FEEDING BEHAVIOR OF THE CORN WIREFORM, MELANOTUS COMMUNIS, IN FLORIDA SUGARCANE

By

MICHAEL KAROUNOS

A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2018
To my Yiayia Catherine
ACKNOWLEDGMENTS

My family’s undying belief in me and love are paramount. There will be faculty, students, and staff at the Everglades Education and Research Center (EREC) that I will forget to mention because nearly everyone there has helped me in one way or another.

Firstly, my chair, Dr. Ron Cherry, can’t be thanked enough for his guidance, fairness, respect, and help in keeping it sweet, simple, and “staying irie.” I’m grateful to my committee - Dr. Calvin Odero, Dr. Hardev Sandhu, and Dr. Julien Beuzelin - for their guidance and input through this research.

Nikol Havranek helped in collecting and processing weeds for the host plant studies. Erick Roldan and Annie Mills helped set up light traps on station to collect click beetles. Interns from Universidad Zamorano - Pedro Arango, Ivan Alarcon, who arrived just as I broke my leg, and Franklin Casco - helped dig up wireworms and run the experiments.

Kathy Krawchuk guided me in perfecting a poster, distance-learning, and using the Belle Glade EREC library, a powerful tool for every faculty and student.

Anne Hartman, Gary Hartman, who also helped us construct and modify the light traps, and Dorothy Sistrunk showed me hospitality and warmth at EREC, which was representative of the entire community there. For their help acclimating to life in southern Florida, I am so grateful.
# TABLE OF CONTENTS

ACKNOWLEDGMENTS ........................................................................................................... 4

LIST OF TABLES .................................................................................................................... 6

LIST OF FIGURES .................................................................................................................. 7

ABSTRACT .............................................................................................................................. 8

CHAPTER

1 INTRODUCTION .................................................................................................................. 10

2 BIOASSAYS OF MELANOTUS COMMUNIS FEEDING BEHAVIOR IN RELATION TO TEMPERATURE ........................................................................................................... 13

   Materials and Methods ....................................................................................................... 13
   Collection and Storage ......................................................................................................... 13
   Feeding Frequency ............................................................................................................... 14
   Weight Change .................................................................................................................... 16

   Results ................................................................................................................................... 17
   Feeding Frequency ............................................................................................................... 17
   Weight Change .................................................................................................................... 17

   Discussion ............................................................................................................................ 18

3 HOST PLANT PREFERENCE OF MELANOTUS COMMUNIS (COLEOPTERA: ELATERIDAE) IN FLORIDA SUGARCANE ................................................................................ 23

   Materials and Methods ....................................................................................................... 24
   Collection and Storage ......................................................................................................... 24
   Adult Free Choice Tests ....................................................................................................... 25
   Larval Free Choice Tests ..................................................................................................... 27

   Results and Discussion ....................................................................................................... 29
   Adults .................................................................................................................................... 29
   Larvae ................................................................................................................................... 31
   Muck soil test ....................................................................................................................... 31
   Sand soil test ......................................................................................................................... 32

4 SUMMARY ............................................................................................................................. 37

LIST OF REFERENCES .............................................................................................................. 39

BIOGRAPHICAL SKETCH ....................................................................................................... 43
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>Number of times wireworms fed* at different soil temperatures</td>
<td>21</td>
</tr>
<tr>
<td>2-2</td>
<td>Weight change of <em>M. communis</em> at 2 and 4 weeks at different soil temperatures</td>
<td>21</td>
</tr>
<tr>
<td>3-1</td>
<td>Adult <em>M. communis</em> found in free choice tests after exposure to 10 mL whole plant juices for 24 hours</td>
<td>34</td>
</tr>
<tr>
<td>3-2</td>
<td>Adult <em>M. communis</em> grouped by plant type found in free choice tests after exposure to 10 mL whole plant juices for 24 hours</td>
<td>34</td>
</tr>
<tr>
<td>3-3</td>
<td>Larval <em>M. communis</em> found in free choice tests after exposure to 3 grams of chopped roots in muck soil for 48 hours</td>
<td>35</td>
</tr>
<tr>
<td>3-4</td>
<td>Larval <em>M. communis</em> grouped by plant type found in free choice tests after exposure to 3 grams of chopped roots in muck soil for 48 hours</td>
<td>35</td>
</tr>
<tr>
<td>3-5</td>
<td>Larval <em>M. communis</em> found in free choice tests after exposure to 3 grams of chopped roots in sand soil for 48 hours</td>
<td>36</td>
</tr>
<tr>
<td>3-6</td>
<td>Larval <em>M. communis</em> grouped by plant type found in free choice tests after exposure to 3 grams of chopped roots in sand soil for 48 hours</td>
<td>36</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>21</td>
</tr>
<tr>
<td>2-2</td>
<td>22</td>
</tr>
</tbody>
</table>

- 2-1 Correlation of wireworm feeding with soil temperatures. ................................
- 2-2 Correlation of wireworm weight change with soil temperatures. .........................
FEEDING BEHAVIOR OF THE CORN WIREWORM, MELANOTUS COMMUNIS, IN FLORIDA SUGARCANE

By

Michael Karounos

August 2018

Chair: Ron Cherry
Major: Entomology and Nematology

*Melanotus communis* (Gyllenhal) (Coleoptera: Elateridae) is the most important wireworm pest of sugarcane (*Saccharum* spp. hybrid) production in Florida. Wireworms are the subterranean larval stage of click beetles. Basic biology and ecology of wireworms are lacking compared to other agricultural pests.

The feeding behavior of *M. communis* (larvae) at soil temperatures characteristic of Florida sugarcane fields was determined in two parts. In blind tests we showed that small, smooth-skinned potatoes could be used to directly detect even minor feeding by the larvae. Direct and indirect (weight change) measures of larval feeding increased with soil temperatures. Larvae were studied in one-month individual assays. Our data showed that, although less in winter (18 °C soil temperature), feeding damage by the larvae is expected throughout the year in Florida sugarcane. Overall, we observed high variability in larval feeding frequency and weight change even under constant conditions.

Sugarcane fields contain many potential host plants for *M. communis*. Six common weed species along with three sugarcane varieties were used in adult and larval tests determining preference. In free choice tests using modified petri dishes,
muck soil, and whole plant juices, significantly more adults were found in sugarcane, specifically variety CP88-1762 after 24 hours at 24°C. Larval free choice tests were performed using circular pans, muck or sand, and chopped roots. *M. communis* were counted by radial sector after 48 hours. Significantly more larvae were found residing in soils with sugarcane roots than weedy plant roots, specifically variety CP88-1762 in muck and variety CP00-1101 in sand.
CHAPTER 1
INTRODUCTION

Wireworms (Coleoptera: Elateridae), the subterranean larval stage of click beetles, are soil insect pests of economic importance in newly planted sugarcane (Saccharum spp. hybrid) where they attack emerging buds or root primordia (Hall 1990). Sugarcane, along with sweet corn, lettuce, and other winter vegetables, make Palm Beach the most productive agricultural county in Florida (USDA 2012). This production is concentrated, especially the 160,000 hectares of sugarcane, in an area around the southern edge of Lake Okeechobee in southern Florida called the Everglades Agricultural Area (EAA). Soils in southern Florida range from highly organic muck (where most sugarcane is grown) to low organic sand with wireworms found in both these soil types in sugarcane fields (Cherry and Stansly 2008).

The dominant species of wireworm attacking Florida sugarcane is Melanotus communis (Gyllenhal) as shown in field surveys. Across these soil-insect relative abundance studies, M. communis accounted for approximately 75% of all insects collected and 90% of wireworms (Cherry 1988, Cherry and Stansly 2008, Cherry et al. 2017a). They are the wireworms of utmost importance to growers since the earliest years of cultivation in the EAA (Gifford 1964).

M. communis is polyphagous and considered to cause significant agricultural damage in several crops. They are the most common wireworms in corn (Zea mays) fields in the northern central states of the United States, being 85% of wireworms in the region (Riley et al. 1974). Therefore, this species is commonly called the corn wireworm. Wireworms are also important economic pests of potatoes (Solanum tuberosum L.), destroying seeds, boring into roots, crown tissue, and plant stems
(Traugott et al. 2015). They feed on the seed pieces causing weak stands, but major yield losses are due to tunneling into tubers (Jansson and Lecrone 1989). *M. communis* was the dominant species found in potato fields on the Eastern Shore of Virginia, accounting for approximately 80% of individuals collected (Kuhar and Alvarez 2007).

Infestations can be difficult to control. In Florida, researchers estimated *M. communis* remains in the larval or feeding stage nearly two years after which it pupates in spring, takes flight, and oviposits in summer (Cherry and Stansly 2008). These months of flight activity, oviposition, and early-instar larvae are when *M. communis* are less damaging to the vegetatively propagated sugarcane (Larsen et al. 2013). Growers contend with high populations of larger or late instar larvae using other cultural and chemical controls, specifically disking, flooding, and drenching seeds pieces with organochlorides or spreading granulated organophosphates at planting (Hall and Cherry 1993, Larsen et al. 2013).

Disking fields brings larvae out of the roots and stools of sugarcane to the surface where they are exposed to elements, disease, and predation by birds. However, it alone isn’t sufficient to prevent economic damage by wireworms in Florida sugarcane (Hall and Cherry 1993). Flooding for soil insect pest control is common cultural practice in the EAA. Sugarcane is sometimes rotated after ratoon with flooded rice fields, which can be effective at killing larvae (> 40 % mortality) if flooded for more than four weeks and especially at the higher summer temperatures when rice is typically grown in the EAA (Hall and Cherry 1993).

Organochlorides and then organophosphates are chemicals that have been in use for wireworm control since World War II. Presently, two very potent
organophosphates, phorate and ethoprop, are used as prophylactics at planting throughout the EAA. In muck soils their efficacy is reduced compared to sand soils (Cherry and Raid 1999). Most of the sugarcane grown in the EAA is in muck soil. Soil insecticide has always been widespread such that insecticide efficiency research was entomologists’ focus, leaving a dearth of alternative controls and basic biological research on Elateridae far behind other common agricultural pests (Vernon and van Herk 2013). These neglected areas of elaterid feeding biology and ecology are the focus of this thesis work.
Besides directly attacking crops, other studies have reported on various aspects of feeding by *M. communis*. Fenton (1926) reported that adults fed readily on pollen collected from pollen cells in hives of the honey bee. Jansson and LeCrone (1989) recommended oatmeal-cornflake or rolled oat baits for sampling *M. communis* larvae in marl soil in potato fields in southern Florida. Later, Cherry (1993) determined that rolled oats were the most highly attractive food bait to *Conoderus* spp. and *M. communis* larvae in the highly organic muck soils in southern Florida, and that time of bait exposure affected catches (Cherry and Alvarez 1995). Hall (2003), while conducting insecticide efficacy tests reported that storing *M. communis* larvae for long periods may cause a reduction in larval feeding. Despite these earlier studies, there is currently little understanding of the actual feeding behavior of corn wireworms or factors affecting this behavior. As most recently noted by Traugott et al. (2015), our current knowledge of elaterid feeding ecology is rudimentary.

Our objective was to determine characteristics of *M. communis* feeding behavior at varying temperatures found in Florida sugarcane fields where they are a major pest.

**Materials and Methods**

**Collection and Storage**

Larvae were collected by digging under Florida sugarcane stools where they are aggregated (Cherry 2007). After collection, to simulate natural conditions, larvae were stored in moist muck soil where they are most abundant in Florida sugarcane soils (Cherry and Stansly 2008). To simulate natural field conditions, larvae were stored in muck soils at 24 °C which is the mean field temperature under Florida sugarcane stools.
for the 9 month period from August to May selected for test temperatures (Cherry 1991). This is the time when Florida sugarcane is being planted, germinating, and most susceptible to larval attack. Recent temperature data from the University of Florida Everglades Research and Education Center (EREC) weather station (available at http://erec.ifas.ufl.edu/WD/Ewdmain.htm) showed the earlier Cherry (1991) soil temperature data still valid today.

Temperatures were controlled throughout these studies with use of a temperature cabinet (Fisher Scientific Low Temperature Incubator Model 307, Thermo Fisher Scientific, Waltham, MA). The moist muck used in storage and all tests was approximately 50% water as determined in subsampling. Potatoes were provided for food.

**Feeding Frequency**

The objective of this test was to determine the feeding frequency of larvae at the different soil temperatures found in sugarcane fields during August to May. Preliminary tests indicated that it was difficult to accurately measure small feeding bites on sugarcane, larger potatoes, or carrots because of larger size and/or rough surfaces. Hence, we selected Baby Yukon Gold potatoes for all tests. Baby Yukon Gold potatoes are small averaging 40 g per potato and have smooth skins that we believed would make it possible to measure even minor feeding such as small bites in the skin using microscopic examination.

We needed to ensure our accuracy in detecting feeding before starting frequency testing. Hence, we conducted blind tests. Tests were conducted in 760 mL plastic containers with lids. Each container was half-full of moist muck soil with one potato buried in the soil. Potatoes were chosen for smoothness before soil placement to help in
detecting feeding. Thereafter, containers were paired with one larva in one container and not in the other. Each pair of containers was a replicate and containers were stored at 24 °C for 7 days. At the end of 7 days, potatoes were examined for feeding damage by a researcher unaware if a larva had been present or not. Potatoes were examined microscopically for bites or tunneling into the skin. Twenty four replicates were conducted. At conclusion of the blind tests, the researcher never recorded feeding in any of the 24 containers with no insects. The researcher did record feeding 12 times in containers with insects. This feeding frequency at 24 °C and 7 days is consistent with our later observations. Hence, we were accurate in determining feeding frequency and moved on to temperature related testing.

Frequency of laval feeding was tested at three soil temperatures occurring during August to May. Using data from Cherry (1991), we tested at the highest temperature being 28 °C in August, the mean temperature during the 9 months being 24 °C, and the lowest temperature being 18 °C in January. Larval weights averaged 62 mg and were selected so that mean weights were similar at each temperature tested. One larva was held in a container as previously described for one month. Twenty five larvae were tested at each temperature. Every 7 days the potato was removed from the container arena, checked for feeding by identifying tunneling or bites on the skin, and replaced with a new potato. One larva died and four pupated. All the puation occurred at the highest temperature of the study, 28 °C. These five larvae were removed from data analyses.

Chi-square analysis of feeding frequency during the month was conducted at each temperature using an expected 20% frequency for each of the five possibilities (0
to 4 feedings). Linear regression was also made of percent feeding each week (N = 4 weeks) versus temperature (N = 3 temperatures) where x = degrees above 18 °C (lm, R Core Team, 2014).

Weight Change

The previous tests directly measured feeding responses by measuring feeding frequency. The objective of this test was to indirectly measure larval feeding at different temperatures as indicated by weight change. The initial weight of all larvae used in these assays averaged 66 mg. Twenty larvae were selected for each of nine monthly temperatures (Table 2-2). Larvae were selected so that there were no significant differences in mean weights of test groups between temperature treatments.

Larvae were left undisturbed in containers described previously to feed ad libitum on potatoes. The potato was cut into sections weighing approximately 10 g. One section was placed with a larva in muck soil inside each container. Containers were held in the temperature cabinet for 4 weeks at each of the 9 mean monthly soil temperatures. Potatoes were replaced at 2 weeks, and weight measured. Larvae were weighed again at 4 weeks at the test end. Of the 180 larvae used for the test, eight were excluded from analysis due to pupation or death.

Our interest was in determining the direction of weight change being positive, negative or no change during the test. Hence, we determined the percent of larvae in each of the three categories at each temperature and at 2 and 4 weeks. Data from the 9 months were then pooled and the mean frequencies in the three weight change categories at 2 and 4 weeks compared using the LSD test. Actual weight changes (mg) after 4 weeks versus temperature where x = degrees above 18 °C were also compared using linear regression (R Core Team 2014).
Results

Feeding Frequency

At 18 °C, 23 of the 25 larvae (92%) fed only one time or not at all ($\chi^2 = 161.6$, df = 4, $P < 0.001$) (Table 2-1). Within this group, 17 larvae (68%) never fed on their potato and 6 (24% of larvae) fed once. At 24 °C, larvae fed more frequently, this being one time (42% of larvae) and two times (38% of the larvae) ($\chi^2 = 69.3$, df = 4, $P < 0.001$). The larvae fed most frequently at 28 °C being two times (29% of larvae) or three times (48% of larvae) ($\chi^2 = 63.2$, df = 4, $P < 0.001$). Linear regression showed a strong positive correlation between temperature and percent of larvae feeding ($r = 0.85$, $P < 0.001$) (Fig. 2-1). These latter data corroborate the trend noted in Table 2-1 of increasing number of times larvae fed per month with increased temperature as Fig. 2-1 also shows that percent of larvae feeding also increased with temperature.

Weight Change

Larval weight change at mean monthly soil temperatures is shown in Table 2-2. The variability in percent of larvae gaining weight was high, ranging from 35% to 90% from 0 to 2 weeks and 35% to 74% from 2 to 4 weeks. Low percents of weight gain were found at the lowest temperature (18 °C) at both time periods. However, low percents of weight gain were found at higher temperatures such as 27 °C in 2 to 4 weeks. These highly variable data indicate that temperature was not a strong driving force in weight change within the temperature range we tested. Overall, most larvae gained weight during the test at both time periods showing test conditions were appropriate for normal growth expected in larvae. However, the data show large variability in overall growth responses at both time periods in that most larvae gained weight, 10% did not change weight, and 24% to 34% lost weight.
The correlation of weight change with temperature is given in Fig. 2-2. There was a statistically significant positive correlation \((r = 0.19, P = 0.01)\) of weight change with temperature. This trend is expected since generally with insects, weight change would be expected to increase with temperature except at temperature extremes. However, the slope of the regression line is low showing the weight change did increase with temperature, but not greatly as indicated by the small \(r\) value of 0.19.

**Discussion**

Numerous studies have been conducted on wireworm feeding and damage in many agricultural crops. In most of these studies, it is not feeding that is measured, but rather feeding damage to the plant i.e. tunneling, less germination, reduced yield, etc. Other studies have also not directly measured wireworm feeding. Thorpe et al. (1946) in an excellent paper reported on the behavior of wireworms in response to chemical stimulation using bite marks on filter paper. However, the authors acknowledged that the biting was primarily designed to measure palpability of a food substance and not necessarily feeding response. Similarly, Burrage (1963) reported that potatoes were good for feeding studies on the wireworms, *Ctenicera destructor* (Brown) and *Hypolithus bicolor* (Escholtz). He reported several reasons for his selection of potatoes including ease of detecting wireworm damage. Thereafter, wireworm feeding damage was measured as tunneling into the potatoes. However, more subtle feeding than tunneling may have been missed. As noted by Traugott et al. (2015), wireworms probe and bite plant tissue to locate their preferred host plants. In our study, we frequently saw small bites taken out of the potato which would have been missed if we only recorded tunneling as feeding. Burrage (1963) deserves credit for suggesting potatoes for wireworm damage for the two species he studied. In this study, we have expanded his
suggestion by giving the specific methods and accuracy of using Baby Yukon Gold potatoes for measuring even subtle feeding in corn wireworms. We believe this technique should be of value to other researchers interested in variables affecting wireworm feeding.

Our data showing the effect of soil temperature on wireworm feeding were consistent throughout the study. Feeding frequency data showed the number of times wireworms fed per month increased with temperature as did the proportion of wireworms feeding. Similarly, weight change data showed the lowest percentage of wireworms gaining weight was at the lowest temperature of 18 °C and there was a positive correlation of actual weight change (mg) with temperature. These data are consistent with how poikilotherms such as insects generally respond when tested at moderate temperatures such as 18 °C to 28 °C in our study. Interestingly, Fulton (1928) in behavioral experiments determined that *M. communis* larvae showed no marked preference for movement between 17 °C and 29 °C, closely matching our temperature range.

Soil temperature has been shown to be an important factor affecting seasonal vertical migration of wireworms in Kansas (Bryson 1935), the Pacific Northwest (Jones and Shirck 1942), and Missouri (Fisher et al. 1975). Also, Burrage (1963) reported that tunnels in potatoes caused by wireworms increased with rising soil temperatures in Canada. These studies and other similar studies have much cooler soil temperatures than found in our study due to the subtropical climate of southern Florida. Hence, vertical soil migration of corn wireworms caused by soil temperatures does not occur in Florida sugarcane (R.H.C. personal observation) as may occur in cooler climates. Also,
because of our moderate soil temperatures (Cherry 1991), corn wireworm feeding would be expected year-round in Florida sugarcane since some feeding was observed in our tests even at the lowest soil temperature of 18 °C in January.

Lastly, we should note the high variability we observed in feeding and weight changes even under constant conditions in our study. Vernon and van Herk (2013) have reported that pest wireworm species may not cause damage even when present at economic levels. Also, wireworms may engage in apparent “fasting” because wireworms might only spend a fraction of each instar engaged in feeding and the rest of the instar in more quiescent states such as premolting, molting, and mandibular hardening (Furlan 1998). Evans and Gough (1942) stated that sometimes a wireworm would feed appreciably, yet its weight would remain constant or even decrease. In contrast, starving wireworms might remain constant in weight over long periods or even increase in weight for no apparent reason. Researchers have used different methods to try to overcome the high feeding variability observed in many wireworms. For example, wireworms have been preselected to be in their feeding stage for tests (van Herk and Vernon 2013, Vernon et al. 2008). Others have starved wireworms before testing (Cherry and Nuessly 2010, Keaster et al. 1975). And most recently, Cherry at al. (2017b) used high density wireworm populations to guarantee feeding pressure on corn plants for insecticide evaluations. Overall our experience in this study is consistent with the general theme that wireworm feeding and weight change are highly variable even under constant conditions.
Table 2-1. Number of times wireworms fed* at different soil temperatures.

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>68</td>
<td>24</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>13</td>
<td>42</td>
<td>38</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>10</td>
<td>10</td>
<td>29</td>
<td>48</td>
<td>5</td>
</tr>
</tbody>
</table>

*Wireworm feeding was measured once per week for one month.

**χ² = 161.6, df = 4, P < 0.001 at 18 °C.
χ² = 69.3, df = 4, P < 0.001 at 24 °C.
χ² = 63.2, df = 4, P < 0.001 at 28 °C.

Table 2-2. Weight change of M. communis at 2 and 4 weeks at different soil temperatures.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temp (°C)</th>
<th>% of larvae showing weight change from 0 to 2 weeks*</th>
<th>% of larvae showing weight change from 2 to 4 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug</td>
<td>28</td>
<td>85 10 5 53 11 37</td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>27</td>
<td>70 5 25 30 20 50</td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>26</td>
<td>90 0 10 55 15 30</td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>26</td>
<td>79 0 21 68 0 32</td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>23</td>
<td>53 16 32 74 5 21</td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>18</td>
<td>35 20 45 35 15 50</td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td>20</td>
<td>53 11 37 74 0 26</td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>21</td>
<td>84 11 5 37 16 47</td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>23</td>
<td>50 17 33 78 11 11</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>24</td>
<td>66 A 10 B 24 B 56 A 10 C 34 B</td>
<td></td>
</tr>
</tbody>
</table>

* Columns labelled + are % of wireworms that gained weight, - lost, 0 are no weight change.

**Overall means within 0 to 2 weeks or 2 to 4 weeks followed by the same letter are not significantly different (alpha = 0.05) using the Least Significant Difference (LSD) test.

Figure 2-1. Correlation of wireworm feeding with soil temperatures.
Figure 2-2. Correlation of wireworm weight change with soil temperatures.
CHAPTER 3
HOST PLANT PREFERENCE OF MELANOTUS COMMUNIS (COLEOPTERA: ELATERIDAE) IN FLORIDA SUGARCANE

Along with *M. communis*, the most abundant soil insect pest, weedy pests are ubiquitous throughout the 160,469 hectares of sugarcane in the EAA (Cherry 1988, Cherry and Stansly 2008, Cherry et al. 2017a, VanWeelden et al. 2017). Understanding weed-insect interactions is complex especially with systems such as sugarcane, which contain a variety of weeds external to and within the crop system. Weeds can provide alternative resources to arthropod pests, including overwintering sites, oviposition sites, and host plant sites to important soil insects in the EAA (Norris and Kogan 2000).

Wireworms of the genus *Melanotus* have mobility estimated at 1.07 meters in their entire larval stage in cultivated sugarcane in Japan (Arakaki et al. 2010). Wireworms locate preferred host plants through probing and biting of plant tissue, but current knowledge of elaterid feeding ecology remains rudimentary. How plant community composition affects elaterid food choice and how interaction with roots determines fine-tuned decisions of wireworms currently need research (Traugott et al. 2015). Most important to southern Florida farmers, *M. communis* causes serious economic damage to newly planted sugarcane by attacking emerging buds or root primordia during germination (Cherry 1988, Cherry and Hall 1986, Hall 1990). In laboratory and field tests, wireworms’ feeding rhythm depended on temperature, soil moisture, and food availability in the soil (Chaton et al. 2008, Karounos et al. 2018).

Since *M. communis* is polyphagous and has several known host plants throughout the country on which they feed variably in different climates, determining movement and orientation behaviors of *M. communis* with respect to sugarcane and
weedy hosts is the first step towards identifying direct trophic interactions in the root systems of the EAA. Our objective was to determine if adult and larval *M. communis* showed any preference to find and reside in soils containing different host plant material in laboratory assays simulating natural conditions of sugarcane fields of the EAA.

**Materials and Methods**

**Collection and Storage**

Adults were collected using ultraviolet light traps adjacent sugarcane fields at the UF/IFAS EREC in Belle Glade, Florida. Traps ran nightly from the last week of May through the second week of July 2017. This is the period of maximum flight activity of *M. communis* in southern Florida (Cherry and Hall 1986). Adults were stored at 24 °C in moist muck with sliced carrots for food. Muck for adult storage was collected in sugarcane fields at the EREC and sterilized to reduce broad mite (*Polyphagotarsonemus latus*) infestations, however mites weren’t an observed issue with wireworms. As described in the previous studies, larvae were collected by digging under Florida sugarcane stools where they are aggregated (Cherry 2007). After collection, to simulate natural conditions, larvae were stored in moist muck soil where they are most abundant (Cherry and Stansly 2008). Larvae were stored at 24 °C with sliced carrots provided for food. The moist muck used in storage and all tests was approximately 50% water as determined by subsampling and drying. Wireworms have variable feeding behavior and spend most of their larval instars in a non-feeding state so past researchers have preselected larvae to be in their feeding stage for tests sometimes by starving larvae before testing (Cherry and Nuessly 2010, Keaster et al. 1975, van Herk and Vernon 2007, van Herk and Vernon 2013). At two weeks prior to testing, larvae were starved to induce searching and probing behavior.
For both adult and larval experiments, treatments consisting of plant material placed in soil were tested plus one control treatment without plant material. The same species of treatment plants were used in the larval study as with the adult study. The nine treatments with plants were three sugarcane varieties, three grassy weed species, and three broadleaf weed species. The sugarcane cultivars – CP96-1252, CP88-1762, and CP00-1101 – are the most, third-most, and fifth-most grown in the Everglades Agricultural Area, respectively (VanWeelden et al. 2017). Sugarcane used in this test was harvested on station at the EREC. The broadleaf and grassy weed species selected for this study are frequently found in sugarcane fields in southern Florida and are major weed pests for sugarcane growers (Odero et al. 2013, Odero and Dusky 2013). Weedy host species were dug up individually and whole by shovel and hand within fields at the EREC. The grassy weeds used were columbus grass (Sorghum almum Parodi), fall panicum (Panicum dichotomiflorum Michx.), and elephant grass (Pennisetum purpureum Schumach.). The broadleaf weeds used were spiny amaranth (Amaranthus spinosus L.), common ragweed (Ambrosia artemisiifolia L.), and purslane (Portulaca oleracea L.).

For tests and storage, all muck and sandy soils were collected by shovel and buckets from fields in Palm Beach County. Muck came from fields at the EREC in Belle Glade while sand came from a sandy field in Loxahatchee, FL.

**Adult Free Choice Tests**

Adult *M. communis* are both terrestrial and subterranean insects, so both the roots and shoots may serve as cues for the insect’s behavior. Therefore, plants were collected whole for the adult study. To reduce variability between replicates of this experiment, frozen juice was utilized in the adult tests. Plants were rinsed thoroughly
and shredded into pulp. Roughly 900 g of pulpy plant material was pressed for juice in a hydraulic press with a maximum pressure of 700 kPa (Codistil Dedini, Piracicaba, Brazil). Juice was aliquoted into 30 mL graduated jars and frozen at -4 °C immediately. Plant juices were removed from the freezer and thawed at room temperature before each replicate.

Tests on choice of adult *M. communis* were conducted in a temperature-controlled insectary at 26 °C. A 14 hour light and 10 hour dark cycle was maintained using two 40 watt 3000 K fluorescent bulbs. Tests were conducted inside cubic aluminum screen mesh cages with 61 cm sides (Bioquip 1450D, Rancho Dominguez, CA, USA). One replicate consisted of one cage with ten dishes spaced uniformly in a randomized radial pattern at the base of the metal mesh cages. Fisherbrand 100 x 15 mm polystyrene petri dishes were modified to create the treatments (Thermo Fisher Scientific, Waltham, MA, USA). The top of the lid was painted black, because adults hide in litter during daylight. The base was modified giving 2 cm entrance sections on four sides to allow adults entry into the residences without climbing or flying. Into the petri dish, 60 mL of freshly collected, filtered with a 4.75 mm sieve, and homogenized muck soil was added (Thermo Fisher Scientific, Waltham, MA, USA). At most 10 mL of the treatment could be absorbed into the muck soil in each base without significant pooling or spilling out of the residence. Therefore, 10 mL of plant juice was used in each treatment. After the plant juice was poured directly onto the muck soil, a wooden craft stick with the treatment number was placed ontop.

Into the center of the circle of ten equally spaced dishes, 40 active adults were released. The mesh cage was subsequently closed and left in the insectary for 24 hours
before being examined. Contents of each dish were collected in whole by emptying the contents into labelled freezer-proof plastic bags and frozen immediately, including adults, labels, and muck with treatment juice. Any adults found outside the dishes on cage walls, floor, or anywhere outside of the modified dishes, were collected as null choice, counted, sexed, and removed from statistical analysis. There were 8 replicates utilizing 40 adults each.

After completing all 8 replicates, adults were separated from the other contents of the dish, thawed, and dissected using a stereomicroscope. Total adults were counted for each of the 10 treatments. They were sexed using genitalia, identifying the male aedeagus and parameres contrasting with the female conspicuous tacklike bursal spines, spermathecal duct, and diverticulum as described and illustrated by Quate and Thompson (1967). Whether or not the females were gravid was also noted (unpublished). Data analyses comparing means of total adults, male adults, and female adults counted between treatments and also pooled by plant treatment type (sugarcane, grassy weed, broadleaf weed) were performed with Fisher’s LSD, alpha = 0.05, using R (LSD.test, R Core Team 2014).

**Larval Free Choice Tests**

Tests with larvae were conducted in a temperature-controlled insectary at 26°C. A 14 hour light and 10 hour dark cycle, using two 40 watt 3000 K fluorescent bulbs, was controlled by timers in the insectary because the soil-dwelling larvae are also sensitive to light (Falconer 1945, van Herk and Vernon 2007). Chopped roots were used because elaterid larvae are soil-dwelling and only interact with root systems of host plants. The plants were collected whole, washed, and clipped at the roots which were frozen to
ensure availability over the duration of the experiment. Before each test, roots were thawed, weighed, and chopped as needed.

Circular aluminum pans, 35 cm in diameter by 4 cm deep, were used for these larval tests (Nordic Ware, St. Louis Park, MN). A modified version of bioassays utilizing a circular pan for observing larval orientation and feeding behavior was employed (Apablaza et al. 1977, van Herk and Vernon 2007). Larval response varies with humidity and soil moisture, so these were controlled with moistened and homogenized soil covered by a pane of glass over the testing arena (Wigglesworth 1950, Villani and Wright 1990).

The ten treatments were spaced out evenly in a randomized radial pattern in the pan. Each radial sector measured 11 cm of the circumference and 10 cm of radius of the pan. There was no room for gaps between treatment areas. The remaining center area where the insects were initially placed in the pan measuring 15 cm in diameter was the non-treatment or no choice zone. Maximum three grams of chopped root material could be used without interfering with the neighboring treatments, meaning there was enough space in the soil between adjacent treatments so that root materials were not touching. A treatment comprised roots that were thawed, washed, chopped, homogenized, weighed to 3 g, then finally buried in the soil along the outer rim of the pan. The control treatment was moist soil only. The treatments were placed adjacent to the rim of the pan and a small wooden marker was placed on the soil surface to mark their locations.

Each replicate was 20 larvae placed into the center of the circular pan. Larval weight was measured before and after each replicate. Larvae used in this test were an
initial mean weight of 72 mg. Larvae were given more time than the adults (48 versus 24 hours) to move freely in the pan arena and orient because of their limited movement ability through the soil medium as compared to the adults in open air spaces. The free choice larval tests comprised eight replicates of larval free choice using muck soil and eight replicates of larval free choice using sand totalling 16 replicates.

At tests’ conclusions, the samples were collected sectionally. Each section was partitioned, immediately dug up, and placed into temporary labelled containers. Roots were separated, and soil was carefully sifted for larvae. Larvae found within treatments in the 10-cm band around the outside of the pan were counted and weighed. Any larvae found in the 15-cm diameter center of the pan and therefore outside the treatment sections were considered null choice, counted, weighed, and removed from statistical analysis. Data were analysed by comparing means of larvae counted between treatments and pooled by treatment type (sugarcane, grassy weed, broadleaf weed) were performed with Fisher’s LSD, alpha = 0.05, using R (LSD.test, R Core Team 2014).

Results and Discussion

Adults

Adult responded to the treatments. In this test 85% or 257 adults responded to the treatment dishes with 15% or 44 total adults non-responsive to the treatments but alive within the cage. Adults were found in sugarcane CP88-1762 significantly more than all other treatments with 7.0 adults per treatment (Table 3-1). The water control was chosen an intermediate amount, with 3.5 adults per treatment. Only ragweed and CP88-1762 separated from the water control statistically, with 7.0 and 0.9 adults per
treatment respectively. Adults found in treatments throughout the replicates ranged from 0 to 11 adults per treatment.

When treatments were grouped by plant type (three of each), adults showed a preference of sugarcane over broadleaf plant juices. Nearly twice as many total adults were found in cane as broadleaf, 102 versus 55 respectively. However, grassy plants were an intermediate choice, with a total of 72 adults, and not statistically different. In sugarcane treatments an average of 4.3 adults were found, compared to 3.0 for grassy weeds, and 2.3 for broadleaf weeds (Table 3-2).

These adults can’t be easily sexed before experimentation. At experiment conclusion, we confirmed that 89% of the adults were male and 11% were female. This is consistent with light-trapped flight activity of *M. communis* as previously reported by Cherry and Hall (1986). For males, 42, 32, and 26% found in sugarcane, grassy weeds, and broadleaf weed treatments respectively. For females, 62, 27, and 12% were found in cane, grassy weed, and broadleaf weed treatments respectively. These data show that both sexes were responding similarly to the treatments of plant juices.

There were only 6% or 19 adults found dead outside of treatments. Adult response was highly variable with conditions in the cage. Attempts at greenhouse tests proved very prone to adult desiccation, despite daily misting. Greenhouse tests with jars of muck and juice were too difficult for the adults to enter. Full floors of muck retained moisture but led to very low response by the adults to the juice, as the majority of insects were found on cage walls where muck interfaced with air, rather than in the central areas with plant juice and labels. Therefore, the final form of these tests with
open air cages inside insectary or indoor conditions, petri dishes, and only enough muck to retain the adequate plant material, proved successful.

To create a reproducible and standardized test between plants with different sizes and rates of growth, only plant juice was used in adult tests. Time was limited as adults only live and fly for a relatively short period of one to two months creating a strong logistical limitation on live whole plant tests. In future research, having large numbers of whole plants roughly the same size at the same short time period that adults are flying would be ideal and could be more representative of field conditions.

**Larvae**

**Muck soil test**

Larvae found in the no-choice zone of the muck test comprised 27% of the test or 43 larvae. Most larvae (73%) were found in the treatment areas of the pans. Larval choice in muck soil mirrored the adult preference numerically for CP88-1762, with 2.5 larvae per treatment, however it was not significant (Table 3-3). A mean of 1.1 larvae per sector were found in the water control, which did not differ statistically with any other treatment sectors in muck. Across all replicates the number of larvae found in any treatment ranged from 0 to 5.

When grouped by plant type, larval choice also mirrored adults in that they chose sugarcane numerically over both weedy plant types. Three of the four most chosen treatments were sugarcane with 2.5, 2.1, and 1.6 larvae found per treatment in CP88-1762, CP00-1101, and CP88-1252 respectively. However, unlike the adults which did not choose sugarcane significantly more than grass, the larvae chose the sugarcane variety treatments significantly more than both the grass and broadleaf weeds (Table 3-4).
The response of larvae to the chopped root treatments was variable in muck soil and not significantly different from the control across all treatments. The primary sources for larval probing and orientation are likely carbon dioxide related to their food sources (Bernklau and Bjostad 1998, Doane et al. 1975). The first larval tests were conducted in muck soil, which is 80% organic matter consisting of complex microbial communities, which could explain the variability of larval choice in muck. Host choice of soil-dwelling arthropods by root volatiles is a noted phenomenon and how the soil composition and accompanying microbes may affect the root volatiles is unknown (Gfeller et al. 2013, Wenke et al. 2010). For example, elaterid larvae are strongly repelled by many fungi (Kabaluk and Ericsson 2007). Notably in our tests varying levels of sporulation were observable only in muck soils from certain plant juice and root treatments (researcher observation).

**Sand soil test**

In the first two tests with muck, CP88-1762 was most chosen among the adults and larvae. Larvae tested in sand soils significantly chose CP00-1101 over all the other treatments (Table 3-5). The selection of a different cultivar may have resulted from interactions with the soil, unknown variables relating to the source sugarcane, or other unknowns. Fewer larvae (0.6 per) were found in the control than any of the treatments across both tests. However, this control was not significantly less than any of the treatments in the sand test except CP00-1101 and spiny amaranth, with 3.8 and 2.0 larvae per treatment, respectively. The number of larvae found in treatments across all replicates ranged from 0 to 7.

When grouped by plant type, larvae tested in sand chose sugarcane significantly more than grassy and broadleaf weeds (Table 3-6). This mirrored the previous muck
test and aligns with the adult test, further reinforcing that *Melonotus communis* prefers sugarcane over grassy and broadleaf weeds when selecting from host plant materials.

These laboratory assays showed *M. communis* collected from sugarcane fields prefer sugarcane plant material to weedy plant materials in natural soils in the EAA. Future testing could use a smaller cross-section of soil, such that wireworm movements could be tracked easily, especially using dual-paned glass arenas as demonstrated by Doane et al. (1975). This would give data on minute movements of these insects which are relatively immobile in the soil.
Table 3-1. Adult *M. communis* found in free choice tests after exposure to 10 mL whole plant juices for 24 hours.

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Mean*</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Weeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purslane</td>
<td>3.8 b</td>
<td>2.9</td>
<td>0-9</td>
</tr>
<tr>
<td>Spiny amaranth</td>
<td>2.3 bc</td>
<td>1.9</td>
<td>0-5</td>
</tr>
<tr>
<td>Ragweed</td>
<td>0.9 c</td>
<td>1.1</td>
<td>0-3</td>
</tr>
<tr>
<td>Grassy Weeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elephantgrass</td>
<td>3.5 b</td>
<td>2.1</td>
<td>1-7</td>
</tr>
<tr>
<td>Sorghum grass</td>
<td>2.4 bc</td>
<td>1.9</td>
<td>0-5</td>
</tr>
<tr>
<td>Fall panicum</td>
<td>3.1 bc</td>
<td>1.4</td>
<td>1-6</td>
</tr>
<tr>
<td>Sugarcane Varieties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP88-1762</td>
<td>7.0 a</td>
<td>3.7</td>
<td>2-11</td>
</tr>
<tr>
<td>CP96-1252</td>
<td>3.0 bc</td>
<td>2.5</td>
<td>0-7</td>
</tr>
<tr>
<td>CP00-1101</td>
<td>2.8 bc</td>
<td>1.8</td>
<td>1-6</td>
</tr>
<tr>
<td>Control</td>
<td>3.5 b</td>
<td>2.1</td>
<td>2-8</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (alpha = 0.05) using LSD

Table 3-2. Adult *M. communis* grouped by plant type found in free choice tests after exposure to 10 mL whole plant juices for 24 hours.

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Mean*</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Weeds</td>
<td>2.3 b</td>
<td>2.4</td>
<td>0-9</td>
</tr>
<tr>
<td>Grassy Weeds</td>
<td>3.0 ab</td>
<td>1.8</td>
<td>0-7</td>
</tr>
<tr>
<td>Sugarcane Varieties</td>
<td>4.3 a</td>
<td>3.3</td>
<td>0-11</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (alpha = 0.05) using LSD
Table 3-3. Larval *M. communis* found in free choice tests after exposure to 3 grams of chopped roots in muck soil for 48 hours.

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Mean*</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Weeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purslane</td>
<td>0.8 b</td>
<td>0.5</td>
<td>0-1</td>
</tr>
<tr>
<td>Spiny amaranth</td>
<td>1.6 ab</td>
<td>1.8</td>
<td>0-5</td>
</tr>
<tr>
<td>Ragweed</td>
<td>1.1 ab</td>
<td>1.2</td>
<td>0-3</td>
</tr>
<tr>
<td>Grassy Weeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elephantgrass</td>
<td>1.3 ab</td>
<td>1.8</td>
<td>0-5</td>
</tr>
<tr>
<td>Sorghum grass</td>
<td>0.8 b</td>
<td>1.0</td>
<td>0-3</td>
</tr>
<tr>
<td>Fall panicum</td>
<td>1.8 ab</td>
<td>1.2</td>
<td>0-4</td>
</tr>
<tr>
<td>Sugarcane Varieties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP88-1762</td>
<td>2.5 a</td>
<td>1.2</td>
<td>1-4</td>
</tr>
<tr>
<td>CP96-1252</td>
<td>1.6 ab</td>
<td>1.6</td>
<td>0-4</td>
</tr>
<tr>
<td>CP00-1101</td>
<td>2.1 ab</td>
<td>1.7</td>
<td>0-4</td>
</tr>
<tr>
<td>Control</td>
<td>1.1 ab</td>
<td>0.8</td>
<td>0-2</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (alpha = 0.05) using LSD

Table 3-4. Larval *M. communis* grouped by plant type found in free choice tests after exposure to 3 grams of chopped roots in muck soil for 48 hours.

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Mean*</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Weeds</td>
<td>1.2 b</td>
<td>1.3</td>
<td>0-5</td>
</tr>
<tr>
<td>Grassy Weeds</td>
<td>1.3 b</td>
<td>1.4</td>
<td>0-5</td>
</tr>
<tr>
<td>Sugarcane Varieties</td>
<td>2.1 a</td>
<td>1.5</td>
<td>0-4</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (alpha = 0.05) using LSD
Table 3-5. Larval *M. communis* found in free choice tests after exposure to 3 grams of chopped roots in sand soil for 48 hours.

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Mean*</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Weeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purslane</td>
<td>1.0 bc</td>
<td>1.1</td>
<td>0-3</td>
</tr>
<tr>
<td>Spiny amaranth</td>
<td>2.0 b</td>
<td>1.4</td>
<td>0-4</td>
</tr>
<tr>
<td>Ragweed</td>
<td>1.1 bc</td>
<td>1.1</td>
<td>0-2</td>
</tr>
<tr>
<td>Grassy Weeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elephantgrass</td>
<td>1.3 bc</td>
<td>1.0</td>
<td>0-3</td>
</tr>
<tr>
<td>Sorghum grass</td>
<td>0.9 bc</td>
<td>0.6</td>
<td>0-2</td>
</tr>
<tr>
<td>Fall panicum</td>
<td>0.9 bc</td>
<td>0.6</td>
<td>0-2</td>
</tr>
<tr>
<td>Sugarcane Varieties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP88-1762</td>
<td>1.8 bc</td>
<td>0.9</td>
<td>1-3</td>
</tr>
<tr>
<td>CP96-1252</td>
<td>1.5 bc</td>
<td>0.9</td>
<td>0-3</td>
</tr>
<tr>
<td>CP00-1101</td>
<td>3.8 a</td>
<td>1.8</td>
<td>2-7</td>
</tr>
<tr>
<td>Control</td>
<td>0.6 c</td>
<td>0.7</td>
<td>0-2</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (alpha = 0.05) using LSD

Table 3-6. Larval *M. communis* grouped by plant type found in free choice tests after exposure to 3 grams of chopped roots in sand soil for 48 hours.

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Mean*</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Weeds</td>
<td>1.4 b</td>
<td>1.2</td>
<td>0-4</td>
</tr>
<tr>
<td>Grassy Weeds</td>
<td>1.0 b</td>
<td>0.8</td>
<td>0-3</td>
</tr>
<tr>
<td>Sugarcane Varieties</td>
<td>2.3 a</td>
<td>1.6</td>
<td>0-7</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (alpha = 0.05) using LSD
CHAPTER 4
SUMMARY

In the first studies of larval feeding behavior at different temperatures, our data showing the effect of soil temperature on larvae feeding were consistent. Feeding frequency increased with temperature as did the proportion of larvae feeding. Similarly, weight change data showed the lowest percentage of larvae gaining weight at the lowest temperature of 18 °C and a positive correlation of actual weight change (mg) with temperature. These data were consistent with how poikilotherms such as insects generally respond when tested at moderate temperatures. *M. communis* feeding would be expected year-round in Florida sugarcane since some feeding was observed in our tests even at the lowest soil temperature of 18 °C in January.

In all tests in the larval feeding behavior studies we observed high variability even under constant conditions. The positive correlation with weight change was significant but very low and did not explain the variability in the data. This is consistent with literature on larval feeding and attributable to their long-life cycle and larval stage with extended non-feeding periods. We detailed many techniques researchers used to circumvent the issue and it remains a challenge for future research into alternative control methods like attractive or targeted baits.

Why *M. communis* prefer sugarcane plant hosts over other commonly found weeds in the EAA deserves further study. Higher sucrose content of these plants could be attractive and is known to elicit responses to plant extracts (Thorpe et al. 1946). It could be a long-term adaptation to sugarcane as a food source that is perennial and provides a sustainable host for the duration of a larva’s multi-year life stage.
The moisture absorption or retention ability of each root type varies greatly as well as the overall morphology of the mass of chopped roots used in this test.Although the roots were chopped into the same size and shaped pieces, they absorbed water from the soil differently. Some of the broadleaf roots, for example A. spinosa, which larvae responded to in the sand tests, were much less lignous and more sponge-like than the grasses and cane. Determining if larvae orient first towards moisture and temperature in these roots or are using only olfactory and taste is difficult. A future direction could be researching larval behavior on several of these weedy hosts over long periods and assess larval health and survival. This would require using live plants rather than chopped pieces or solutions of plants, which would also be more informative of larval behavior in nature.

M. communis prefer sugarcane plant material in soils over weedy plant materials in soils. Other common crops attracting wireworms and used as experimental trap crops include corn, pea, lentil, canola, barely, and wheat (Adhikari and Reddy 2017). Future research comparing the attractiveness of sugarcane to these other potential hosts deserves study. Our experience is specific to M. communis in the EAA. The soils, plant material, and insects were all collected in in the EAA. For many decades the predominant ecosystem was commercial sugarcane fields with relatively low pressure from soil predators. How M. communis adapts, orients towards, and develops preferences for host plants in other regions merits further research.
LIST OF REFERENCES


Bernklau, E. and L. Bjostad. 1998. Reinvestigation of host location by western corn rootworm larvae (Coleoptera: Chrysomelidae): CO2 is the only volatile attractant. J. Econ. Entomol. 91: 1331-1340.


Fulton, B. 1928. Some temperature relations of Melanotus (Coleoptera, Elateridae). J. Econ. Entomol. 21: 889-897


BIOGRAPHICAL SKETCH

Michael Karounos was born in Durham, North Carolina to an engineer and a doctor,Chrisi and Dennis. They settled in Lexington, Kentucky where Michael and his younger brother, Christopher, were raised. In 2006, Michael completed his Bachelor of Science in political science and computer science from the University of Kentucky. He worked in Dr. Lisa Cassis’ nutritional sciences laboratory at the University of Kentucky as a technician for four years and co-authored six publications. In 2013 he moved to Palm Beach County, Florida and shortly thereafter began working in plant breeding with Robert Beiriger as a biological scientist at the Everglades Research and Education Center. In 2014 he was hired by Dr. Ron Cherry as a biological scientist in the Entomology and Nematology Department. While working he co-authored five publications, entered the graduate program in September of 2015, and completed his Master of Science in August of 2018.