycines*. The first study was designed to study BLB populations and dynamics. This was done by taking sweep samples in 10 different certified organic soybean fields during two seasons. Sampling confirmed that there are two generations of BLB adults occurring in organic fields. Data also showed that economic populations are a major concern for organic farmers. Along with sweep samples, data on pod injury was also collected. In these organic soybean fields pod injury levels exceed economic thresholds.

The second study was designed to determine if there was a decrease in plant susceptibility due to the organic growing system that most farmers believe will protect their crops from insect damage. Using MBB bioassays, data was collected comparing larval mortality, average pupal weights and egg-to-pupae developmental time between larvae fed organically and conventionally grown soybean. Data was analyzed using GLM
procedures. Results showed that there was no significant difference in larval mortality, pupal weight, and development time between larvae fed on organic and conventional soybean.

The last study looked at a new, invasive pest in North America, the soybean aphid. In order to get a better understanding of aphid populations and dynamics, sampling was done in 10 different organic soybean fields for two seasons. The data was examined and economic populations were found in organic soybean fields. Although multiple years were sampled, due to weather complications aphids did not follow the 2-year cycle as previously seen. This series of studies showed that there are pests in organic soybean fields despite the benefits of the organic system and also that these particular pests are reaching economic thresholds.
APPENDIX A

HIRZEL RESEARCH FARM 2005

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Five replicates of 4 organic soybean fields each were sampled for aphids in 2005. 10 samples per field were taken and averaged for each field and date.
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