Seasonal occurrence of Phyllophaga species and biological studies of Phyllophage ephilida (Say) on sweet potato, Ipomoea batatas (L) Lam, in Louisiana

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A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College
In partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Entomology

By
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ABSTRACT

The biology of *Phyllophaga ephilida* (Say) was studied in Louisiana with both laboratory and field experiments from 1998 through 2003. The seasonal occurrence of common adult *Phyllophaga* species in sweet potato growing areas was surveyed with blacklight traps. *P. ephilida* and *P. crinita* (Burmeister) were the most common species at all locations. The attractiveness of seven methyl esters of L-isoleucine and L-valine blends to *P. ephilida* males was evaluated in sweet potato fields in 1999 and 2000. The 100% methyl ester of L-isoleucine was significantly more attractive than all other blend ratios that were tested. The life cycle of *P. ephilida* in southern Louisiana was determined to be univoltine. In the laboratory, the effect of three physical factors (soil moisture, organic matter content and soil texture) on the depth of adult *Phyllophaga* diurnal burrowing was investigated. Soil moisture and organic matter content had a significant effect on the depth of burrowing, while soil texture did not affect burrowing depth. The feeding preference of adult *P. ephilida* for the foliage of eight tree species was determined in the laboratory with choice tests. Beetles exhibited a significant preference for pecan, oak and elm, with maple, and sweetgum being less preferred. Magnolia and slash pine were not fed upon at all. Pheromone traps were operated in grower fields in 2001 and 2002. Data on percent white grub injury to sweet potatoes in these fields, the proximity of traps to tree lines, and the harvest date of the crop were collected. An analysis of covariance revealed that percent white grub damaged roots was significantly affected by mean adult *P. ephilida* captured in pheromone traps, whereas proximity to tree lines and harvest date were not significant. The year effect was significant as were interactions between year and tree line, year and harvest date, and year and mean adult
capture. The covariance model had an r-square of 0.29. A linear polynomial regression model predicting white grub damage as a function of trap catch, tree line proximity and harvest date was developed. The model had an r-square of 0.18 and estimates a damage threshold (5% root damage) of one to two $P. \text{ephilida}$ per week in pheromone traps. The pheromone trap provides sweet potato growers with a practical means to monitor adult activity and thereby determine the peak flight period and assess the need for an insecticide application timed to coincide with beetle oviposition.
CHAPTER I

INTRODUCTION
Sweet potato, *Ipomoea batatas* (L.) Lam, is cultivated throughout the tropical, subtropical, and warmer zones of the temperate regions of the world (Chalfant et al. 1990). Sweet potato plays an important role in the nutrition of rural people throughout much of the tropical and subtropical world. In 1994, United Nations Food and Agriculture Organization figures indicated that 9,380,000 hectares of sweet potatoes were harvested in the world, corresponding to a production of about 124 million metric tons, with a yield of 13,256 kg/ha (Anonymous 1995). During the same year, the United States sweet potato production was about 593,000 metric tons (Anonymous 1995). Sweet potato ranked ninth among world crops in 1994 (Yamaguchi and Rubatsky 1997).

Crop losses due to insect pests of sweet potato are substantial in most parts of the world. Stiling (1985) estimated the percentage root loss due to insects to be 8.9% on sweet potato worldwide. Many insects feed on the sweet potato root, reducing its marketable yield. On a worldwide basis the white grub complex (Scarabaeidae) is among the most injurious pests of sweet potato (Yamaguchi and Rubatsky 1997, Janssen and Raman 1991, Chalfant et al. 1990, Subramanian et al. 1977). Although several species of white grub (*Phyllophaga* spp.) can cause significant damage to cultivated crops in the US, the biology of only a limited number of *Phyllophaga* species has been studied. *Phyllophaga* spend most of their life below the soil surface. The adult life span is relatively brief, lasting only a few weeks. *Phyllophaga ephilida* (Say) has been implicated as the primary white grub pest of sweet potato in south central Louisiana (Rolston and Barlow 1980). Adults feed on the foliage of deciduous trees adjacent to sweet potato fields, while larvae gouge shallow channels on the surface of roots, rendering them unmarketable.
An insect pest management program for white grubs in the southern US sweet potato production system has not been developed. In Louisiana, virtually 100% of the acreage is treated with a prophylactic application of a preplant, soil incorporated insecticide for white grubs and other soil insect pests (Dr. R. N. Story\textsuperscript{1} personal communication). Practical sampling methods for assessing white grub populations do not exist and damage thresholds have not been developed. Insecticide test results over the years indicate that in any given year, a grower in Louisiana has only a 5 to 10% chance of sustaining economic damage (> 5% root damage) from all soil insect pests. The probability of sustaining white grub damage is generally less than 5% (Dr. R. N. Story\textsuperscript{1} personal communication). In spite of these low probabilities, growers apply insecticides because of the inability to identify fields that are at risk to soil insect damage. The development of a management system for white grubs has the potential to reduce the use of prophylactic treatments. The basic principles of IPM dictate that an insect pest should be present before a control measure is applied, and that the pest should be present in sufficient numbers to warrant control. These precepts can only be met when we have knowledge of the life cycle and basic biology of the insect, a sampling method that is practical for crop consultants and growers to use for assessing insect population levels, and a damage threshold. There is a paucity of information on which species of \emph{Phyllophaga} occur in the sweet potato production areas of Louisiana. Little is known about their biology. A determination of the common species of \emph{Phyllophaga} that occur in these areas and knowledge of their relative abundance and temporal occurrence is needed. Information on the life cycle duration and feeding habits of adult \emph{P. ephilida} are lacking. The development of a practical sampling

\textsuperscript{1} R. N. Story, Entomology Department, LSU AgCenter, Baton Rouge, LA.
method is an indispensable prerequisite to the creation of a white grub management system. The relationship between insect pest population density as estimated with a sampling method and root damage needs to be quantified in order to develop a damage threshold. The overall objective of this research is to improve our understanding of the white grub problem in sweet potato production in Louisiana and make progress towards the development of an integrated pest management system for this pest.

The specific objectives are:

1) determine which *Phyllophaga* species are common in the sweet potato production areas in Louisiana and quantify the seasonal activity period of the adults,

2) improve our understanding of the biology of *P. ephilida*,
   a) determine the duration of its life cycle,
   b) evaluate the feeding preference of adults,
   c) examine the effect of soil properties on the burrowing of adults,

3) develop a practical sampling method that can be used by growers and crop consultants to monitor adult *P. ephilida* populations, and

4) develop a damage threshold for the sampling method.

**Literature Cited**


Biology of *Phyllophaga* Species

A) Adults

Several names (May beetles, June beetles, Junebugs) have been given to the adults of the scarab beetles in the genus *Phyllophaga* Harris (Metcalf and Metcalf 1993, Crocker et al. 1995). These appellations derive from the season of their reproductive flight. The period of flight activity varies with the latitude and to some extent with the altitude of the geographical site (Luginbill and Painter 1953). However, the Greek etymology of the name *Phyllophaga* is reflective of their dietary habits. The root name *Phyll* means ‘leaf’, while the verb *Phaga* means ‘to eat’. This specific naming is due to the habit of these insects to feed on the leaves of trees, notably hardwood trees (Woodruff and Beck 1989). The color of adult *Phyllophaga* species ranges from brown (*P. crinita* Burmeister) to almost black (*P. anxia* LeConte). They are usually more than 25 mm long (Watschke et al. 1995, Potter 1998). There is also a species variation in the abundance of body pubescence (Potter 1998). The body of *P. ephilida* (Say) is slightly cylindrical, elongate and rufotestaceous (Luginbill and Painter 1953). Characteristic teeth-like structures on the outer margins of the tibia of the front legs enable the oval bodied, stout beetles to burrow into the soil (Potter 1998). The head and thorax are commonly darker than the remaining parts of the body. The body surface of *P. ephilida* will moderately reflect light, giving it a shiny appearance. The criteria for identification of adults are often general and superficial: size, coloration, feeding habits and periods of adult activity (Potter 1998). *Phyllophaga* species are similar to each other in morphology and are difficult to distinguish (Dillon and Dillon 1961). Woodruff and Beck (1989) stated that external morphology alone cannot be used to distinguish between species. The structure of the internal genitalia of males is the diagnostic feature used to identify species (Luginbill and Painter 1953, King 1984, Woodruff and Beck 1989, Crocker et al. 1995). Potter (1998) indicates that males have larger antennal clubs than females, with the last antennal segment being longer in the male than in the female. The tooth-like structures on the
claws are longer in the females than in the males (Luginbill and Painter 1953). In some species males and females can be distinguished by differences in the width of the segments of the lower surface of the abdomen (Crocker et al. 1995). With *P. ephilida*, the antenna is ten segmented, and the clypeus is largely emarginate with the border reflexed (Luginbill and Painter 1953).

**B) Larvae**

A variety of names are applied to immature *Phyllophaga* species: white grubs, grubworms or simply worms (Watschke et al. 1995). The larval stage has three instars. All *Phyllophaga* larvae are characterized by a broad Y-shaped anus with conspicuous rows of bristles (palidia) around the anal slit (Watschke et al. 1995). The stem of the Y-shaped anus tends to be shorter than the arms (Tashiro 1987). The lower anal lip tends to have a cleft or groove (Richter 1966). Larval structures sometimes utilized in their identification are the epipharynx, the rastral characters (Ritcher 1966, Riley 1988) and the mouthparts (Crocker et al. 1995). In general, the grubs of *Phyllophaga* are identified painstakingly (Flanders et al. 2000). At later stages of larval development, white grubs are usually described as having a robust C-shaped body of white or cream color with three pairs of legs. The legs are four segmented, as well as are the antennae (Richter 1966). Two setae are present on each claw. The last antennal segment is characterized by the presence of a single, dorsal sensory spot with an ellipsoidal shape (Richter 1966). At their late stage of larval development, the contents of the intestinal tract are visible through the skin in the posterior portion of the abdomen (Tashiro 1987). The head is light tan, smooth and shiny (Davis 1916, Shurtleff et al. 1987). The rastral pattern is like a 'fingerprint' on the underside of the last segment of the abdomen before the anus (Potter 1998). This rastral pattern is made of an arrangement of small hairs and spines (Liskey 1995). Tashiro (1987) noted that with *Phyllophaga*, the arrangement of pali and spines within the palidia is parallel.
C) Taxonomy

The white grub complex belongs to the Coleoptera, superfamily Scarabaeoidea, family Scarabaeidae, subfamily Melolonthinae, and the tribes Melolonthini and Plectrini (Ritcher 1966). The genus *Phyllophaga* is in the tribe *Melolonthini* (Ritcher 1966). *Phyllophaga* were referred to in earlier literature as the genus *Lachnosterna* (Tashiro 1987). Woodruff and Beck (1989) indicate that in the past there was confusion and disagreement among taxonomists about the validity of some homonyms. The early synonymies of *Phyllophaga* are presented by King (1984). King (1984) recorded the use of different names by several authors in diverse regions. Thus, the genus *Phyllophaga* was *Cnernarachis* in the Antilles and *Schizonycha* in Botswana and Sudan. In India, entomologists designated *Aserica* and *Holotrichia* for *Phyllophaga*, the Chileans utilized *Phytoloema*, *Sericoides*, *Shizochelus* and the Philippinos used *Leucopholis* to indicate *Phyllophaga*. *Amphimallon* had been the name of *Phyllophaga* in North America and Europe. In Australia, the genus *Phyllophaga* was *Dermolepida* or *Lepidiota*. Other names such as *Hypopholis* and *Schizonycha* in South Africa, *Costelytra* in New Zealand, and *Melolontha* in Europe are synonymous with *Phyllophaga*. Before 1916, *P. ephilida* (Say) and *P. forbesi* Glasgow were considered one species (Woodruff and Beck 1989). Woodruff and Beck (1989) suggest that the subspecies *virilis* from Reinhard’s collection made in Louisiana and a few other southern states in 1939 may need clarification. *P. ephilida* subspecies *virilis* Reinhard is presented as differing from *P. ephilida ephilida* primarily on the basis of phallic characters (Luginbill and Painter 1953). In subspecies *virilis* males, parameres are barely excised in the caudal area, while in subspecies *ephilida*, the excisions are generally very deep. The female genitalia tend to be similar in the two subspecies (Luginbill and Painter 1953). In Florida, Woodruff and Beck (1989) indicated that the two subspecies of *P. ephilida* have shown variations in the genitalia that overlap. Riley (1988) considers the possibility of two distinct species of *P. ephilida*
after he collected both forms (subspecies *ephilida* and *virilis*) in three different locations in Louisiana.

D) Oviposition Behavior and Life Cycle

Adults are clumsy flyers. Male *Phyllophaga* locate females for mating purposes during their nocturnal flight. A pheromone is probably released by the female during the process of male attraction and during the copulation stage as reported for many beetles (Haynes and Potter 1995). It has been suggested that the mating site is on foliage where the female is feeding (Richter 1958, Woodruff and Beck 1989). It may be that this copulatory behavior is linked to the release of volatile compounds during the leaf feeding process. An adult female can survive up to twenty one days without food (Chalfant et al. 1990). Females will oviposit in the vicinity of their food source (McLeod et al. 1986).

Oviposition occurs about nine to ten days after mating (Tashiro 1987). The pearly white oval eggs are one to two millimeters long and after absorption of moisture can enlarge and take on a round shape (Fattig 1944, Tashiro 1987, Watschke et al. 1995). Oviposition occurs in the soil at a depth of seven to fifteen centimeters with eggs placed in groups of five to ten (Fattig 1944). One to several eggs are placed in the center of tiny, slightly elongated earthen cells held loosely together with a glutinous fluid secreted by the female (Davis 1916, Richter 1958, Tashiro 1987, Potter 1998). The construction of a semipermanent earthen cell might have evolved as a mechanism to reduce egg mortality from soil organisms and drought (Villani and Wright 1990). This is thought to be achieved by insulating the microclimate of the eggs within the earthen cell (Villani and Wright 1990). Villani and Wright (1990) indicate that scarab grubs are slow to move through the soil profile. Larvae tend to curl (C-shape), thereby reducing moisture loss from evaporation (Villani and Wright 1990). Egg stage duration is variable within and between species (Riley 1988). Soil temperature, moisture, and specific rearing conditions can influence the duration of each stage (Riley 1988). In some species, eggs overwinter in the earthen cells (Davis 1916, Chalfant et al. 1990). A mated female *Phyllophaga* will lay
20 to 50 eggs during her lifetime (Tashiro 1987, Watschke et al. 1995, Potter 1998). Fattig (1944) indicated that on average fifty eggs are laid over a period of one to three weeks in about eight to ten days after mating. Satisfactory soil moisture levels where eggs are deposited are indispensable for larval development (Watschke et al. 1995). Potter (1998) reported that *Phyllophaga* egg hatch begins after 3-4 weeks. Fattig (1944) reported a hatching period of fifteen to twenty days for *P. ephilida*. The eggs of *P. tristis* (Fabricius) and *P. micans* (Knoch) have the same hatching period as *P. ephilida*, while for *P. fusca* (Frolich), *P. hirticula* (Knoch), *P. ulkei* (Smith) and *P. luctuosa* (Horn) this period extends to 20-25 days. In Georgia, Fattig (1944) reported that the larvae of *P. tristis, P. micans*, and *P. ephilida* have a two-year life cycle with two molts during the first year. These species overwinter as third-instar larvae. The young larvae feed on subterranean plant parts, rootlets and decaying vegetation before tunneling deeper in the soil during the fall (Fattig 1944, Landis and Haas 1992). At this late stage, the third larval instar has typically a protuberant sclerotized head capsule. Crocker et al. (1995) reported the presence of a prepupal phase at the end of the third larval stage. Larvae stop feeding and empty their stomach, releasing an exuvium to the posterior. Ultimately, the rear end of their abdomen shrinks and the body becomes ready for pupation. Pupation occurs in an earthen cell structure (Potter 1998). Some species will spend winter as a mature third instar larva toward the end of their development. Their pupation and metamorphosis to adulthood is brief. *P. ephilida* overwinters as a full-grown larva that will pupate in June and emerge as an imago in July (Richter 1958). Other species pupate in the fall and emerge in the spring (Crocker et al. 1995). The depth of pupation in the soil profile varies with species. *P. ephilida* pupates at a depth of 8.4 cm (Richter 1958). In laboratory settings, Rodriguez del-Bosque (1996) found the duration of pupation for *P. crinita* averaged 21.5 days. Richter (1958) found that the average length of the pupal stage for *P. ephilida* was 19.5 days. Adult emergence is dependent on latitude and on species. A life cycle of one, two, three, or four years can occur among the *Phyllophaga* (Landis and
Haas 1992, Potter 1998). After emergence, beetles hide in the soil during the day (Woodruff and Beck 1989). Davis (1916) concluded that many *Phyllophaga* in the northern parts of the Nearctic have a generation time of three years compared to an annual generation in the southern US. In Kentucky, *P. ephilida* has a two-year cycle, overwintering as a third instar and pupating in June before adult emergence the same season (Tashiro 1987). In south central Louisiana, *P. ephilida* is stated to be a univoltine species (Rolston and Barlow 1980). This assertion was based on an observation by Rolston and Barlow (1980) that only third instar larvae were found in sweet potato fields in the fall. Rodrigues del-Bosque (1996) reported that *P. crinita* has one generation per year in North Tamaulipas, Mexico. In the Texas High Plains *P. crinita* were recorded as pupae in mid-June, as adults predominantly in early July, and as larvae from August through May (Teetes et al. 1976). In Central America, June beetle distribution is a function of several climatic factors. June beetles are limited by the amount of rainfall, the rainfall distribution and the elevation above sea level (King 1984). Moron (2000) recorded 12 new species of *Phyllophaga* in southern and eastern Mexico, mainly in pine-oak forests (1345-3160 m). A few species were located in cloud forests (1470-1550 m) or in deciduous tropical forests (700-900 m). In rare Mexican micro-habitats, Moron (1999) found 4 new *Phyllophaga* species in small numbers with a restricted season of flight. Out of the 152 species of *Phyllophaga* native to the U.S. and Canada, the greatest numbers are present in the eastern part of the US (Tashiro 1987). Riley (1988) indicated that the genus *Phyllophaga* is one of the most abundant and diverse of the scarab fauna. Luginbill and Painter (1953) claimed there to be more than 90 species of June beetles in the southeastern US. A 1945 listing from Loding (quoted by Flanders et al. 2000) put the number of *Phyllophaga* species at 63 for Alabama. Riley (1988) reported 62 species in Louisiana.
Pest Damage and Plant Hosts

Adult *Phyllophaga* beetles feed on the leaves of deciduous trees (Fattig 1944). At the turn of the century in North Carolina, Butler (1888) observed damage caused by adult *L. hirticula* (Knoch) on native poplars and oaks. Riley (1891) reported that adult *Lachnosterna* Hope, mainly *L. hirticula* and *L. fusca*, feed on the foliage of swamp oak and chestnut. More recently, Fattig (1944) reported damage due to the genus *Phyllophaga* on deciduous trees in Wisconsin. It is likely that the beetle’s defoliation is overlooked by growers. A multitude of *Phyllophaga* species are angiosperm feeders, while a smaller number of them feed on gymnosperms (Luginbill and Painter 1953). Adult *Phyllophaga* attack leaves of trees and shrubs of diverse plant species (Crocker et al. 1995). Adult *Phyllophaga* have been observed feeding on foliage of pecan and willow oak (McLeod et al. 1986, Chalfant et al. 1990), as well as apple, poplar, birch, hickory, oak, willow, small grains and soybeans (Shurtleff et al. 1987).

*Phyllophaga* larvae are damaging to root crops. Perkins (1892) found a sizeable number of larvae of *Lachnosterna* species in the sandy grassland at the Vermont Experimental Station. At variable depths extending from 7.6 cm to 0.3 m below the sod, the larvae were actively feeding. Feeding is done below ground on roots of seedlings during the spring (Landis and Haas 1992). When the grubs are found within the upper topsoil layer (ca 5 cm) they are considered to be in a feeding site around the rhizosphere of root grasses (Tashiro 1987). Damage from *Phyllophaga* in root crops results from larvae gouging out shallow to wide channels on the surface of tubers and roots (Schalk et al. 1991). Feeding can occur on agronomically important plants such as corn, potatoes, sugar cane, sorghum, forage grasses and others. Largely due to the cryptic nature of the larvae, detection of injury from species of the white grub complex (*Phyllophaga*) is problematic. The abundance of the pest is difficult to assess, and the grub damage is difficult to detect. The cavital excavations on sweet potato roots in the field can lower the root quality, and cause significant losses to sweet potato growers. Milner et al. (1992)
reported a 6% yield loss of groundnuts with a density of one larva per three meters of row. In Mexico, Moron et al. (1996) observed that mean densities of 14 to 25 larvae per square meter produce serious damage to the roots of sugar cane and caused 43% shoot death. Wightman and Amin (1988) observed that white grubs are able to bore holes in developing groundnuts, while in the Indian region of Tamil Nadu (Nilgiris) *Phyllophaga* accounts for most of the potato tuber losses (Subramanian et al. 1977). It is the damage from the third larval instar that is the most severe (Tashiro 1987). In Central America, surveys by King (1984) have revealed severe damage on young maize and sorghum from white grubs. Leaf wilting, initial purpling, diminished vigor and sometimes plant death are characteristic of injuries on those crops (King 1984). Metcalf and Metcalf (1993) reported that white grubs have been observed feeding on strawberries, roses, nursery stocks and almost all cultivated crops. Aragon and Moron (2000) found damage to the roots of *Amaranthus hypocondriacus* L. and *Limonium sinuatum* (L.) from *Phyllophaga* larvae in Mexico. Villalobos (1992) reported that recent surveys in Mexican cornfields have shown losses in production of 0.4 to 1.3 tonnes/ha/year due to larvae of *Phyllophaga*. *P. crinita* was the dominant species found in this study and the most injurious pest (reduction of up to 1000 kg/ha in the region of Tamaulipas). King (1985) reported that the destruction of young corn seedlings in Costa Rica was caused by larvae of *P. menetriesii* (Blanchard) and *P. vicini* (Moser), and that the yield reduction was greater in weedy lands of old cassava plantations. Teetes (1973) reported *Phyllophaga* feeding on grain sorghum, resulting in stunting, lodging and death of seedlings. On sugar cane, under diverse agroecosystems, several authors have described *Phyllophaga* damage. Damage has been reported in Texas (Huffman et al. 1976) and in the Indian Gujarat region concomitantly with cereal damage (Desai and Patel 1965). In Australia, white grubs account for up to 75% of insect damage on sugar cane (Samuels and Pinnock 1990). Milner (1992) found the most serious insect pests of cultivated sugar cane in Australia to be the white grubs of *Antitrogus* spp. and *Lepidiota* spp. Gruner (1973)
quoted several authors reporting sugar cane damage by *Phyllophaga* in the Caribbean islands. Pal and Doval (1970) listed *Phyllophaga* as a serious pest of local Indian crops (kharif crops) and also noted damage on sweet potato, tomato, lucern, castor, papaya, mint and *Eucalyptus* species in Rajasthan. A two-year sampling in the neighboring areas of Tepic, Nayarit in Mexico revealed a white grub complex formed by 60 scarab beetle species that feed on the rhizosphere of wild grasses, corn and sugar cane. The scarab species belonged to the following genera: *Phyllophaga*, *Diplotaxis*, *Macrodactylus*, *Isonychus*, *Anomala*, *Cyclocephala*, *Dyscinetus*, *Oxygryllus*, *Ligyrus* and *Golofa* (Moron et al. 1996).

**Phyllophaga Concern in Louisiana**

Sixty-two *Phyllophaga* species representing two subgenera are reported to occur in Louisiana (Riley 1988). Climatic conditions in Louisiana favor shorter generation times of June beetles than in more northerly latitudes. In the 1950’s, heavy infestations of this pest on sweet potato were observed in East Baton Rouge and Avoyelles parishes (Floyd 1955). Sweet potato provides a substantial contribution to the total agricultural output of the State (79.8 million dollars) with 8679 hectares statewide in 2002 (Anonymous 2002). Research in the 1950's focused on insecticide control (Floyd 1955, Kantack and Floyd 1956). Kantack and Floyd (1956) explored new methods of application of insecticides for *Phyllophaga* control in Louisiana. Control relied heavily on organochlorine insecticides that are no longer used. More recently, *Phyllophaga* research has focused on both chemical control (Rolston and Barlow 1980, Story et al. 1998, Hammond and Story 1999, Hammond et al. 2000, Story et al. 2003) and host plant resistance (Rolston et al. 1981, Story et al. 1999, Story et al. 2000, Story and Hammond 2001). Rolston and Barlow (1980) tested the use of preplant insecticides. Rolston et al. (1981) noted that insect injury to sweet potato roots was not effectively controlled by the available insecticides. Rolston et al. (1981) reported that some sweet potato breeding lines could provide a moderate level of resistance for white grubs, especially when an insecticide was used. In south
Central Louisiana, *P. ephilida* larvae damage sweet potato roots (Rolston and Barlow 1980, Riley 1988).

**Control Measures**

Several cultural control methods have been applied to white grubs. Crop rotation has been perceived as a good method for reducing grub populations and damage (Chamberlin and Callenbach 1943). In southern Wisconsin, cultural techniques such as renovation were reported as being effective in reducing white grub populations in permanent pastures (Ahlgren et al. 1944). Renovation is the establishment of dry-weather legumes in permanent bluegrass pastures without plowing and without destroying the grasses (Burcalow et al. 1940). Renovation as a method of pasture improvement can include the use of dry-weather legumes such as alfalfa (*Medicago sativa*), sweet clover (*Melilotus alba* and *M. officinalis*), and red clover (*Trifolium pratense*) in thinned pasture sods without plowing (Fuelleman and Graber 1938). Cultural operations such as disk ing and bottom plowing have been successful against white grubs after they have been noticed around the root system of plants (Forschler and Gardner 1990). Sweet potato lines were evaluated for resistance to soil insect pests in the 1980s, with little success (Cuthbert and Davis 1970, Jones et al. 1987, Shalk et al. 1991). More recently, sweet potato lines have been screened for resistance to white grubs in field trials in Louisiana (Story et al. 1999, Story et al. 2000, Story and Hammond 2001). Moderate to high levels of resistance were not detected among the lines screened.

Adult trapping has been used as a technique to reduce pest populations (Cantelo et al. 1974). June beetles have been attracted by physical means (blacklight trap) as well as with pheromones. Butler (1888) suggested the use of a lantern suspended over a pan filled with water, and the application of a thin layer of coal-oil on tree tops. Similarly, Riley (1891) reported the use of lamps floating in a tub of water with a surface layer of kerosene. Moron and Salvatori (1998) suggested in their sampling of *P. triticophaga*, a new species of Melolonthidae in Brazil, that the unequal sex ratio of 16.8 males to 1
female can be explained by females being less attracted by lights. Capinera (2001) concluded that light traps used to monitor *Phyllophaga* populations collect a greater proportion of males than females. The first pheromone of a June beetle was identified as a phenol from a New Zealand species (Leal 1998). Recently, a sex pheromone composed of methyl ester L-valine and methyl ester L-isoleucine was isolated from the cranberry white grub, *P. anxia* (Leal 1998, Zhang et al. 1997). Synthetic pheromones play a valuable function as a monitoring tool in pest management systems.

Many natural enemies of *Phyllophaga* have been identified. *Phyllophaga* pupae have been found to be parasitized by bombyliid larvae (*Exoprosopa fasciata* Macq.) in the soils of Wisconsin at an average depth of 39.3 cm (Richter and Fluke 1935). The bombyliid larvae were found feeding on the ventral part of white grub pupae during the summer, with devastating results on the grubs. Fattig (1944) included the bombyliid *Sparnopolius fulvus* Wied. in a list of parasites of *Phyllophaga*. In Georgia, *Pyrgota undata* Wied and *P. Perkins* Harris were recorded as parasites of adult *Phyllophaga*. Perkins (1892) observed in Vermont several underground larvae of *Lachnosterna* infected by mites from the genus *Tyroglyphus* or *Rhizoglyphus*. Some larvae were also infected by *Cordyceps ravenellii* Ber. Perkins (1892) proposed the idea of using red ants to fight grubs. In Puerto Rico, Wolcott (1950) observed predation by larvae of *Pyrochorus luminorus* Illiger, a predaceous subterranean wireworm, on May beetle grubs. Wolcott (1950) reported two tachinid fly parasites, *Crytomeigenia aurifacies* Walton and *Eutrixoides jonesii* Walton, and several species of Scoliid wasps as parasites of white grubs. A more recent survey in southern Quebec (Canada) of the natural enemies of *P. anxia* revealed sixteen species of parasitic and predatory insects (Lim et al. 1981). A survey of viruses and pathogenic microorganisms of white grubs identified one bacterium, *Bacillus cereus* Fr. & Fr., and four fungal species, *Metarhizium anisopliae* Metsch Sorok., *Beauveria bassiana* Bals. Vuill., *Fusarium* sp., and *Penicillium* sp. parasitic on larvae. Jackson and Glare (1992) reported on a rickettsia attacking scarabs
that belonged to the genus *Rickettsia*. A *popillia* strain, *Ricketsiella popilliae* is responsible for the “blue disease” of several scarab beetles including *P. ephilida*. Jackson and Glare (1992) noted that very few rickettsia have been studied. Poprawski and Yule (1990) reported the first indovirus (PaIV) infection in North American scarabaeid beetles. The same authors (Poprawski and Yule 1992) found an endemic infection of a eugregarine protozoan, *Actinocephalus*, on *Phyllophaga* in the Canadian province of Quebec. Recent advances in microbiology and insect pathology have made the utilization of pathogenic microorganisms for grub control plausible. Poprawski and Yule (1991) reported in a bioassay study a high pathogenicity of *Hyphomycetes* to *Phyllophaga* grubs. *Beauveria bassiana* (Balsamo) Vuillemin and *Metarhizium anisopliae* (Metschnikoff) were the most potent preparations. Insect pathogenic microorganisms can be “an integral part of applied insect control” (Tanada 1959).

Biopesticides have been evaluated in field trials (Kard et al. 1988, Milner et al. 1992, Klein 1995). Milner (1992) documented the potency of Australian mycoinsecticidal isolates of *Metarhizium anisopliae* (FI 147, FI 153) on *Lepidiota frenchi* and *L. consobrina*. The isolate FI 114 was effective on *Antitrogus parvulus*. The advantages of biopesticides include a reduced environmental impact, but the method still presents some shortcomings difficult to overcome. Among the problems raised with biocontrol are the sensitivity of the microorganism to atmospheric conditions and the determination of their specificity to the pest species. The response of the grub in different larval instars can vary. The efficacy of the microbe depends upon the successful dispersal of a high number of spores to create an epizootic infection on the target pest. Dulmage et al. (1971), in their attempt to standardize the bioassay for formulations of *Bacillus thuringiensis* (Berliner), indicated that some biotic and climatic factors such as temperature, humidity, and the age and vigor of the insect affects the insect response to a biopesticide. Recent studies are trying to circumvent these limitations, using combined applications of biopesticides with other products (Gruner 1973, Schalk et al. 1993, Thurston et al. 1993, Rajagopalan et al.)

The use of insecticides has remained the main means of *Phyllophaga* control due to its effectiveness (Day 1958). The negative effect of insecticides includes the potential long term effects on beneficial organisms, possible contamination of the underground water table, and an adverse impact on human health. In sweet potato, three soil insecticides are labeled for control of soil insects: ethoprop (Mocap), chlorpyrifos (Lorsban) and bifenthrin (Capture). Mocap is an organophosphate soil insecticide with nematicidal propeties (Anonymous 1985). It has been widely used on many crops (Santo et al. 1985). Lorsban (chlorpyrifos) has been used against a wide range of soil organisms on several crops (Kucharek and Edmonton 1991, Giles and Obrycki 1997). Capture is a pyrethroid soil insecticide that has a broad spectrum of activity. The efficacy of these registered compounds and other products for control of white grubs has been studied in Louisiana in recent years (Story et al. 1998, Hammond and Story 1999, Hammond et al. 2000, Story et al. 2003).

Jackson (1992) noted that white grubs are an impediment to agricultural development in many parts of the world. The capacity of white grubs to occupy diverse agricultural environments and the lack of effective insecticides for their control are the primary reasons for their status as serious pests. Research teams have been formed in several countries (USA, France, Australia, New Zealand) during the last sixty years in an attempt to address these problems. These efforts have helped advance our understanding of *Phyllophaga*. However, our understanding of the biology of *Phyllophaga* lags behind the level of knowledge we have for many other agricultural pests.
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CHAPTER III

SEASONAL OCCURRENCE OF COMMON ADULT *PHYLLOPHAGA* SPECIES ASSOCIATED WITH SWEET POTATO PRODUCTION AREAS OF LOUISIANA
Introduction

Many *Phyllophaga* species inhabit agricultural and forest agroecosystems (Potter 1998). Several species can cause significant damage to cultivated crops (Teetes 1973, Moron et al. 1996). In spite of this, the biology of only a limited number of *Phyllophaga* species has been studied. *Phyllophaga* are a major pest of sweet potatoes in Louisiana, where the larvae feed on the roots and render them unmarketable (Rolston and Barlow 1980). Adult *Phyllophaga* are nocturnal, feed on the foliage of trees adjacent to crop production fields, and deposit eggs in cultivated land. Little is known about which *Phyllophaga* species occur in the sweet potato production areas of Louisiana.

*Phyllophaga* larvae can be sampled from the soil with wet or dry sieving or soil washing and flotation (Southwood 1978). However, the immature stages of only 17 of the 62 *Phyllophaga* species known to occur in Louisiana have been described (Riley 1988, Richter 1966), making larval identifications problematic. *Phyllophaga* adults are highly attractive to lights and can be readily collected with blacklight traps (Riley 1988). Riley (1988) surveyed the adult *Phyllophaga* of Louisiana with blacklight traps and identified the species that occur in the state. However, this survey did not include sweet potato production areas, and did not determine the seasonal occurrence or relative abundance of these species. Knowledge of the common *Phyllophaga* occurring in the sweet potato production areas in Louisiana would help identify the species that warrant further biological studies. Information on their seasonal occurrence could improve the timing of insecticide applications that are directed at their control.

The purpose of this study was to determine the common *Phyllophaga* species associated with sweet potato production areas in Louisiana and to quantify their temporal
occurrence and relative abundance.

Materials and Methods

A) Trap sites

A survey of adult *Phyllophaga* was conducted at three locations in Louisiana with blacklight traps. A single trap was operated (8:00 pm-12:00 am) at each location from mid-May to mid-August. The sites of collection were: LSU AgCenter Sweet Potato Research Center (Franklin Parish), Fontenot Farms (St Landry Parish) and LSU AgCenter Burden Research Plantation (East Baton Rouge Parish). The Sweet Potato Research Center is located in the northeastern part of Louisiana and borders the northeastern sweet potato growing area. The trap was located in an area of about ten hectares of contiguous open flat agricultural land devoted to sweet potato production and surrounded by deciduous and coniferous trees. The blacklight trap was located along the edge of a sweet potato field adjacent to a wooded area. The trap was operated from 18 May to 3 August, 1998, and 4 May to 27 July, 2001. Fontenot Farms is located in central Louisiana and is in a commercial sweet potato growing area of south central Louisiana. The site for the blacklight trap was along the edge of a sweet potato field of about one hectare bordered to the north, to the east, and the west by deciduous and coniferous trees and to the south by a road and a horse stable. Few habitations were in the vicinity. The trap was operated from 8 June to 17 August, 1999, and from 7 June to 8 August, 2000. The Burden Research Plantation is located in the southern part of Louisiana and is mostly farmland of about five hectares planted with vegetable crops. The area is surrounded by woods, ponds (1/10 of the total area) and urban dwellings. The blacklight trap was on the edge of strawberry plots about 200 m from a wooded area.
The trap was operated from 20 May to 12 August, 1998, and from 24 May to 2 August, 1999.

**B) Sampling**

Blacklight traps (Universal Collecting System # 2851 A, BioQuip® Products, Inc, Gardena, CA) consisted of a plastic bucket with a 50% ethylene glycol solution serving as a killing agent, a blacklight bulb mounted on a tripod above the bucket with an A. C. power supply at Burden and a battery power supply at the other locations. Nabli et al. (1999) determined that blacklight and blacklight blue were the most efficient lights for attracting *Phyllophaga* in a study comparing different light sources. The blacklight and the blacklight blue lamps have their main wavelength peaks in the ultraviolet range at approximately 365 nm (Nabli et al. 1999). A weekly collection of the insects was made at all locations by sieving the insects from the liquid and transferring them into labeled jars. Insects collected from the blacklight were kept in 70% ethyl alcohol. Later, the insects were removed from the jars and counted. The genitalia were dissected and a species determination made by the author. Identified adults were sent to Dr. E. R. Woodruff for confirmation (Entomology Department, University of Florida, Gainsville, FL). Dissections and identifications were made using a binocular microscope (Wild MSA). All voucher specimens were deposited in the LSU Entomology Museum, Baton Rouge, LA.

**Results and Discussion**

The three most abundant species captured at the Sweet Potato Research Center (Chase) were *P. crinita*, *P. hirtiventris*, and *P. profunda* (Table 3.1). In 1998, *P. crinita* was the most numerous species collected (58.4%) with a mean weekly catch of 31 individuals. This species was active from mid-May through late July, with a peak catch
on 22 June (Figure 3.1). *P. hirtiventris* and *P. profunda* were captured in almost equal numbers, with each species representing approximately 20% of the total (Table 3.1). *P. hirtiventris* was most active on 15 June while *P. profunda* was most active on 1 June. In 2001, *P. crinita* was the most numerous species collected (63.5%) with a mean weekly catch of 37.1 individuals. It was active from 11 May through 20 July, with a maximum catch on 15 June. *P. hirtiventris* (19.4%) and *P. profunda* (6.9%) were also common with maximum flight activity dates of 29 June and 25 May, respectively (Figure 3.2).

The three most abundant species captured at Fontenot Farms were *P. ephilida*, *P. crinita*, and *P. bipartita* (Table 3.1). In 1999, *P. ephilida* was the most numerous species collected (66.3%) with a mean weekly catch of 59 individuals. It was active from early June through early August, with a peak catch on 22 June (Figure 3.3). *P. crinita* was the second most numerous (29.8%). *P. crinita* was most active from 8 June to 3 August, with a maximum catch on 29 June. *P. bipartita* (3.7%) was the third most common and was active during the month of June. In 2000, *P. ephilida* was the most numerous species collected (54.6%) with a mean weekly catch of 36.1 individuals. It was active from early June through early August, with a maximum catch on 7 June (Figure 3.4). *P. crinita* (39.8%) was the second most numerous species collected with a maximum catch on 28 June. It was active from early June to early August. *P. bipartita* (5.4%) was less common with a maximum catch on 7 June, although it was active during most of June.

The three most abundant species captured at Burden were *P. ephilida*, *P. crinita*, and *P. latifrons* (Table 3.1). In 1998, *P. crinita* (48.5%) was the most numerous species collected with a mean weekly catch of 75.2 individuals. It was active from 20 May through 12 August with a maximum catch on 1 July (Figure 3.5). *P. ephilida* (46.8%)
was the second most numerous species collected with a maximum catch on 17 June. It was active from the end of May through early August. *P. latifrons* (4.6%) was the third most common species. It was active from the end of May through 15 July. In 1999, *P. ephilida* (48.3%) was the most numerous species collected with a mean of 43.9 individuals. It was active from May to early August, with a maximum catch on 28 June (Figure 3.6). *P. crinita* (41.3%) was the second most numerous species collected with a mean of 38.0 individuals. It was active from the end of May through early August with a maximum peak on 14 June. *P. latifrons* (9.7%) was the third most numerous species collected. It was active from June through August, with a maximum catch on 14 June.

*P. ephilida* and *P. crinita* were the most numerous species captured in the blacklight traps across the three sampled locations. They were most active in June and July. *P. hirtiventris*, *P. profunda*, *P. bipartita*, *P. latifrons* were also active during this period, but were less numerous. Species abundance can be related to the suitability of larval and/or adult habitats (Dahl and Mahr 1991). Modifications of these habitats with crop rotation, weed control practices, fertilization and irrigation practices, and the increase of urbanization and landscaping can change species composition. Forschler and Gardner (1991) indicated that natural enemy pressure, soil conditions and the availability of larval and adult food sources helped determine the abundance of soil insects. Sweetman (1931) reported that proximity to a tree line and adequate soil moisture were determinant factors in the abundance of *Phyllophaga*. The *Phyllophaga* species captured in this study were also collected in Alabama in a recent blacklight trap survey of pastures (Flanders et al. 2000), with the exception of *P. profunda*. *P. crinita* was most abundant in their
collections and *P. ephilida* and *P. hirtiventris* were moderately common. Forschler and Gardner (1991) recorded the presence of *P. ephilida* and *P. hirtiventris* during June, July and August in a blacklight trap survey in Georgia. Stone (1986) found *P. crinita* to be the most common scarab collected with blacklight traps in Texas. Our records in Louisiana are similar to surveys conducted in other parts of the southeastern US. All the species found during this study were previously collected by Riley in his survey in 1988. *P. ephilida* and *P. crinita* are endemic to the southeast and are the most common species occurring in sweet potato growing areas of Louisiana.

In summary, adult *Phyllophaga* are active for several weeks during the summer months. The *Phyllophaga* are a diverse group, but in the sweet potato growing areas of Louisiana, two species predominate, *P. ephilida* and *P. crinita*. Both species are potentially responsible for sweet potato damage attributed to white grubs. Adults are active and deposit eggs in the soil from mid May to early August. The abundance and wide distribution of *P. ephilida* and *P. crinita* underscores the need for further biological studies on these species.
Table 3.1. Blacklight trap collections of common *Phyllophaga* in three Louisiana locations: Sweet Potato Research Center at Chase (Franklin Parish), Fontenot Farm (St Landry Parish), and LSU AgCenter Burden Research Plantation (East Baton Rouge Parish).

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Year</th>
<th>Percent</th>
<th>Weekly Mean</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. crinita</em></td>
<td>Chase 1998</td>
<td>58.4</td>
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<tr>
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<td>21.0</td>
<td>11.1</td>
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<tr>
<td><em>P. profunda</em></td>
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<td>10.9</td>
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<td></td>
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<tr>
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<td>37.1</td>
<td>483</td>
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<tr>
<td><em>P. hirtiventris</em></td>
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<td>9.9</td>
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<tr>
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<td>29.8</td>
<td>26.5</td>
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<tr>
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<td>3.3</td>
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<td>Burden 1998</td>
<td>48.5</td>
<td>75.2</td>
<td>978</td>
<td></td>
</tr>
<tr>
<td><em>P. ephilida</em></td>
<td>Burden 1998</td>
<td>46.8</td>
<td>72.6</td>
<td>944</td>
<td></td>
</tr>
<tr>
<td><em>P. latifrons</em></td>
<td>Burden 1998</td>
<td>4.6</td>
<td>7.2</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td><em>P. ephilida</em></td>
<td>Burden 1999</td>
<td>48.3</td>
<td>43.9</td>
<td>483</td>
<td></td>
</tr>
<tr>
<td><em>P. crinita</em></td>
<td>Burden 1999</td>
<td>41.3</td>
<td>38.0</td>
<td>418</td>
<td></td>
</tr>
<tr>
<td><em>P. latifrons</em></td>
<td>Burden 1999</td>
<td>9.7</td>
<td>8.8</td>
<td>97</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3.1. Weekly catch of *Phyllophaga hirtiventris*, *P. crinita* and *P. profunda* at the LSU AgCenter Sweet Potato Research Station, Chase, St. Franklin Parish, LA, 1998.

Figure 3.2. Weekly catch of *Phyllophaga hirtiventris*, *P. crinita* and *P. profunda* at the LSU AgCenter Sweet Potato Research Station, Chase, St. Franklin Parish, LA, 2001.
Figure 3.3. Weekly catch of *Phyllophaga ephilida*, *P. crinita* and *P. bipartita* at Fontenot Farm, St. Landry Parish, LA, 1999.

Figure 3.4. Weekly catch of *Phyllophaga ephilida*, *P. crinita* and *P. bipartita* at Fontenot Farm, St. Landry Parish, LA, 2000.
Figure 3.5. Weekly catch of *Phyllophaga crinita*, *P. ephilida*, and *P. latifrons* at the LSU AgCenter Burden Research Plantation, East Baton Rouge Parish, LA, 1998.

Figure 3.6. Weekly catch of *Phyllophaga crinita*, *P. ephilida*, and *P. latifrons* at the LSU AgCenter Burden Research Plantation, East Baton Rouge Parish, LA, 1999.
Literature Cited


CHAPTER IV

ATTRACTIVENESS OF METHYL ESTERS OF L-ISOLEUCINE AND L-VALINE
BLENDSTO *PHYLOPHTAGA EPHILIDA* (SAY) IN LOUISIANA
Introduction

The scarab beetle *Phyllophaga ephilida* is a serious pest of sweet potato in south central Louisiana (Rolston and Barlow 1980). Adults feed on deciduous trees (Crocker et al. 1995, Potter 1998) while larvae feed on plant roots (Tashiro 1987). On sweet potato, larvae gouge shallow channels on the surface of roots, rendering them unmarketable. When adults emerge in the spring, mating occurs at feeding sites (Shenefelt and Simkover 1951). Successful mating is followed by the female ovipositing in the soil where larval growth and development occurs. The subterranean life of *P. ephilida* comprises most of its life cycle. Larvae are difficult to detect in the soil. Larval extraction from the soil can be accomplished by dry or wet sieving, or soil washing and flotation (Southwood 1978). However, these methods are labor intensive and the density level of larvae in the soil that can cause economic damage in sweet potatoes (5% of roots damaged) is very low. Crop consultants and growers consider these sampling methods impractical. Adults can be sampled effectively with blacklight traps. However, light traps are expensive and a technician would be required to sort through and properly identify the pest species. Adult *Phyllophaga* are similar in appearance and hence difficult to identify to species.

A recent isolation of the sex pheromone of *Phyllophaga anxia* (Zhang et al. 1997) has made it feasible to sample adult *P. ephilida* with pheromones. A pheromone attractive to *P. ephilida* would provide an inexpensive and practical sampling tool that would enable sweet potato growers and crop consultants to monitor *P. ephilida* populations. The pheromone developed by Zhang et al. (1997) consists of a two component mixture of the methyl esters of two essential amino acids, L-valine and L-isoleucine, in a 75%-25%
blend. This pheromone was tested in field conditions in New England with different ratios of the methyl esters of L-valine and L-isoleucine (Zhang et al. 1997). *P. ephilida* was not collected in these tests. The species of *Phyllophaga* captured varied depending on the blend ratio of the methyl esters of the two amino acids.

The purpose of this investigation was to identify the optimum ratio of methyl esters of L-isoleucine and L-valine for attracting *P. ephilida*.

**Materials and Methods**

Amino acid blends (methyl ester of L-isoleucine and L-valine, ChemTica Internacional, Costa Rica) were evaluated in a sweet potato field in St Landry Parish, Louisiana during the summers of 1999 and 2000. Seven ratios of the two amino acids were evaluated: 100/0, 95/5, 65/35, 50/50, 35/65, 5/95, 0/100 (methyl ester of L-isoleucine/methyl ester of L-valine). Rubber septa were loaded with 4 mg of the appropriate blend and used in commercial Trece® pheromone traps. Seven traps were placed on wood poles (1m high) along the edge of a sweet potato field next to a tree line in St. Landry Parish. Traps were placed about 15 meters apart. The positions of the traps within the trap line were changed weekly by rotating each trap one position in the same direction after the traps were checked. Beetles were removed each week from traps and identified later. The pheromone traps were present in the fields during June and July; the lures were not changed. In 1999, the test started on 4 June and ended on 15 July (six weeks, five counts), while in 2000 it started on 7 June and ended on 26 July (six weeks, 4 counts). St Landry is located in central Louisiana and occurs in a commercial sweet potato growing area. Field trials were conducted in the same area both years. The genitalia of the beetles were dissected in the laboratory and identified using a binocular microscope (Wild MSA) and the aedegus illustrations and species determination key of
Woodruff and Beck (1989). Dr. E. R. Woodruff (Entomology Department, University of Florida, Gainsville, FL) confirmed all identifications. Voucher specimens were deposited at the LSU Entomology Museum, Baton Rouge, LA. Data were analyzed with Proc GLM (SAS Institute 1990) as an analysis of variance, with pheromone blend and year as independent variables and mean number and percentage of total beetles collected as dependent variables. Mean separation tests were conducted with a protected Duncans Multiple Range Test with alpha = 0.05.

**Results and Discussion**

Pheromone blend had a significant effect (F = 24.1; df = 5; P < 0.0001) on the number of beetles collected (Table 4.1), whereas year did not have a significant effect (F = 0; df = 1; P = 0.9700) on beetle capture. Methyl ester of L-isoleucine alone was far more attractive to *P. ephilida* and captured significantly more beetles than other blend ratios (Table 4.1). This chemical captured 79% and 85% of all *P. ephilida* collected in 1999 and 2000, respectively. In both years, the 100/0 (methyl ester of L-isoleucine: methyl ester of L-valine) attracted the most beetles while the 5/95 and 0/100 blends were the least attractive and captured no beetles. The 95/5 blend was the second most attractive, followed by the 65/35 blend, the 50/50 blend, and the 35/65 blend. The 100% methyl ester of L-isoleucine appears to be highly attractive to adult male *P. ephilida*.

A survey of similar blend ratios was conducted in several states (AL, FL, LA, MA, MS, NB, NJ, NY and TX) from 1996 through 1998 (Robbins et al. personal communication). *P. ephilida* was captured in Louisiana, with the 100% methyl ester of 1

---

L-isoleucine and the 65/35 ratio the only blends to capture this species. Although \textit{P. ephilida} occurs throughout the southeast, it was not captured in any other state. These sites were not located in sweet potato growing areas and the surveys were of limited duration with limited replication (AL, FL, MS one site for one year only, TX four sites for one year only). In the Louisiana survey in 1997, only two \textit{P. ephilida} individuals were captured (one in the 100/0 and one in the 65/35 ratio), while in 1998, 5 \textit{P. ephilida} beetles were captured (all in the 100% ratio). Our study was conducted in south central Louisiana in a sweet potato growing area where \textit{P. ephilida} is abundant. Our far greater capture reflects this abundance and demonstrates conclusively that the methyl ester of L-isoleucine is a strong attractant for male \textit{P. ephilida}. This finding makes possible the monitoring of adult \textit{P. ephilida} populations in sweet potato production areas of Louisiana by crop consultants and growers.

Table 4. 1. Mean and percent of \textit{Phyllophaga ephilida} captured in traps with different ratios of methyl esters of L-isoleucine and L-valine, St. Landry Parish, LA, 1999-2000.

<table>
<thead>
<tr>
<th>Pheromone blend 1</th>
<th>\textit{Phyllophaga ephilida} capture per week 2</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Percent</td>
</tr>
<tr>
<td>100/0</td>
<td>22.6</td>
<td>18.5</td>
<td>78.5 a</td>
</tr>
<tr>
<td>95/5</td>
<td>3.0</td>
<td>1.9</td>
<td>10.4 b</td>
</tr>
<tr>
<td>65/35</td>
<td>1.4</td>
<td>1.1</td>
<td>4.9 c</td>
</tr>
<tr>
<td>50/50</td>
<td>1.2</td>
<td>1.3</td>
<td>4.1 c</td>
</tr>
<tr>
<td>35/65</td>
<td>0.6</td>
<td>0.9</td>
<td>2.1 c</td>
</tr>
<tr>
<td>5/95</td>
<td>0</td>
<td>0</td>
<td>0 c</td>
</tr>
<tr>
<td>0/100</td>
<td>0</td>
<td>0</td>
<td>0 c</td>
</tr>
</tbody>
</table>

1 Pheromone blend ratios of methyl ester of L-isoleucine and L-valine.
2 Mean separation with Duncan Multiple Range Test, alpha = 0.05.
Literature Cited


CHAPTER V

THE LIFE CYCLE OF *PHYLLOPHAGA EPHILIDA* (SAY) (COLEOPTERA: SCARABAEIDAE) IN SOUTH LOUISIANA
**Introduction**

*Phyllophaga ephilida* is widely distributed in the Americas (Tashiro 1987, Woodruff and Beck 1989). In Louisiana, this beetle is a serious pest of sweet potatoes (Rolston and Barlow 1980) and preplant, soil incorporated insecticides are routinely applied to prevent damage from white grubs and other soil pests. Adult *P. ephilida* feed nocturnally on leaves of several deciduous trees (Potter 1998). During the day, adult beetles burrow into the soil or hide under leaves and debris. Eggs are deposited in grassy areas or bare soil. Third instar larvae gouge shallow channels on the surface of sweet potato roots. Damaged roots cannot be sold on the fresh market and are either sold to a cannery at a greatly reduced price or are discarded.

Knowledge of the life cycle of *P. ephilida* could improve the management of this pest in sweet potatoes. The duration of the life cycle of *Phyllophaga* species varies from one to four years depending on the species and geographical latitude (Davis 1916, Sweetman 1927, Vittum et al. 1999). Rolston and Barlow (1980) expressed the view that in south central Louisiana *P. ephilida* is univoltine. This inference was based on their observation that during the fall season only third instar larvae were collected in sweet potato fields. In Georgia (Fattig 1944) and Kentucky (Davis 1916) *P. ephilida* is reported to have a two year cycle, while in Canada and the northern US (Tashiro 1987) it has a three year cycle. The number of generations of *P. ephilida* in the subtropical latitudes of south Louisiana has not been determined conclusively.

The purpose of this study was to determine the generation time of *P. ephilida* in south Louisiana.

**Materials and Methods**

The study was conducted at the LSU Agricultural Center, Burden Research Plantation
(East Baton Rouge Parish, Louisiana) from May 2002 through August 2003. Six saran (BioQuip, Gardenas, CA) screen cages (1.8 m by 1.8 m by 1.8 m) were erected and the soil floor was covered with black plastic. Six plastic pots (0.05 cubic meter volume) were placed in each cage, filled with sandy loam soil, and planted with sweet potato slips during June and July 2002. A battery powered blacklight trap was operated in a sweet potato field in St Landry Parish, Louisiana, during June and July 2002. On a daily basis, *Phyllophaga* adults were collected and brought back to Baton Rouge. Twenty *P. ephilida* adults were selected from the captured insects and released into the plastic pots. Adults were supplied with fresh pecan leaves daily and confined to the pots with a layer of a flexible mesh netting (0.394 mesh). The netting was supported by four 25 cm-tall wood stakes, creating a small space above the soil surface. Duct tape was used to firmly hold the netting to the sides of the pots. Beetles were released into the plastic pots from the beginning of June until the end of July 2002. Pots were periodically waterered with a garden hose to maintain adequate soil moisture. A granular formulation of Talstar® was applied around the exterior of the cages to prevent fire ants from entering the pots. In October 2002, two pots were checked for the presence of *P. ephilida* to determine if the attempt to infest the pots with larvae was successful and to determine the developmental stage(s) present during the fall. Pots were protected from freezing during the winter by covering them with plastic. Starting in April 2003, on a weekly basis, two pots were removed and carefully checked for larvae, pupae and adults. The soil was searched by hand and inspected visually. Larvae were placed in Quinters solution (Baker Chemical Co, Phillipsburg, N. J.) before being preserved in 80% alcohol. Species determinations of adults collected from the soil were made by the author and confirmed by Dr. Chris
Carlton (Entomology Department, LSU AgCenter, Baton Rouge, LA). The specimens were deposited in the LSU Entomological Museum. Weather data (rainfall, air and soil temperature) were recorded from a meteorological station adjacent (three meters) to the cages. The soil temperature reading was taken at a depth of 15.2 centimeters.

**Results and Discussion**

Third instar larvae were found in October 2002 and during late spring from 28 April through 9 June (Table 5.1), indicating that the beetle overwintered in the soil in this stage. This corroborates the observations of Rolston and Barlow (1980) concerning the presence of third instar larvae in the soil during the fall. During our sampling between April and July 2003, we observed that most larvae were present in the upper 30 cm of the soil surface. On two occasions, two larvae were found approximately 60 cm from the soil surface. Pupation occurred in earthen chambers. Our sampling first detected the presence of pupae by mid-May (three pupae). A total of 26 pupae were found immobile in earthen chambers located between 10-15 cm deep in the soil. Two pupae were held in an incubator until eclosion and identified using genitalia characters as *P. ephilida*.

In July, teneral adults were first observed and their number increased during subsequent weeks. Twenty-seven *P. ephilida* adults were collected in the soil close to the surface (within 30 cm) and appeared ready to emerge. In Louisiana, beetles are active from the end of May to the beginning of August. The univoltine character of *P. ephilida* can be inferred from our soil sampling from 25 October, 2002 through 21 July, 2003. We collected 56 larvae from 25 October, 2002 to 9 June, 2003, 26 pupae from 12 May to 21 July, 2003, and 27 adults from 26 May to 21 July, 2003. No first or second instar larvae were found.
The monthly air and soil temperatures (Figure 5.1) and mean monthly rainfall (Figure 5.2) document the climatic conditions present during the fall, winter and spring of 2002 through 2003 at Burden. The life cycle duration of an insect is related to geographical latitude and concomitantly to the climatic conditions. The three year cycle of *P. ephilida* in northern latitudes of the US and southern Canada is reduced to two years in the central US (Davis 1916, Tashiro 1987). In the south Louisiana latitudes, *P. ephilida* is univoltine (Figure 5.3). The exact geographical transition zones of voltinism have not been determined for *P. ephilida* and may vary from year to year with the weather.

Knowledge of the beetle’s life cycle has the potential to improve the management of *P. ephilida* in sweet potatoes. In Louisiana, sweet potatoes are planted in May and June and roots are present in the soil from late June through harvest in September or October and sometimes November. Overwintering larvae will not damage sweet potato roots during the next growing season if they have a univoltine life cycle, for they will emerge as adults in May and June before roots are present in the soil. If a two-year cycle were present, first year overwintering larvae would remain in the field through the entire sweet potato growing season and damage roots throughout the summer and the fall. Growers routinely apply soil insecticides before planting to control several soil insect pests of sweet potato (Ring et al. 1996). These applications will control overwintering *P. ephilida* larvae in the spring. However, these applications will only indirectly reduce sweet potato damage in the fall caused by *P. ephilida* through the reduction of the number of adult beetles emerging from production fields in May and June. The subsequent generation is responsible for damage to the fall crop. To control fall populations, growers may need to make a mid season insecticide application that is timed
to coincide with the peak flight activity of *P. ephilida*. The univoltine life cycle suggests that early planted crops may escape root injury by maturing before third instar larvae are present in the field.

Table 5.1. Number of larvae, pupae and adults of *Phyllophaga ephilida* collected in caged pots at the LSU AgCenter Burden Research Plantation, Baton Rouge, LA. 2002, 2003.

<table>
<thead>
<tr>
<th>Date of collection</th>
<th>3rd instar larvae</th>
<th>pupae</th>
<th>adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Oct. 2002</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>28 Apr. 2003</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>05 May 2003</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12 May 2003</td>
<td>8</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>18 May 2003</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>26 May 2003</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>02 June 2003</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>09 June 2003</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>16 June 2003</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>23 June 2003</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>30 June 2003</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>07 July 2003</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>14 July 2003</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>21 July 2003</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>26</td>
<td>27</td>
</tr>
</tbody>
</table>
Figure 5.1. Monthly air and soil temperatures at the LSU AgCenter Burden Research Plantation, Baton Rouge, LA. May 2002-July 2003.
Figure 5.2. Mean monthly rainfall at the LSU AgCenter Burden Research Plantation, Baton Rouge, LA. May 2002-July 2003.
Figure 5.3. Life cycle of *Phyllophaga ephilida* in southern LA.
Literature Cited


CHAPTER VI

INFLUENCE OF SOIL MOISTURE, ORGANIC MATTER AND SOIL TEXTURE ON THE DIURNAL BURROWING OF ADULT *PHYLLOPHAGA EPHILIDA* (SAY)
Introduction

*Phyllophaga* species spend most of their life below the soil surface. Eggs are deposited in the soil and larvae spend one to four years in the soil feeding on plant roots, depending on the species and the latitude (Sweetman 1931, Rolston and Barlow 1980, Potter 1998). Pupation likewise occurs beneath the soil surface. The adult life span is relatively brief, lasting for only a few weeks. Adults are nocturnal and at daybreak they burrow into the ground (McColloch and Hayes 1923, Sweetman 1931, Gruner 1973) or hide under loose vegetation (Miner 1944). *Phyllophaga* adults tend to alter the growing conditions of plants close to the soil surface as a result of their burrowing. The selection of an entry site by the beetle could be influenced by several physical characteristics of the soil (temperature, rainfall, moisture, organic matter content, vegetation, soil type and texture). Miner (1944) stated that the physical features of the ground cover influenced the site selection of *Phyllophaga* species. The role of moisture on the ecology of invertebrates is often overlooked (Tauber et al. 1998). Soil moisture can affect larval distribution in the soil environment. Sweetman (1931) found that soil moisture influences egg and larval survival in the field. Organic matter is another often overlooked parameter which may play a role in the subterranean behavior of *Phyllophaga*. Even though *P. ephilida* is a pest of sweet potatoes, little is known about the behavior and habitat preference of adults.

The purpose of our study was to determine the effect of three physical factors (moisture, organic matter and soil texture) on the burrowing depth of adult *P. ephilida*.

Materials and Methods

Experiments were conducted in the laboratory during the summers of 2001 and 2002.
The experimental unit consisted of a transparent plastic cylinder (30 cm by 3 cm diameter) filled with silt loam or sandy loam soil and held vertically in a Solo® plastic cup (0.5 l). A 2.5 cm space was left in the top of the cylinder to provide an air space above the soil for the beetles. The top and bottom surfaces of the cylinders were covered with fine mesh netting (0.394 mesh) and held in place with rubber bands. Cups were placed inside a transparent plastic container (22.33 l Rubbermaid Hi Top®). Containers were kept under a photoperiodic regime of L:D (16:8) in the laboratory at room temperature (25-27 degrees Celsius). Three adult male *P. ephilida* were placed in the top of each cylinder during the afternoon and the netting was secured to prevent their escape. Beetles were collected in a sweet potato field at St Landry Parish, Louisiana in pheromone traps (Japanese beetle traps, Trece®, Salinas, CA) and released into the cylinders on the same day they were captured. Adults were left undisturbed for either one day (24 hours) or three days (72 hours). At the expiration of the time period, the depth of each burrow was measured. The location and condition (dead or alive) of the beetles were noted. Two experiments were conducted, one to evaluate the effect of soil texture and soil moisture level on beetle burrowing depth and a second to evaluate the effect of soil texture and soil organic matter on beetle burrowing depth. Both experiments were conducted as a 2*3 factorially arranged randomized complete block design with four replications. Both experiments were repeated a second year, and both experiments were conducted using two different time intervals (24 hours and 72 hours). Two soil textures were evaluated. A common texture triangle was used to create a silt loam and a sandy loam. The silt loam was made of 60% silt, 25% sand and 15% clay, while the sandy loam was made of 70% sand, 20% silt and 10% clay. The two soil textures are
representative of soils used in Louisiana for growing sweet potato. The soil was air-dried before use. Three levels of organic matter (organic compost derived from cow manure compost-Garden Basics®) were added to the two textures to create three levels of organic matter (0, 50, 75 grams). Three levels of soil moisture levels were created by adding 0, 50, 75 ml of distilled water to the soil cylinder. Data were analyzed with Proc GLM (SAS Institute 1990) as an analysis of variance with a factorial arrangement of treatments. Mean separation was conducted with the Tukey test (alpha = 0.05).

Results and Discussion

Soil texture did not have a significant effect on burrowing depth in both the moisture and the organic matter experiments, although there was a trend for burrow depth to be greater with the sandy loam soil (Tables 6.1, 6.2). Soil texture was not significant in 2001 (moisture experiment) either in the 24 hour test ($F = 1.64; df = 1; P = 0.2046$) or the 72 hour test ($F = 0.66; df = 1; P = 0.4183$). Likewise, soil texture was not significant in 2002 (moisture experiment) in either the 24 hour test ($F = 0.42; df = 1; P = 0.5221$) or in the 72 hour test ($F = 2.07; df = 1; P = 0.1559$). Soil texture was not significant in 2001 (organic matter experiment) in either the 24 hour test ($F = 1.43; df = 1; P = 0.2366$) or the 72 hour test ($F = 0.40; df = 1; P = 0.5311$). Soil texture was not significant in 2002 (organic matter experiment) in either the 24 hour test ($F = 1.97; df = 1; P = 0.2547$) or the 72 hour test ($F = 0.01; df = 1; P = 0.9382$).

Soil moisture had a significant effect on burrowing depth, with deeper burrows associated with higher levels of moisture (Table 6.1). This moisture effect was significant in 2001 in the 24 hour test ($F = 3.73; df = 5; P = 0.0040$) and the 72 hour test ($F = 2.94; df = 5; P = 0.0100$) as well as in 2002 in the 24 hour test ($F = 6.61; df = 5; P < 0.0001$)
Table 6.1. Main effects of soil texture and soil moisture on the depth of burrowing (cm) of adult male *Phyllophaga ephilida* at two time durations in a 2*3 factorially arranged experiment, 2001, 2002.

<table>
<thead>
<tr>
<th>Main Effect</th>
<th>Treatments</th>
<th>Mean Depth (cm) of Burrow (SE)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001</td>
<td>2002</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
<td>72 hours</td>
</tr>
<tr>
<td>Texture</td>
<td>Silt Loam</td>
<td>17.3(25.4) a 42.6(5.8) a</td>
</tr>
<tr>
<td></td>
<td>Sandy Loam</td>
<td>21.8(25.4) a 47.3(5.7) a</td>
</tr>
<tr>
<td>Moisture</td>
<td>0 ml</td>
<td>9.6(25.5) b 30.7(5.7) b</td>
</tr>
<tr>
<td></td>
<td>50 ml</td>
<td>23.7(25.5) a 48.3(5.7) a</td>
</tr>
<tr>
<td></td>
<td>75 ml</td>
<td>25.5(25.5) a 55.8(5.6) a</td>
</tr>
</tbody>
</table>

¹Mean separation with Tukey test, alpha=0.05.

Table 6.2. Main effects of soil texture and organic matter on the depth of burrowing (cm) of adult male *Phyllophaga ephilida* at two time durations in a 2*3 factorially arranged experiment, 2001, 2002.

<table>
<thead>
<tr>
<th>Main Effect</th>
<th>Treatments</th>
<th>Mean Depth (cm) of Burrow (SE)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001</td>
<td>2002</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
<td>72 hours</td>
</tr>
<tr>
<td>Texture</td>
<td>Silt Loam</td>
<td>22.7(15.7) a 21.8(2.1) a</td>
</tr>
<tr>
<td></td>
<td>Sandy Loam</td>
<td>26.2(15.7) a 23.2(2.1) a</td>
</tr>
<tr>
<td>Organic</td>
<td>0 gr.</td>
<td>12.7(15.8) b 13.3(2.3) b</td>
</tr>
<tr>
<td>Matter</td>
<td>50 gr.</td>
<td>27.9(15.8) a 25.0(2.2) a</td>
</tr>
<tr>
<td></td>
<td>75 gr.</td>
<td>32.8(15.8) a 29.3(2.3) a</td>
</tr>
</tbody>
</table>

¹Mean separation with Tukey test, alpha=0.05.

and the 72 hour test (F = 2.77; df = 5; P = 0.0200). Organic matter had a significant effect on burrowing depth with deeper burrows associated with higher levels of organic matter in 2001 in the 24 hour test (F = 4.49; df = 5; P = 0.0010) and the 72 hour test (F = 5.68; df = 5; P = 0.0002). In 2002, the organic matter was significant in the 24 hour test (F = 2.34; df = 5; P = 0.0500), but not in the 72 hour test (F = 0.23; df = 5; P = 0.9400). Our results indicate that both soil moisture and organic matter can influence the depth of
burrowing of adult *P. ephilida*.

The selection by *Phyllophaga* for a burrowing habitat may be influenced by factors such as soil organic matter content and soil moisture. Chamberlin and Callenbach (1943) stated that the preferences of *P. hirticula* and *P. rugosa* for grass rather than legumes was probably the result of different soil conditions produced by the host plants. Gruner (1973) observed in the Caribbean island of Guadalupe that *P. pleei* adults tend to fly at low altitudes and seek dark areas in woodlots at the base of banana trees for burrowing. The beetles were observed to burrow a one centimeter diameter hole into the ground and spend the day inside soil chambers. These chambers were usually located under tree roots, where adults aggregated in clusters of 40-50 individuals during the day.

Brandhorst-Hubbard et al. (2001) reported that Green June beetle adults and grubs are attracted to soil surfaces fertilized with cow manure, hay and broiler litter. Higher levels of organic matter content were associated with deeper burrows. Katovich et al. (1998) noticed that *Phyllophaga* species appeared to penetrate more easily soils with a higher organic matter content. Vertical burrowing within the soil matrix may be an attempt by the beetle to find its optimal habitat. Lentz (1985) speculated that the high population of *P. implicita* and *P. congrua* in a soybean field was a result of the presence of willow growing in the drainage areas adjacent to the field. Burrowing behavior may play a role in the habitat choice and potential areas of oviposition by females. Gaylor and Frankie (1979) concluded that *P. crinita* egg deposition, egg development and first instar survival required adequate levels of soil moisture. Adults sought moist soil for oviposition. Low areas that collect rainfall may represent a preferred habitat for oviposition. Knowledge of the habitat preference of *P. ephilida* would allow for the use of directed sampling
techniques. Globoza et al. (1998) suggested that one should take into consideration the vertical migration and distribution of larvae when developing sampling plans for management decisions. The foliage of trees, a source of food for adults, provide shade and increased soil moisture, creating a preferred microclimate for the beetle and, presumably, a higher risk of larval infestation to adjacent crops. Soil manipulation techniques (plowing, irrigation, flooding, drainage) might be used to modify the soil habitat of *Phyllophaga* to reduce the suitability of these areas for larval and adult populations.

**Literature Cited**


CHAPTER VII

ADULT *PHYLLOPHAGA EPHILIDA* (SAY) HOST PLANT FEEDING PREFERENCE
Introduction

Adult June beetles are nocturnal defoliators of trees, shrubs and grasses in diverse ecological regions (Vallejo et al. 1998, Richter 1958). There are several reports in the literature that describe observations of adult *Phyllophaga* spp. feeding on the foliage of woody plants (Davis 1916, Potter 1998, McLeod 1986). However, the host range and feeding preference of adult *Phyllophaga* have not been investigated. Insects may be classified as monophagous (host range includes plants of one or a few closely related species within a genus), oligophagous (host range includes several genera within a family), or polyphagous (host range includes several families in one or more orders of plants) (Metcalf and Luckman 1975). However, within the range of possible host plants, the suitability of these plants for insect development and survival can vary tremendously. A polyphagous insect may show a strong preference for a relatively small number of species. Often the underlying common traits of the preferred host plants has a chemical basis.

Very little is known about the feeding preference of adult *P. ephilida*. The larvae of *P. ephilida* damage sweet potato roots in Louisiana (Rolston and Barlow 1980). Most commercial sweet potato fields are relatively small and bordered by tree lines or woody areas. These trees provide food for adults. Knowledge of the host range and feeding preference of adults for the common tree species in south central Louisiana would help in understanding the biology of the pest and perhaps explain this pest’s specific distribution among grower fields.

The purpose of this study was to investigate the host range and feeding preference of *P. ephilida* adults for the foliage of eight host plants of trees common in the sweet potato
growing areas of Louisiana and representative of seven plant families.

**Materials and Methods**

Host preference tests were conducted in an arena constructed from an 11.3 l Rubbermaid® plastic container (40.6 by 28.5 by 27.5 cm) with a snap cover. A 10 by 40 cm rectangular opening was cut in the center of the plastic cover and flexible screen (0.394 mesh) was glued to the edges of the opening with a hot glue gun to allow for air exchange and to prevent beetles from escaping. A layer of sand (3 cm deep) was placed in the bottom of the container and a styrofoam board (2 cm thick) was placed on top. Cut into the board were circular holes to accommodate 20 ml glass scintillation vials. These vials stood erect in the board and held the host plant stems. Vials were filled with water, the host plant stems inserted into the top, and parafilm was wrapped over the top of the vial to hold the host plant in place. Freshly picked young leaves from eight species of trees were evaluated: water oak (*Quercus nigra* L., Fagaceae), live oak (*Quercus virginiana* Mill., Fagaceae), red maple (*Acer rubrum* L., Aceraceae), slash pine (*Pinus caribaea* Morelet, Pinaceae), pecan (*Carya illinoensis* (Wangenh) K. Koch, Juglandaceae), sweetgum (*Liquidambar styraciflua* L., Hamamelidaceae), southern magnolia (*Magnolia grandiflora* L., Magnoliaceae), and American elm (*Ulmus americana* L., Ulmaceae). All eight test plants were randomly assigned a position in a circular arrangement within the arena. Twenty adult *P. ephilida* males were placed in the center of the arena and allowed to feed for 24 hours. Adult beetles were collected in Japanese beetle pheromone traps (Trece®, Incorporated, Salinas, CA) using 4 ml of methyl ester of L-isoleucine impregnated in a rubber septum as the attractant. These traps were placed in sweet potato grower fields in St Landry Parish on 22 May, 2001 and
4 June, 2002 and checked weekly. The photoperiod in the arena was maintained at 16 L : 8 D and the temperature held at 24 degrees Celsius. The quantity of food consumed after 24 hours was determined by measuring the leaves before and after insect feeding with a leaf area reader (Li-Cor®). Leaf area consumption was calculated by subtracting the final leaf area from the initial leaf area. Leaf weight was measured using a Mettler Toledo® scale. Control leaves without beetles were used to adjust for weight loss due to dessication. The experiment was conducted in both 2001 and 2002, using a randomized complete block design with six replicates for each trial. A total of six trials were conducted in both 2001 and 2002. Data were analyzed using SAS Proc GLM and a LSD was used for mean separation (SAS Institute 1990).

**Results and Discussion**

The leaf area consumed by male *P. ephilida* was significantly different among the eight host plants in both 2001 (F = 6.99; df = 7; P < 0.0001) and 2002 (F = 14.4; df = 7; P < 0.0001) (Tables 7.1, 7.2). No discernable losses in leaf area were detected in the controls, hence adjustments were not made to leaf area measurements of the treatments. In 2001, the order of leaf area consumption of male *P. ephilida* was: pecan, with a mean leaf area consumption of 5.04 square cm, followed by elm (3.14), water oak (2.37), maple (1.76), live oak (0.38), and sweetgum (0.04). Southern magnolia and slash pine were not consumed. In 2002, the order of leaf area consumption was: pecan, with a mean of 6.28 square cm, followed by elm (3.90), water oak (2.04), maple (0.75), and live oak (0.30). Southern magnolia, sweetgum and slash pine were not consumed. Leaf area measurements are a somewhat less reliable measurement of beetle feeding than weight of leaf tissue consumed due to the variation in leaf density and leaf thickness between plant species.
The consumption (weight) by male *P. ephilida* was significantly different among the eight host plants in both 2001 ($F = 5.23; df = 7; P = 0.0005$) and 2002 ($F = 10.90; df = 7; P < 0.0001$) (Tables 7.3, 7.4). No discernable losses in weight were detected in the controls, hence adjustments were not made to the leaf weight measurements of the treatments. In 2001, the order of leaf consumption in grams was: pecan (0.084), water oak (0.037), maple (0.035), live oak (0.013), elm (0.003), and sweetgum (0.0006). Southern magnolia and slash pine were not consumed at all. In 2002, the order of consumption was: pecan (0.100), elm (0.042), water oak (0.032), maple (0.015) and live oak (0.010). Southern magnolia, sweetgum and slash pine were not consumed. Within the range of host plants evaluated, *P. ephilida* showed a strong preference for the foliage of pecan, elm, water oak, and maple. Southern magnolia and slash pine were avoided completely, while sweetgum was barely fed on up.

Measurements of leaf area and leaf weight consumed revealed a similar ranking of host plant preference. These results show that although *P. ephilida* is polyphagous, this insect has a strong preference for individual host plant species from the plant families Juglandaceae, Ulmaceae, Fagaceae and Aceraceae. This pattern of preference is common among insect herbivores that are polyphagous (Metcalf and Luckman 1975). There have been several incidental reports of *Phyllophaga* feeding on the foliage of trees. *P. hirticula*, *P. tristis*, and *P. fraterna* were reported feeding on hickory and oak (Davis 1916). Sweetman (1931) reported that *P. implicata*, *P. fusca* and *P. drakei* selectively feed on woody plants. *P. implicata* adults were reported to feed on the foliage of elm, ash, poplar and willow (Lago et al. 1979, McLeod 1986). Adult *Phyllophaga* not identified to species have been observed feeding on walnut, persimmon, birch, elm,
poplar, hickory and oak foliage (Potter 1998). At least two *Phyllophaga* species have been reported feeding on the foliage of non-woody hosts. Travis (1939) reported that *P. lanceolata* adults have been recorded in Iowa feeding on close to thirty host plants, among them corn, soybeans and potato. Sweetman (1931) reported that *P. anxia* feeds on a broad range of herbaceous plants. There is no evidence that *P. ephilida* feeds on the foliage of host plants other than woody plants. Our study suggests that *P. ephilida* will not feed on conifers, and its host range is limited to the woody dicotyledons.

The underlying determinant of the host range of *P. ephilida* is likely to be the presence of phytochemicals, volatile compounds acting as an attractant or phagostimulant to the beetle. The observations of adult *Phyllophaga* feeding on leaves of trees have been mostly empirical and no study has been published on the feeding preference of adult *P. ephilida*. Sweetman (1931) suggested that the odor of plants can influence the direction of flight in some species of *Phyllophaga*. *P. implicita* is attracted to willow twigs, particularly when its foliage has been bruised. The chemical ecology of *P. ephilida* has not been studied. Anderson et al. (2000) identified a volatile isoprene compound in live oak that is profusely emitted. This compound could be a phagostimulant or an attractant, but its effect on *P. ephilida* is unknown. Insects feeding on plants may induce the production of toxins and digestibility reducers which will affect a wide range of insects (Dicke 1999). Constitutive secondary plant chemicals have the same effects on several herbivore species, with only specialist species able to overcome the negative effects of the chemicals. For example, leaves of red maple contain ethanolic substances (such as ethyl m-digallate) that tend to reduce the feeding of the forest tent caterpillar, *Malacosoma disstria* Hbn (Abou-Zaid et al. 2001). It is probable that secondary
compounds are present in the host plants evaluated in this study, and their presence could contribute to the preferences shown by *P. ephilida*. The nutritional elements of the leaf content, notably nitrogen, can also influence the feeding preference of some insects (Bentz and Townsend 2001). The phenological stage of the host plant is accompanied by changes in the quality or quantity of secondary compounds, water, and oil content, and can affect the feeding behavior of insects. In our study, only the new growth of the trees was used so as to keep the age of the leaves relatively constant.

*P. ephilida* exhibited a preference for pecan, oak and elm. These species are commonly found in tree lines along the edges of sweet potato fields in Louisiana. Their close proximity to sweet potato production areas helps to explain the abundance of both adult *P. ephilida* that are captured in blacklight traps and pheromone traps, and the presence of damaging populations of larvae in the fields.

Table 7.1. Leaf area consumed (cm²) by male *Phyllophaga ephilida* from the foliage of eight plant species in a choice test, 2001.

<table>
<thead>
<tr>
<th>Host Plant</th>
<th>Mean area (cm²) consumed/trial¹</th>
<th>Mean/6 trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>Pecan</td>
<td>2.41 a 8.36 a 4.58 a 6.32 a 7.23 a 1.39 b</td>
<td>5.04 a</td>
</tr>
<tr>
<td>Elm</td>
<td>1.37 a 0.78 b 1.70 bc 4.73 ab 2.36 b 7.85 a</td>
<td>3.14 ab</td>
</tr>
<tr>
<td>Maple</td>
<td>1.40 a 0.69 b 1.02 cd 2.03 bc 0.00 c 5.43 a</td>
<td>1.76 bc</td>
</tr>
<tr>
<td>Live oak</td>
<td>0.00 b 0.00 b 0.08 dc 0.00 c 0.00 c 2.25 b</td>
<td>0.38 c</td>
</tr>
<tr>
<td>Water oak</td>
<td>0.00 b 1.50 b 3.29 ab 3.45 b 0.53 bc 5.50 a</td>
<td>2.37 b</td>
</tr>
<tr>
<td>Southern magnolia</td>
<td>0.00 b 0.00 b 0.00 d 0.00 c 0.00 c 0.00 c</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Sweetgum</td>
<td>0.00 b 0.28 b 0.00 d 0.00 c 0.00 c 0.00 c</td>
<td>0.04 c</td>
</tr>
<tr>
<td>Slash pine</td>
<td>0.00 b 0.00 b 0.00 d 0.00 c 0.00 c 0.00 c</td>
<td>0.00 c</td>
</tr>
</tbody>
</table>

¹Means with the same letter are not significantly different based on LSD test, alpha=0.05.
Table 7.2. Leaf area consumed (cm²) by male *Phyllophaga ephilida* from the foliage of eight plant species in a choice test, 2002.

<table>
<thead>
<tr>
<th>Host Plant</th>
<th>Mean area (cm²) consumed/trial¹</th>
<th>Mean/6 trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pecan</td>
<td>2.20 a</td>
<td>5.46 a</td>
</tr>
<tr>
<td>Elm</td>
<td>2.40 a</td>
<td>3.64 ab</td>
</tr>
<tr>
<td>Maple</td>
<td>0.00 b</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Live oak</td>
<td>0.00 b</td>
<td>0.36 bc</td>
</tr>
<tr>
<td>Water oak</td>
<td>0.07 b</td>
<td>2.72 abc</td>
</tr>
<tr>
<td>Southern magnolia</td>
<td>0.00 b</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Sweetgum</td>
<td>0.00 b</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Slash pine</td>
<td>0.00 b</td>
<td>0.00 c</td>
</tr>
</tbody>
</table>

¹Means with the same letter are not significantly different based on LSD test, alpha=0.05.

Table 7.3. Consumption (gr) by male *Phyllophaga ephilida* from the foliage of eight plant species in a choice test, 2001.

<table>
<thead>
<tr>
<th>Host Plant</th>
<th>Mean weight (gr.) consumed/trial¹</th>
<th>Mean/6 trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pecan</td>
<td>0.040 a</td>
<td>0.140 a</td>
</tr>
<tr>
<td>Elm</td>
<td>0.014 bc</td>
<td>0.008 b</td>
</tr>
<tr>
<td>Maple</td>
<td>0.028 ab</td>
<td>0.014 b</td>
</tr>
<tr>
<td>Live oak</td>
<td>0.000 c</td>
<td>0.000 b</td>
</tr>
<tr>
<td>Water oak</td>
<td>0.000 c</td>
<td>0.023 b</td>
</tr>
<tr>
<td>Southern magnolia</td>
<td>0.000 c</td>
<td>0.000 b</td>
</tr>
<tr>
<td>Sweetgum</td>
<td>0.000 c</td>
<td>0.004 b</td>
</tr>
<tr>
<td>Slash pine</td>
<td>0.000 c</td>
<td>0.000 b</td>
</tr>
</tbody>
</table>

¹Means with the same letter are not significantly different based on LSD test, alpha=0.05.
Table 7.4. Consumption (gr) by male *Phyllophaga ephilida* from the foliage of eight plant species in a choice test, 2002.

<table>
<thead>
<tr>
<th>Host Plant</th>
<th>Mean weight (gr) consumed/trial&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Mean/6 trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pecan</td>
<td>0.035 a</td>
<td>0.087 a</td>
</tr>
<tr>
<td>Elm</td>
<td>0.026 a</td>
<td>0.039 b</td>
</tr>
<tr>
<td>Maple</td>
<td>0.000 b</td>
<td>0.000 b</td>
</tr>
<tr>
<td>Live oak</td>
<td>0.000 b</td>
<td>0.012 b</td>
</tr>
<tr>
<td>Water oak</td>
<td>0.001 b</td>
<td>0.043 ab</td>
</tr>
<tr>
<td>Southern magnolia</td>
<td>0.000 b</td>
<td>0.000 b</td>
</tr>
<tr>
<td>Sweetgum</td>
<td>0.000 b</td>
<td>0.000 b</td>
</tr>
<tr>
<td>Slash pine</td>
<td>0.000 b</td>
<td>0.000 b</td>
</tr>
</tbody>
</table>

<sup>1</sup>Means with the same letter are not significantly different based on LSD test, alpha=0.05.

**Literature Cited**


Travis, B. V. 1939. Habits of the June beetle, Phyllophaga lanceolata (Say), in Iowa. J. Econ. Entomol. 32: 690-695.

CHAPTER VIII

SWEET POTATO DAMAGE BY *PHYLLOPHAGA EPHILIDA* (SAY): RELATIONSHIPS BETWEEN PHEROMONE TRAP CATCH, TREE LINE PROXIMITY, HARVEST DATE AND ROOT DAMAGE
Introduction

Several soil insect pests (white grubs, rootworms and flea beetles) damage the roots of sweet potatoes in Louisiana (Ring et al. 1996). *P. ephilida* is an abundant white grub species in south central Louisiana and has been implicated as the *Phyllophaga* species responsible for damage to sweet potato roots in this area (Rolston and Barlow 1980). Little is known about the biology of this species. Adult beetles feed on the foliage of deciduous trees (Potter 1998, Vittum et al. 1999) and female beetles oviposit into the soil in the vicinity of host plants at night (McLeod et al. 1986). Larvae gouge shallow channels on the surface of the sweet potato roots, rendering them unmarketable.

Growers typically apply a prophylactic, preplant, soil incorporated insecticide to prevent soil insect damage. In Louisiana, virtually all commercial acreage is treated with a preplant insecticide without sampling for the presence of insect pests (Dr. R. N. Story\(^1\) personal communication). Knowledge of the temporal occurrence and peak flight period of *P. ephilida* could help in determining the need for and timing of soil applied insecticides for white grub control. Sampling for larvae in the soil (soil sieving) is too time consuming to be a practical sampling method for growers and consultants. Although blacklight traps can be used to sample adults, light traps are expensive to operate and a technician would be required to sort through and properly identify the pest species. Pheromone traps offer an inexpensive and effective way to monitor adult activity (Flint and Gouveia 2001). In general, sampling the adult stage of an insect pest to predict subsequent larval damage is problematic. However, with soil insect pests, this approach

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\(^1\)R. N. Story, Entomology Department, LSU AgCenter, Baton Rouge, LA.
is used in many crop systems (sweet potatoes, Irish potatoes, corn) due to the lack of practical sampling methods for larvae. In sweet potatoes, banded cucumber beetles (*Diabrotica balteata* LeConte), spotted cucumber beetles (*Diabrotica undecimpunctata howardi* Barber) and white fringed beetles (*Graphognathus* spp.) are sampled in the adult stage with sweep nets to estimate root damage and to determine the need for an insecticide application (Ring et al. 1996). Pheromone trap catches of agricultural pests are relatively poor predictors of subsequent larval populations in crops (Metcalf and Luckman 1994). However, they can be useful in determining the timing of control methods and alert growers to the potential of crop damage (Flint and Gouveia 2001). Sweet potato growers lack practical sampling methods for both larval and adult *Phyllophaga*. A pheromone optimized to attract *P. ephilida* has the potential to provide growers with a means to identify fields that are at risk to white grub injury.

The purpose of this investigation was to 1) document the seasonal abundance and temporal occurrence of adult *P. ephilida* in commercial sweet potato fields, 2) quantify the relationship between adult abundance in pheromone traps and the intensity of white grub damage to sweet potato roots, 3) determine if adult abundance in sweet potato fields is affected by the tree line proximity, and 4) if harvest date has an effect on root damage.

**Materials and Methods**

**A) Adult Sampling**

Adult *P. ephilida* were surveyed in commercial sweet potato fields in Louisiana with pheromone traps (Japanese Beetle traps, Trece®, Salinas, CA). Rubber septa impregnated with 4 mg of methyl ester of L-isoleucine were used as an attractant. The septum was inserted into one of the wing flanges of the trap and changed every 3 weeks.
during the season. Pheromone traps were supported one meter above the ground with wooden stakes. Studies were conducted during the sweet potato growing seasons of 2001 and 2002 in St. Landry and St. Martin Parishes in south central Louisiana. In 2001, ten grower fields were sampled (size range of 10 to 100 acres) while in 2002, nine different grower fields were sampled (size range of 50 to 150 acres). Fields were typically flat and surrounded on two or more sides by mixed stands of coniferous and deciduous trees. Routine farming practices (cultivation, chemical spraying) were conducted by the growers in the fields. Each field was sampled with 15 pheromone traps arranged in five, 3 trap clusters, with each cluster consisting of 3 traps arranged in a straight line spaced at 10 meter intervals. The perimeter of each field (square fields with 4 sides) was sampled by placing pheromone traps just outside the field edges so as not to interfere with grower operations. Field centers were sampled with traps placed along a center row. The distance between each cluster of traps and the closest tree line was measured. Traps were checked weekly from May until flight activity of *P. ephilida* ceased in late August. Beetles were removed from the traps, placed in labeled plastic bags, and returned to the laboratory for identification. Selected specimens of *P. ephilida* at each sampling date were dissected to remove and point mount the genitalia. Species determinations were made by the author with a binocular microscope (Wild MSA) using the aedegus illustrations and keys provided by Woodruff and Beck (1989). Identifications were confirmed by Dr. E. R. Woodruff (Entomology Department, University of Florida, Gainsville, FL). Voucher specimens were deposited at the LSU Entomology Museum, Baton Rouge, LA.

**B) Root Damage Sampling**

Larval *Phyllophaga* damage to sweet potato roots was sampled just before grower
harvest. At the appropriate sample date, 25 roots in an area within 5 meters of each pheromone trap (15 sample locations/field) were excavated by hand with a pitch fork, removed from the soil and placed in labeled paper bags. The samples were returned to Baton Rouge and stored in a cool room (10-12 Celsius). The roots were later washed with a stream of water to remove dirt and visually examined for presence or absence of white grub injury (*Phyllophaga* species.).

**C) Data Analysis**

The temporal occurrence and peak activity of male *P. ephilida* was determined by calculating the mean weekly catch of beetles in each field. The aptness of the data for parametric models was examined by plotting the residuals to determine if the error variances were independent random variables, and by conducting a test of normality (Shapiro-Wilks statistic). Mean percent white grub damage was analyzed in both a non-transformed and transformed (Log (X+1)) state. The data set consists of four independent variables, mean *P. ephilida* capture, tree line proximity, harvest date, and year and one independent (percent white grub damage). Three of the independent variables are continuous (quantitative), while year is an indicator variable (non-quantitative). Covariance analysis is appropriate when there is a combination of quantitative and non-quantitative variables in a single model (Neter and Wasserman 1974). Data from both years were pooled and analyzed using a covariance analysis with both a transformed and non-transformed dependent variable (Proc COV, SAS Institute 1990). Regression analysis was used to create a predictive equation that relates pheromone trap catch to larval damage (Proc REG, SAS Institute 1990). Records of
Results and Discussion

A) Seasonal Flight Pattern

In 2001, beetles were first captured during late May and early June in St Landry Parish (Table 8.1). The peak beetle capture (2.5 beetles) occurred on 3 July. The number of beetles captured declined to a low level by the end of July and during August. In 2001, in St Martin Parish, the peak beetle capture (60.2 beetles on 19 June) was earlier than in St. Landry Parish and considerably higher. The numbers of beetles captured in each of the 3 trap clusters (location) within fields showed moderate variability (Table 8.2), with significantly different mean capture rates among the clusters detected in most fields. Traps in field centers tended to capture fewer beetles, although this difference was not always statistically significant.

In 2002, peak beetle capture occurred (27.4 beetles) in St. Landry Parish (Table 8.3). The beetle flight ended by early August. In St. Martin Parish, the peak beetle capture (10.5 beetles) occurred on 8 July. Only small numbers of beetles were captured in late July. Overall, more beetles were collected in St. Landry Parish than in St. Martin Parish in 2002. As in 2001, variation in trap catch within fields was moderate, with significant differences between trap clusters (field location) noted in most fields (Table 8.4). Traps in field centers tended to capture fewer beetles, although this difference was not always statistically significant.

The seasonal activity patterns of adult *P. ephilida* differed in the two parishes and within each parish between years. In 2001, St. Landry Parish had a peak activity date of...
3 July, while in 2002 it occurred in 18 June. In St. Martin Parish in 2001, the peak activity level occurred on 19 June, while in 2002 it was on 8 July. While the peaks varied from year to year, adult activity occurred from late May to early August, covering a period of time greater than two months.

B) Aptness of Statistical Model

A plot of the residual error variances with a normal probability line indicated that the data were not normal. A test of normality provided a Shapiro-Wilks value of 0.9325, indicating a departure from normality. To correct these departures, the dependent variable, percentage of roots damaged by white grubs, was transformed with the log (X+1) transformation. This transformation improved both the residual error variance and the normality of the data.

C) Graphical Presentation of Independent Variables

Scatter plots of the relationship between each of the three independent quantitative independent variables with percent white grub damage are presented in Figures 8.1 through 8.6. Plots of mean adult *P. ephilida* per season versus percent white grub damage in 2001 (Figure 8.1) and 2002 (Figure 8.2) illustrates the variability in the relationship between these two variables. It is noteworthy that although some fields had high numbers of beetles with little or no larval damage to roots, none of the fields that had larval damage had no beetles in the traps. This suggests that although beetles may be present in the fields, females may not oviposit in the fields to a substantial extent, or if they do, larval mortality may be high. This is why sampling adult insects to predict larval damage is problematic. These data also suggest that the absence of *P. ephilida* in traps may be a good predictor of little or no white grub damage. Given that most fields in any given year
are not damaged by white grubs, an ability to identify fields that are not at risk to white grub injury would be useful information to growers. The sweetpotato weevil (*Cylas elegantulus* L.) pheromone is used in a very similar manner in sweet potatoes (Ring et al 1996). Although the relationship between weevil catch and larval damage to roots is quite variable, the pheromone is used by growers to identify fields that are at risk to weevil damage.

Plots of tree line distance versus percent white grub damage in 2001 (Figure 8.3) and 2002 (Figure 8.4) suggests that as tree line distance increases, percent white grub damage decreases. Given that adult *P. ephilida* feed on the foliage of deciduous trees, one might expect to find white grub damage to be associated with close proximity to tree lines. It is not known how far female adults fly from their food sources to find oviposition sites. Our data show white grub damage as far as 375 meters from the nearest tree line.

Plots of harvest date versus percent white grub damage in 2001 (Figure 8.5) and 2002 (Figure 8.6) show harvest dates ranging from 205 to 325 days. In 2001, no apparent relationship between the variables is present, while in 2002 a high level of damage in one early harvested field implies earlier harvested fields may be more heavily damaged. This is counterintuitive, given that *P. ephilida* has an annual life cycle with eggs being deposited by adults during June and July. This one field may be an aberration.

**D) Covariance Analysis**

The covariance analysis model consists of four independent variables, mean *P. ephilida* capture, tree line proximity, harvest date, and year. The first three variables are continuous (quantitative), while year is an indicator variable (covariant). Data from both years were pooled and analyzed using a covariance analysis with both a transformed and
non-transformed dependent variable (percent white grub damage). The two models were very similar and the significance levels of the parameters did not change. Hence, further discussion is limited to the model with non-transformed data (Table 8.5). The independent variables, mean *P. ephilida* captured (*F* = 9.93; df = 1; *P* = 0.0023) and year (*F* = 16.26; df = 1; *P* = 0.0001) were significant, while tree line distance (*F* = 2.80; df = 1; *P* = 0.0986) and harvest date (*F* = 1.89; df = 1; *P* = 0.01730) were not significant. The interaction terms mean *P. ephilida* *year* (*F* = 10.01; df = 1; *P* = 0.022), tree line distance *year* (*F* = 6.50; df = 1; *P* = 0.0128), and harvest date *year* (*F* = 10.73; df = 1; *P* = 0.0016) were all significant. Hence the independent variables tree line distance and harvest date had a significant effect on the model through their interaction effect with year. The r-square value of the model was 0.29, indicating that 29% of the variability was explained by the model. The slope of each parameter indicates its contribution to the linear model. The variable mean *P. ephilida* captured had a slope of 0.07, indicating an increase of one beetle per trap was associated with an increase of 7.32 percent root damage. The variable tree line distance had a slope of 0.0004, indicating that an increase in tree line distance of one meter was associated with an increase in root damage of 0.04%. The variable harvest date had a slope of 0.0005, indicating that an increase in one day was associated with an increase of only 0.05% root damage. The indicator variable year had a slope of 0.55 (2001 was assigned a value a value of 0, while 2002 had a value of 1). The highly significant year effect indicates that the relationships of the independent variables to percent white grub damage were different between years. Rainfall in 2002 was excessive (Fig 8.7), resulting in delayed harvests and loss of roots (root rot) due to the anaerobic conditions of the soil. It is likely that these anaerobic conditions were
deleterious to larval white grub populations. The significant interaction of year with mean adult *P. ephilida* trap capture, tree line distance, and harvest date indicates that all three independent variables were affected by differences between the two years. Rainfall in 2001 was close to normal.

**E) Regression Analysis**

Due to the significant year effect, a predictive regression equation cannot be developed with a pooled data set. Because 2001 was a normal growing season, data from this year was deemed to be more representative of most growing seasons. The estimated regression line for percent white grub damage as a function of mean male *P. ephilida* captured per week in 2001 was: 

\[-0.20 + 0.068X_1 + 0.0004X_2 + 0.0007X_3\]

where $X_1 = \text{mean } P. ephilida$, $X_2 = \text{distance to tree line}$, and $X_3 = \text{harvest date}$ (Table 8.6). The model had an $r$-square of 0.18. The variable mean adults captured was significant ($P = 0.0247$) while tree line distance ($P = 0.1290$) and harvest date ($P = 0.1266$) were not significant. The slopes of all 3 variables were positive. White grub damage increased by 6.8 percent with each unit increase of mean adult male *P. ephilida* captured when tree line distance and harvest date were held constant.

The estimated regression line for percent white grub damage as a function of mean male *P. ephilida* captured per week in 2002 was:

\[0.53 - 0.0005X_1 - 0.0003X_2 - 0.0015X_3\]

where $X_1 = \text{mean } P. ephilida$, $X_2 = \text{distance to tree line}$, and $X_3 = \text{harvest date}$ (Table 8.6). The model had an $r$-square of 0.31. The slope of all three variables were negative. Tree line distance ($P = 0.0114$) and harvest date ($P = 0.0012$) were significant, while mean *P. ephilida* adults captured ($P = 0.7506$) was not. Later harvest dates and
greater distances to tree lines were associated with less white grub damage. Data from 2002 were considered atypical because of the excessive rainfall.

Crop consultants or growers could check pheromone traps weekly and keep the average trap catch calculated up to the present time. If the average exceeded a damage threshold of 5% root damage, an insecticide application could be applied that would coincide with the peak flight activity of *P. ephilida*. This has the potential to maximize the effectiveness of the chemical application. The 2001 damage model, based on mean *P. ephilida* capture, projected harvest date, and proximity to tree lines, can be used to predict the expected white grub damage (Table 8.7). A mean of two or more adult *P. ephilida* in pheromone traps on a weekly basis was associated with economic damage by white grubs. However, the model had a low r-square value (0.18), and the relationship did not hold up in 2002, an atypical season. Additional data will be needed to determine if this relationship will hold up across several years.

Pheromone traps have been used to sample a number of insect pests to determine the need for insecticide applications (Metcalf and Luckman 1994). The number of male codling moths (*Cydia pomonella* L.) captured in pheromone traps in apple orchards on a weekly basis is used to determine the need for insecticide applications (Valenti and Madsen 1976). Likewise, the number of male sweet potato weevils captured in pheromone traps in sweet potato fields on a weekly basis is used to determine the need for insecticide applications (Ring et al. 1996). The *P. ephilida* pheromone used with a Japanese Beetle trap provides growers and crop consultants with a valuable IPM tool. The pheromone provides a practical means for consultants to monitor adult activity and
thereby determine the peak flight period and the need for an insecticide application that coincides with beetle oviposition in sweet potato fields.
Table 8.1. Mean weekly catch of male *Phyllophaga ephilida* in pheromone traps located in ten commercial sweet potato fields in St. Landry and St. Marin Parishes, Louisiana, 2001.

<table>
<thead>
<tr>
<th>Date</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>St. Landry</th>
<th>St. Martin</th>
</tr>
</thead>
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<td>--</td>
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<td>--</td>
</tr>
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<td>--</td>
<td>--</td>
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<td>0</td>
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<td>1.5</td>
<td>--</td>
<td>--</td>
<td>0.3</td>
<td>--</td>
</tr>
<tr>
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<td>1.3</td>
<td>2.3</td>
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<td>0.5</td>
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<td>23.7</td>
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<td>23.5</td>
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<td>0.5</td>
<td>1.1</td>
<td>0.1</td>
<td>11.5</td>
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</tr>
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<td>0.4</td>
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<td>0.5</td>
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</tr>
<tr>
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<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.1</td>
<td>--</td>
</tr>
</tbody>
</table>

*Average number of P. ephilida in 15 pheromone traps per field. Fields 1-8 were in St. Landry Parish while Fields 9-10 were in St. Martin Parish.*
Table 8.2. Mean seasonal catch of male *Phyllophaga ephilida* relative to pheromone trap placement in ten commercial sweet potato fields in St. Landry and St. Martin Parishes, Louisiana, 2001.

<table>
<thead>
<tr>
<th>Location</th>
<th>Field 1</th>
<th>Field 2</th>
<th>Field 3</th>
<th>Field 4</th>
<th>Field 5</th>
<th>Field 6</th>
<th>Field 7</th>
<th>Field 8</th>
<th>Field 9</th>
<th>Field 10</th>
<th>St. Landry</th>
<th>St. Martin</th>
</tr>
</thead>
<tbody>
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<td>West</td>
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<td>0.5ab</td>
<td>0.8a</td>
<td>1.8ab</td>
<td>2.2a</td>
<td>0.5b</td>
<td>1.3a</td>
<td>1.5ab</td>
<td>15.6bc</td>
<td>12.2cd</td>
<td>1.1</td>
<td>13.9</td>
</tr>
<tr>
<td>North</td>
<td>1.0ab</td>
<td>0.1ac</td>
<td>1.6a</td>
<td>1.5a</td>
<td>1.0b</td>
<td>0.4b</td>
<td>0.7b</td>
<td>1.6a</td>
<td>16.3b</td>
<td>50.8a</td>
<td>0.9</td>
<td>33.5</td>
</tr>
<tr>
<td>East</td>
<td>1.2a</td>
<td>0.8a</td>
<td>1.6a</td>
<td>0.9a</td>
<td>1.0b</td>
<td>0.3b</td>
<td>1.7a</td>
<td>1.3ab</td>
<td>18.7b</td>
<td>20.6cb</td>
<td>1.1</td>
<td>19.6</td>
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<tr>
<td>South</td>
<td>0.4ab</td>
<td>0.6ab</td>
<td>0.9a</td>
<td>1.1a</td>
<td>0.5b</td>
<td>1.0a</td>
<td>1.6a</td>
<td>1.0ab</td>
<td>28.4a</td>
<td>9.7d</td>
<td>0.8</td>
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</tr>
<tr>
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<td>0.2b</td>
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\(^1\) Mean separation with same letter are not significantly different based on Tukey test, \(\alpha = 0.05\). Fields 1-8 were in St. Landry Parish while Fields 9-10 were in St. Martin Parish.
Table 8.3. Mean weekly catch of male *Phyllophaga ephilida* in pheromone traps located in nine commercial sweet potato fields in St. Landry and St. Martin Parishes, Louisiana, 2002.

<table>
<thead>
<tr>
<th>Date</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>St. Landry</th>
<th>St. Martin</th>
</tr>
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<tbody>
<tr>
<td>4 June</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>9.3</td>
<td>5.1</td>
<td>--</td>
<td>7.2</td>
</tr>
<tr>
<td>11 June</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
<td>8.7</td>
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<td>1.0</td>
<td>4.8</td>
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<td>0.2</td>
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<td>0.2</td>
</tr>
<tr>
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<td>0.1</td>
<td>0.2</td>
<td>--</td>
<td>--</td>
<td>2.1</td>
<td>9.6</td>
<td>--</td>
<td>--</td>
<td>2.4</td>
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<td>1.1</td>
<td>8.4</td>
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<td>--</td>
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<tr>
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<td>--</td>
<td>--</td>
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<td>1.0</td>
<td>6.1</td>
<td>--</td>
<td>--</td>
<td>3.5</td>
<td>--</td>
</tr>
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</table>

1average number of *P. ephilida* in 15 pheromone traps per field. Fields 1-7 were in St. Landry Parish while Fields 8-9 were in St. Martin Parish.
Table 8.4. Mean seasonal catch of male *Phyllophaga ephilida* relative to pheromone trap placement in nine commercial sweet potato fields in St. Landry and St. Martin Parishes, Louisiana, 2002.

Mean *P. ephilida* captured per season

<table>
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<tr>
<th>Location</th>
<th>Field</th>
<th>Seasonal Mean/Parish</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>West</td>
<td>7.9b</td>
<td>10.2a</td>
</tr>
<tr>
<td>North</td>
<td>4.3c</td>
<td>2.9c</td>
</tr>
<tr>
<td>East</td>
<td>14.2a</td>
<td>5.4bc</td>
</tr>
<tr>
<td>South</td>
<td>5.0cb</td>
<td>9.4a</td>
</tr>
<tr>
<td>Middle</td>
<td>4.4c</td>
<td>7.1a</td>
</tr>
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</table>

1 means with same letter are not significantly different based on Tukey test, $\alpha = 0.05$. Fields 1-7 were in St. Landry Parish while Fields 8-9 were in St. Martin Parish.
Table 8.5. Covariance analysis model of percent white grub damaged roots (non-transformed) as a function of mean adult *Phyllophaga ephilida* capture, tree line distance, harvest date, year, and interactions.

<table>
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<tr>
<th></th>
<th>P-value</th>
<th>Parameter estimate</th>
<th>Standard error</th>
</tr>
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<tr>
<td>Intercept</td>
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<tr>
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</tr>
<tr>
<td>Tree line distance</td>
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<td>0.0002</td>
</tr>
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<td>Harvest *Year</td>
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\(^1\) R-square value for model = 0.29.
Table 8.6. Regression equations predicting percent white grub damage as a function of mean *Phyllophaga ephilida* captured per week, distance from tree line and harvest date, 2001 and 2002.

<table>
<thead>
<tr>
<th>Model</th>
<th>Year</th>
<th>Variables</th>
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<th>Parameter Estimate</th>
<th>P-Value</th>
<th>Parameter Estimate</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Mean</td>
<td></td>
<td>Mean captured adults</td>
<td>0.0247</td>
<td>0.06798</td>
<td>0.7506</td>
<td>-0.0005</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tree line distance</td>
<td>0.1290</td>
<td>0.00044</td>
<td>0.0114</td>
<td>-0.0003</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harvest date</td>
<td>0.1266</td>
<td>0.00077</td>
<td>0.0012</td>
<td>-0.0015</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Intercept</td>
<td>0.1394</td>
<td>-0.20</td>
<td>&lt;.0001</td>
<td>0.53</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>r-square</td>
<td></td>
<td>0.180</td>
<td></td>
<td>0.3122</td>
<td></td>
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</tbody>
</table>
Table 8.7. Predicted percent white grub damage to sweet potatoes using the 2001 regression damage model

<table>
<thead>
<tr>
<th>Mean Phyllophaga</th>
<th>Harvest Date (Julian)</th>
<th>Predicted % Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>250</td>
<td>2.1</td>
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<tr>
<td>1.0</td>
<td>300</td>
<td>5.6</td>
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<td>15.6</td>
</tr>
<tr>
<td>2.0</td>
<td>330</td>
<td>17.7</td>
</tr>
</tbody>
</table>

¹ Y = -0.20 + 0.068X₁ + 0.0004X₂ + 0.00077X₃, where X₁ = mean Phyllophaga, X₂ = proximity of trees, and X₃ = harvest date. Tree line distance held constant at 30 m.
Figure 8.1. Plot of mean adult *P. ephilida* per season versus mean percent white grub damage to sweet potatoes, 2001.

Figure 8.2. Plot of mean adult *P. ephilida* per season versus mean percent white grub damage to sweet potatoes, 2002.
Figure 8.3. Plot of mean distance to tree line (m) versus mean percent white grub damage to sweet potatoes, 2001.

Figure 8.4. Plot of mean distance to tree line (m) mean percent white grub damage to sweet potatoes, 2002.
Figure 8.5. Plot of harvest date (days) versus mean percent white grub damage to sweet potatoes, 2001.

Figure 8.6. Plot of harvest date (days) versus mean percent white grub damage to sweet potatoes, 2002.
Figure 8.7. Monthly rainfall (cm) in comparison to normal rainfall at Fontenot Farm, St. Landry Parish, LA in 2002.
Literature Cited


A series of experiments was conducted to increase our knowledge of the biology of P. ephilida (Say) and to improve our management of this pest of sweet potatoes in Louisiana. The life cycle of P. ephilida was determined to be univoltine in southern Louisiana. Larvae overwinter as a third instar in the soil, pupation occurs at the end of the spring, and adults emerge and are active from May through early August. Adults feed on foliage of deciduous trees. In laboratory experiments, we evaluated the preference of P. ephilida for the foliage of water oak, live oak, red maple, slash pine, pecan, sweetgum, southern magnolia, and American elm. Beetles displayed a feeding preference for pecan, American elm, and water oak, as indicated by leaf area and weight consumed in choice tests. Magnolia and slash pine were not fed upon at all. These tree species are common in tree lines along the edge of sweet potato fields in Louisiana, and their presence provides the adults a source of food. In laboratory experiments we investigated the influence of soil moisture, organic matter content, and soil texture on the burrowing behavior of adult P. ephilida males. Soil moisture and organic matter content had a significant effect on the depth of burrowing (deeper burrows associated with higher levels of soil moisture and higher levels of organic matter), while soil texture did not affect burrowing depth. Adults seek shelter during the day in soil or under leaf litter, and an understanding of their preferred habitat for burrowing would help us identify the habitats where adults might be found during the day. A survey of the seasonal occurrence of common adult Phyllophaga species associated with sweet potato production areas was conducted with blacklight traps to determine which Phyllophaga species may be responsible for larval damage in sweet potato production areas. P. ephilida and P. crinita were the most abundant species collected in the blacklight traps at all locations. They were most active in June and July.
*P. hirtiventris*, *P. profunda*, *P. bipartita*, and *P. latifrons* were also active during this period, but were less numerous. The availability of a pheromone to monitor adult activity of *P. ephilida* would enhance our ability to study this pest and provide growers and crop consultants with a monitoring tool. The attractiveness of the methyl esters of L-isoleucine and L-valine in several blend ratios to adult male *P. ephilida* was evaluated in grower fields. The 100% methyl ester of L-isoleucine was highly attractive to males and captured significantly more beetles than all other blend ratios. This pheromone is an effective monitoring tool for *P. ephilida*. The potential of this sampling method for use as a tool by growers or scouts to predict white grub injury to sweet potatoes was investigated in a two year study in nineteen sweet potato fields. Each field was monitored with 15 pheromone traps that were checked weekly for adult *P. ephilida*. Data on percent white grub injury to sweet potatoes, the proximity of pheromone traps to tree lines, and the harvest date of the crop were collected. An analysis of covariance revealed that percent white grub damaged roots was significantly affected by mean adult *P. ephilida* captured in pheromone traps, whereas proximity to tree lines and harvest date were not significant. The year effect was significant as were interactions between year and tree line, year and harvest date, and year and mean adult capture. The covariance model had an r-square of 0.29. A linear polynomial regression model predicting white grub damage as a function of trap catch, tree line proximity and harvest date was developed. The model had an r-square of 0.18. It estimates a damage threshold (5% root damage) of one to two *P. ephilida* per week in pheromone traps. The pheromone trap provides sweet potato growers with a practical means to monitor adult beetle activity. Pheromone trap catch data can be used to
determine the peak flight period and assess the need for an insecticide application
timed to coincide with beetle oviposition.
VITA

Mr. Aboubacar Diagne is a citizen of the Republic of Senegal in West Africa where he obtained a diploma of Baccalaureat de l’ Enseignement du 2nd Degree (Serie D-Mathematiques et Sciences de la Nature). In 1975, he entered the Kuban Agricultural Institute in Krasnodar, Russia, for language study and preparatory courses before joining the Ukrainian Academy of Agriculture in Kiev. He obtained a diploma in agricultural engineering and a Master of Science in agriculture with a specialization in plant protection in April 1981. Later, he obtained a Master of Science in plant and soil science at Southern Illinois University in Carbondale in July 1986. He has occupied several responsibilities in the Department of Agriculture in Senegal and has received various fellowships, among them the AFGRAD/AAI. He is currently a candidate for the Degree of Doctor of Philosophy in entomology, with a minor in horticulture, at Louisiana State University and Agricultural and Mechanical College.