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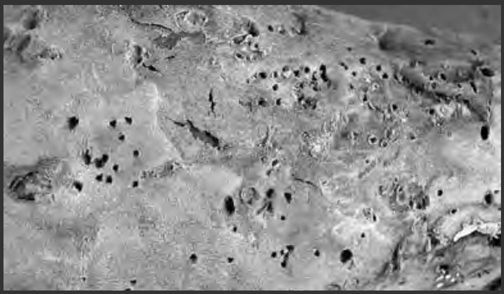
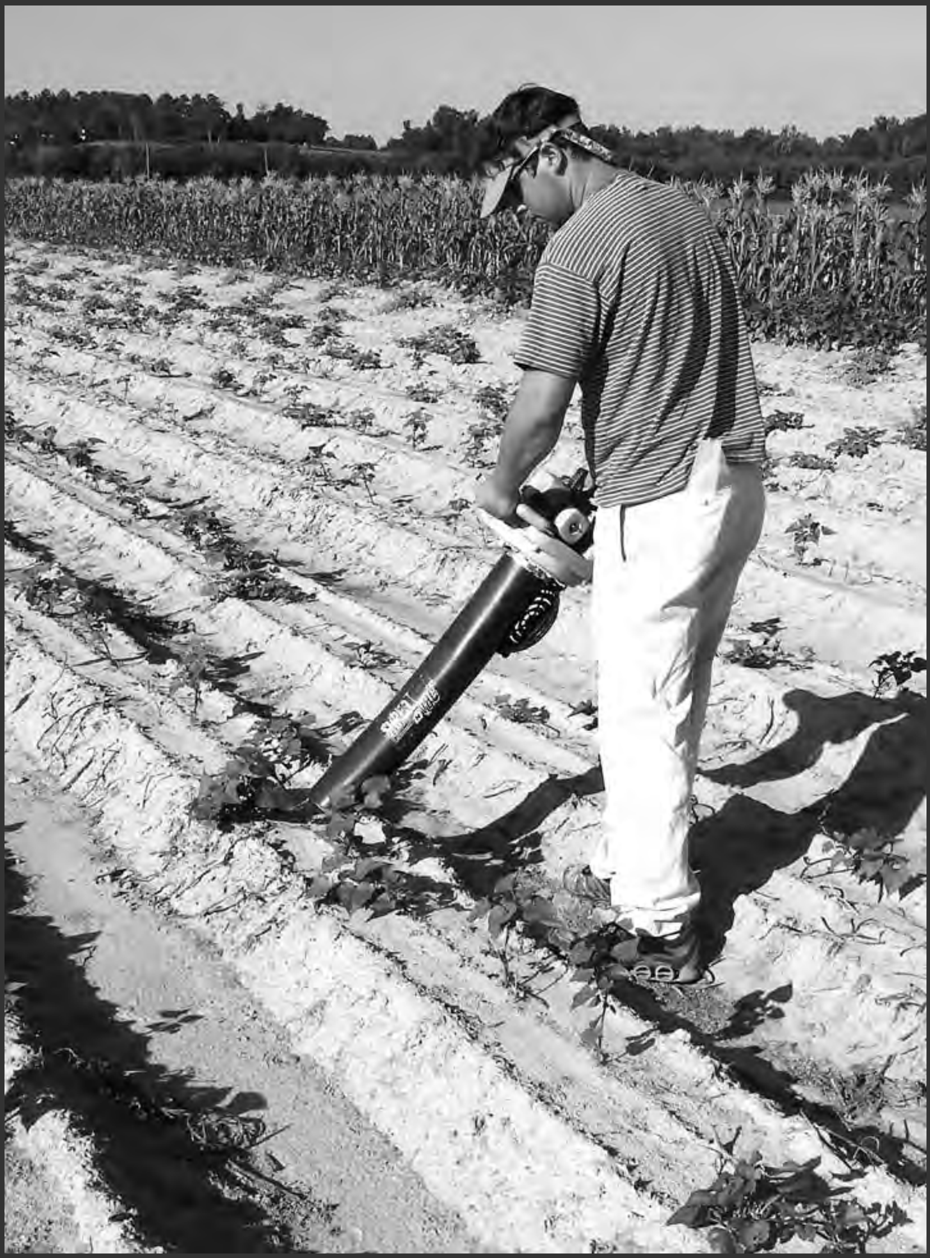
Results of Southern Sweetpotato IPM Project in Mississippi





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Mississippi Agricultural & Forestry Experiment Station • Melissa J. Mixon, Interim Director

Mississippi State University • Mark E. Keenum, President • Gregory A. Bohach, Vice President

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Jack T. Reed
Research Professor
Entomology and Plant Pathology
Mississippi State University

Mark W. Shankle
Associate Research Professor
North Mississippi Research and Extension Center

Michael R. Williams
Extension Professor (Retired)
Entomology and Plant Pathology
Mississippi State University

William Burdine
Area Extension Agent
Chickasaw County Extension Service

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Abstract

Results of research to identify factors of sweetpotato production associated with insects and cultural practices in Mississippi are discussed. Commercial sweetpotato growers cooperated in the project by providing large plots of sweetpotatoes with different insecticide application scenarios. This bulletin discusses results of the following insecticide scenarios: (1) no insecticide; and (2) preplant-incorporated insecticide plus foliarly applied insecticide during the season. Potatoes from these plots were evaluated for insect damage that was then associated with insects sampled from each plot during the season. Results include the listing of insect species associated with sweetpotatoes, determination of primary insect pests, analysis of their likely population trends during the growing season, and evaluation of insect damage on sweetpotatoes. Cultural factors including planting date, harvest date, and time between preplant-incorporated insecticide application and planting date are discussed in relation to sweetpotatoes damaged by primary insect pests.

Results of Southern Sweetpotato IPM Project in Mississippi

Introduction

The Southeast is the center of commercial sweetpotato production in the United States, with North Carolina, Louisiana, Mississippi, and Alabama representing 78% of nationwide production. Mississippi produced $67,550,000 worth of sweetpotatoes from 20,000 harvested acres in 2007, about 18% of the nation's gross product, and ranked third in the nation for value of sweetpotato production (Table 1). Acreage planted to sweetpotatoes in Mississippi has increased dramatically over the last 10 years (Table 2), indicating the potential for continued growth in sweetpotato production in the state.

The acreage planted to sweetpotatoes annually in the United States is relatively small compared with the acres devoted to major row crops. The sweetpotato is considered a minor use or IR4 (Interregional Project 4, minor use pesticides) crop based on pesticide use. Due to the small acreage devoted to sweetpotato production, it is difficult to obtain funding from the agriculture industry to evaluate crop inputs for use on sweetpotatoes, and labeling of pesticides for use on sweetpotatoes lags behind that of major crops. Also, funding specifically for sweetpotato research is generally lacking and difficult to secure. Because of this, researchers from the four Southeastern sweetpotato-producing states sought funding for an in-depth evaluation of integrated pest management (IPM) in sweetpotatoes. The resulting Southern Sweetpotato IPM Project was funded by a USDA-affiliated program called the Risk Assessment and Mitigation Program (RAMP). A total of $2 million was awarded to researchers and Extension personnel in North Carolina, Alabama, Louisiana, and Mississippi for a 4-year period. The first goal of the project was to identify field characteristics, production practices, and postharvest practices that are associated with root damage in sweetpotatoes by various root-feeding insects and postharvest diseases. The research included evaluation of herbicides, evaluation of the benefits of preplant-incorporated and foliar insecticide treatments,

Table 1. Value of sweetpotato production in top production states for 2007.[1]

State rank	State	Value of production
1	North Carolina	$148,286,000
2	California	80,864,000
3	Mississippi	67,550,000
4	Louisiana	59,378,000
5	Alabama	9,187,000

[1]Source: National Agricultural Statistics Service (http://www.nass.usda.gov/).

Table 2. Mississippi sweetpotato annual production data.[1]

Year	Planted all purposes[2]	Harvested[2]	Hundredweight per acre
1997	8.6	8.4	130
1998	9.8	9.7	140
1999	10.5	10.3	150
2000	12.7	12.3	120
2001	16.7	16.0	150
2002	16.0	12.3	160
2003	14.0	13.6	175
2004	16.0	15.3	170
2005	17.4	17.3	180
2006	18.0	15.5	160
2007	20.5	20.0	175

[1]Source: National Agricultural Statistics Service (http://www.nass.usda.gov/).
[2]Thousand acres.

and identification of insect pests. Effects of these factors on sweetpotato damage are discussed in this bulletin.

Insects historically known to damage sweetpotato roots during the growing season include spotted cucumber beetles (*Diabrotica undecimpuntata howardi* Barber), banded cucumber beetles (*D. balteata* LeConte) (Cuthbert and Reid 1965, Cuthbert 1967), sweetpotato flea beetles (*Chaetocnema confinus* Crotch) (Kantack and Floyd 1956, Chalfant et al. 1979), *Systena* flea beetles (several species of the genus *Systena*) (Thomas 1927, Schaulk et al. 1991), white-fringed beetles (*Naupactus leucoloma* [Boheman] and *N. perigrinis* [Buchanan]) (Zehnder 1997), sugarcane beetles (*Euetheola humilis* [LeConte]) (Smith 2006), white grubs (larvae of May/June beetles of the genus *Phyllophaga*) (Kantack and Floyd 1956, Cuthbert and Reid 1965), and wireworms (larvae of the click beetle genera *Conoderus*, *Heteroderes*, and *Melanotus*) (Griffin and Eden 1953, Fronk and Peterson 1956, Cuthbert Jr. 1967, Seal 1990, Chalfant and Seal 1991). Some of these insects can be extremely damaging, and wireworms, white-fringed beetles, and sugarcane beetles may cause sufficient damage to greatly reduce profit. Although the sweetpotato weevil (*Cylas formicarius elegantulus* [Summers]) occurs in the state, the primary sweetpotato production area in Mississippi is within a quarantine zone for this pest and it is rarely a problem. This research has helped to elucidate the economical importance of these insects in sweetpotato production in Mississippi and to evaluate current agronomic practices used to protect the crop from insect damage.

Materials and Methods

Treatments

Several sweetpotato growers participated in the RAMP project by contributing sections of their fields to establish large strip-plots near Vardaman, Mississippi, from 2004 to 2007. Nineteen strip-plots were harvested from cooperative grower locations in 2004, 19 in 2005, 18 in 2006, and 4 in 2007. Each field had six subplots (sample sites) for all treatments. At least 25 different fields were scheduled for inclusion in studies each year before 2007, but adverse environmental conditions (primarily drought), inadvertent aerial chemical applications, or other factors reduced the number of fields in the program. Two treatments were used during 2004 and 2005: (1) an untreated check (NO INSECTICIDE); and (2) the "farmer standard" treatment, preplant-incorporated insecticide plus foliarly applied insecticides during the season (PPI/POST). During 2006 and 2007, four fields included a postemergence insecticide application (POST) without PPI, and a preplant-incorporated application of insecticide only (PPI) without postemergence applications, as well as the NO INSECTICIDE and PPI/POST treatments. Insecticides used in the "farmer standard" treatments varied based on grower preference, but they included only insecticides labeled for use in sweetpotato. Each strip-plot was at least eight rows wide and 300 feet long in 2004, positioned with the NO INSECTICIDE check plots at the edge of the field. After 2004, strip-plot widths were increased to a minimum of 12 rows for the remaining study period, and many growers positioned all plots in the center of the field to help eliminate border effects in the data.

A trial was conducted at the Delta Research and Extension Center in Stoneville, Mississippi, to evaluate the effects of rotation on sweetpotatoes following corn, cotton, soybeans, sweetpotatoes, and fallow ground. Sweetpotatoes were planted in 2004 and 2005, the rotation crops were planted in 2006, and sweetpotatoes were planted again in 2007. Plots were 16 rows wide by 50 feet long with four replications. Sweetpotatoes were not sprayed with insecticide because there were few pests. However, the rotation crops were treated as needed with insecticide. At the end of 2007, sweetpotatoes were harvested from 15 feet of each of the center two rows of each plot. Up to 100 potatoes per plot were evaluated for insect damage as described below for root injury.

Insect Sample Collection

Each strip-plot was divided into six subplots 50 feet long. Each subplot was the basis for sampling. Sweep-net samples were used throughout the study; however, vacuum samples, sticky cards, and bait traps were also used during portions of the study. Because of the number of subplots and fields that required sampling, no attempt was made to sample all plots at the same time of day. Sweep-net samples were made with a 19-inch sweep-net by taking 25 sweeps along 50 feet of row. Vacuum samples were made by holding the intake nozzle of a gasoline-powered leaf vacuum (Figure 1) in the foliage and waving it back and forth along 25 feet of row. During 2006, vacuum sampling was used instead of sweep-net sampling for the first few weeks in each field immediately after planting to eliminate sweep-net damage to sensitive transplants. In 2005, 3x5-inch yellow sticky cards (Figure 2) were added to the sampling protocol for insect pests. Two cards were placed in each subplot in 2005, and one was placed in each subplot in 2006. Sticky cards were left in the fields for 1 week before counting the insects.

In 2004 and 2005, one wireworm bait trap (Figure 3) consisting of about 2 cups of wet crimped oats (Jansson and Lecrone 1989, Cherry and Alverez 1995) was placed about 6 inches deep in the soil in each subplot before planting (when possible) and again during midseason. These baits were left in the field for 1 week and dug up with a handheld post-hole digger. Soil and bait were taken to the laboratory and sifted if the samples were dry or mixed with water to separate wireworms from the soil.

Harvest and Yield

Sweetpotato roots were harvested with a shovel from 15 feet of row in each subplot a few days before commercial harvesting. Roots were graded into U.S. No.1, canner, and jumbo grades using National Sweetpotato Collaborator's standards and weighed. Twenty-five marketable roots (U.S. No.1, canners, or jumbos) were saved from each subplot for evaluation of insect damage, making a total of 150 sweetpotatoes examined from each treatment strip (NO INSECTICIDE, PPI/POST, PPI, or POST) in each field. Data provided by the producers included cultivar, planting date, and insecticide/herbicide application records. In some fields, more than one harvest-sample was dug in order to evaluate the effect of time on insect damage for late-harvested crops.

Root Injury

The sweetpotatoes from each plot were washed, and the number of insect-caused scars on each root was recorded. The percentage of roots damaged with each scar type was then computed. After 2004, the general time period in which injury occurred was assessed during root examination. This assessment was done by determining if the scar was healed over with new skin (old damage) or if the scar was fresh and not healed over (new damage). The following criteria were used to

Figure 1. Hand vacuum sampler.

Figure 2. 3x5-inch sticky card with 30 square-inches of sticky surface (adhesive on both sides).

Figure 3. Wireworm bait trap: hole (left), hole with bait and soil (center), and hole with soil plug replaced (right).

differentiate types of scar damage and the insect species associated with the scar type:

Tracks: Sweetpotato flea beetle — Very narrow winding channels (1–2 mm wide) (Tysowsky 1971) (Figure 4 A).

Channels: White-fringed beetle — Narrow channels (1–5 mm wide), usually on distal end of root (Zehnder et al. 1998) (Figure 4 B, C).

Shallow gouge: White grubs — Broad, rough, shallow gouges (5–10 mm wide) usually contiguous (Figure 4 D) (Hammond et al. 2001).

Deep gouge: Sugarcane beetles — Broad rough, shallow to deep gouges (about 10 mm wide), often with separate shallow holes broader than deep (Smith 2006) (Figure 4 E).

Smooth gouge: Cutworms and armyworms — Broad, shallow to deep, smooth gouges and holes (Hammond et al. 2001) (Figure 4 F).

Pinhole: *Systena* flea beetles — Very small pinhole injury (1 mm diameter or less) (Thomas 1927). This is typical late-season damage for *Systena* flea beetle larvae. Older damage may resemble cucumber beetle damage (Schaulk et al. 1991). However, only pinhole damage was designated as *Systena* damage in the study (Figure 4 G).

Small hole: Cucumber beetle larvae (*Diabrotica* beetles) — Small, round holes clumped on the root surface (1–3 mm diameter), sometimes with irregular shaped, enlarged cavities underneath, sometimes healed and "crater-like" (Byrd et al. 1999, Hammond et al. 2001) (Figure 4 H, I).

Deep hole: Wireworms — Holes of various diameters (2–8 mm diameter), generally deep perhaps with irregular shaped, enlarged cavities underneath, may be partially healed and are usually random on root surface (Chalfant and Seal 1991) (Figure 4 J).

Damage to roots by *Systena* flea beetle, wireworm, and cucumber beetle may be very similar (Chalfant and Seal 1991, Schaulk et al. 1991), and damage from these insects are often presented as a "WSD" index representing damage from Wireworm, *Systena,* and *Diabrotica* species. Because the protocol differentiated among the damage patterns caused by these species, data will not be presented as a WSD index for that pest group. However, it is important to note that assignment of causal insect to the damage on sweetpotatoes is not absolute. Sugarcane beetle and white grub damage are similar also, but since the damaging flight of sugarcane beetles enters fields in late July and August, early-season damage can hypothetically be assigned to white grubs.

Data Analyses

Broad trends and generalities associated with PPI/POST and NO-INSECTICIDE treatments describing insect damage were obtained from data averaged across subplots within strip-plots. Differences between treatment means of percentage of potatoes with specific damage types were identified by ANOVA (type III sums of squares) using a mixed model procedure with years and fields as random variables, and means were separated by use of the least significant difference option (LSD). Before analysis, data were examined by visual examination of histograms and normal probability plots for raw and transformed data in order to select the best option for analysis. Regression equations to determine the effect of time-associated factors on insect damage were obtained by use of the Multiple Regression module or correlation procedures of the STATISTICA data analysis software system (STATISTICA, version 8.0. www.statsoft.com) or with SAS analysis software version 9.1.3 (SAS institute, Carey, North Carolina).

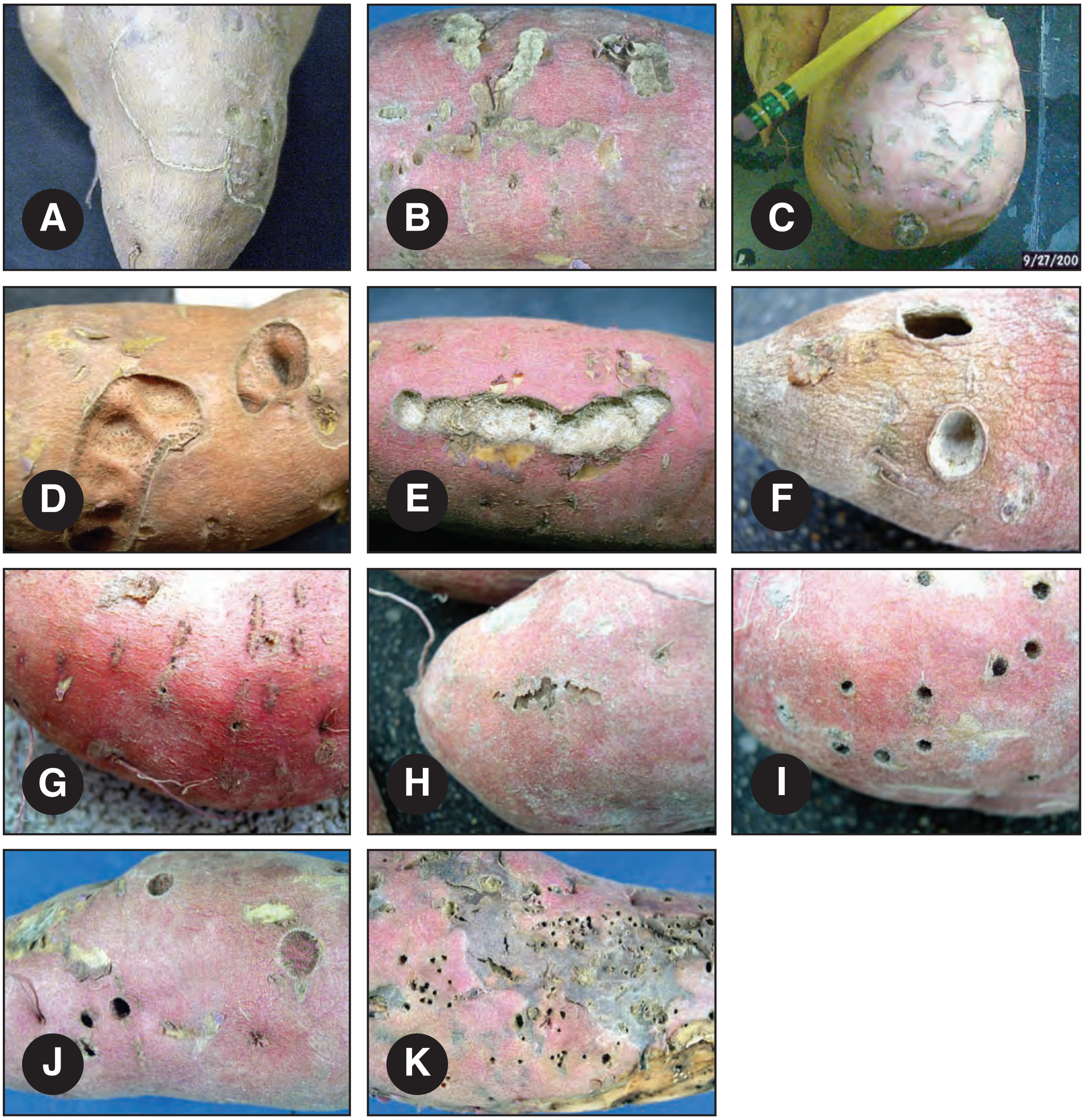

Figure 4. Typical damage according to protocol (suspected causal insect):

A — Sweetpotato Flea Beetle Tracks (sweetpotato flea beetle);
B, C — Narrow Channels (white-fringed beetle);
D — Shallow Gouges (white grub);
E — Deep Gouge (sugarcane beetle);
F — Smooth Gouges (Lepidoptera larvae — cutworm, armyworm);
G — Pinhole Damage (*Systena* flea beetles);
H, I — Small Hole (cucumber beetles);
J — Deep Hole (wireworm); and
K — Sweetpotato Weevil Damage.

Results and Discussion

Pesticide Impacts

Preplant-incorporated applications included chlorpyrifos, bifenthrin, aldicarb, ethoprop, metam-potassium, or combinations. The POST treatments ranged from zero to five per field and included bifenthrin, endosulfan, methyl parathion, beta-cyfluthrin, or deltamethrin. A comparison of at-harvest root damage for the PPI/POST treatment system with that of the NO INSECTICIDE check is summarized in Table 3. Mean percentage of roots damaged in the PPI/POST treatment differed from that of the NO INSECTICIDE treatment by only 6%, with a range of 0–53%. The percentage of potatoes with small-hole and deep-hole injury and the percentage receiving damage from insects were significantly reduced by the farmer standard PPI/POST insecticide application. However, the root injury identified as deep gouges, tracks, smooth gouges, and channels was not significantly greater in the NO INSECTICIDE plots compared with PPI/POST-treated plots. Therefore, the data indicate that numbers of cucumber beetle and wireworm larvae are reduced by the PPI/POST treatments. Although the percentage of potatoes receiving damage other than small or deep holes may differ considerably between treated and untreated plots (Table 3), variation of data prevent identification of statistical significance in these damage types.

Insect control was variable among fields using different insecticides for PPI applications (Table 4). In some instances, there were fewer damaged potatoes in plots with NO INSECTICIDE than in plots with a PPI/POST insecticide system. This variation could be due to the type of insecticide used in certain "farmer standard" treatments. A few fields in the study were treated with Kpam (metam-potassium), which is a fumigant used for nematode management that would have no activity on insects developing during the season but should have activity on any eggs, larvae, or pupae in the soil at the time of insecticide application. This treatment could also affect biological constituents such as bacteria and fungi of the soil that would not be impacted by standard insecticidal treatments. It is interesting to note that the mean percentage of potatoes damaged in Kpam-treated fields is considerably higher than in fields not treated with Kpam. Further use of this product and future research may reveal whether this phenomenon is real and what impact Kpam may have on organisms that may contribute to insect mortality later in the season. Because some treatment combinations were used in only one field, no differential analyses were performed on the data.

Figure 5 shows how the percentage of damaged potatoes was affected by multiple insecticide applications to sweetpotato foliage. The difference between the percentages of insect-damaged potatoes in the NO INSECTICIDE and PPI/POST was 3.8% for fields receiving no spray applications; 4.3%, one application; 5.7%, two applications; 12.3%, three applications; 10.6%, four applications; and 39.3%, five applications. Correlation of number of spray applications with the arcsin(sqrt) transformation of the difference between the percentage of insect-damaged potatoes in NO INSECTICIDE plots and that in PPI/POST plots resulted in a significant relationship between number of insecticidal

Table 3. Mean percent and standard deviation (SD) of roots with various damage types and the percent of undamaged roots averaged over 4 years and PPI/POST and NO INSECTICIDE plots.[1]

Insect	NO INSECTICIDE		PPI/POST[2]		Prob. F
	Mean	SD	Mean	SD	
Small holes (Cucumber beetles)[3]	**12.13 a**	**15.62**	**11.61 b**	**16.32**	<0.0001
Deep holes (Wireworms)	**7.58 a**	**12.90**	**5.03 b**	**9.44**	0.0003
Pinholes (Systena flea beetles)	6.60 a	10.73	6.34 a	9.74	0.2057
Tracks (Sweetpotato flea beetle)	2.72 a	6.36	1.85 a	4.77	0.1757
Channels (White-fringed beetles)	2.02 a	6.39	0.98 a	3.20	0.1073
Deep gouge (Sugarcane beetle)	1.49 a	5.69	0.99 a	3.04	0.8299
Shallow gouge (White grubs)	3.10 a	5.56	2.18 a	4.73	0.5197
Undamaged	**67.98 a**	**24.37**	**73.98 b**	**22.72**	0.0006

[1]The best estimate of probable insect cause is listed in parentheses next to the damage type as an indicator of variation in the data.
[2]PPI + INSECTICIDE — Plots receiving preplant-incorporated insecticide and foliar applications of insecticide during season.
[3]Means within a row not sharing a common letter (bold print) differ significantly between treatments (LSD; p=0.05), based on arcsin(sqrt) transformation.

PPI Components	Strip treatment	Percent damaged	Number of fields	Std. deviation
Brigade	No Insecticide PPI + Foliar	38.0 25.8	1	19.2 13.5
Lorsban	No Insecticide PPI + Foliar	32.3 24.0	22	26.3 21.7
Lorsban, Brigade	No Insecticide PPI + Foliar	48.4 36.0	1	04.8 13.4
Lorsban, Kpam	No Insecticide PPI + Foliar	60.5 39.1	4	24.2 31.0
Lorsban, Mocap	No Insecticide PPI + Foliar	34.8 28.2	15	22.5 23.2
Lorsban, Mocap, Kpam	No Insecticide PPI + Foliar	54.7 54.7	1	25.2 18.8
Lorsban, Temik	No Insecticide PPI + Foliar	17.9 11.2	1	22.0 09.5
Mocap	No Insecticide PPI + Foliar	17.1 19.8	3	09.5 12.7
All Groups		30.7	48	24.6

Table 4. Mean percent and standard deviation (SD) of potatoes damaged by insects at harvest related to strip treatment and insecticidal compounds applied PPI (preplant-incorporated) and the number of fields treated with each insecticide or insecticide combination, 2004–2007.

sprays and the percentage of damaged potatoes (p=0.0265, R=0.8639, slope 0.0857). This indicates that spray applications (in addition to PPI insecticides) are effective in reducing insect damage in Mississippi sweetpotatoes, with an overall reduction of 8.6% of insect-damaged roots with each additional application of insecticide. The mean numbers per sample of all insects with root-damaging larvae for NO INSECTICIDE strips in fields with 0–5 applications of postemergence insecticide were 3.6, 4.1, 3.7, 3.1, 2.1, 1.9, indicating that high insect numbers were not the stimulus for additional insecticide applications. However, lower numbers of insects in the check plots may have been a factor of drift from insecticide applications, or reduced movement of insects from the treated portion of the fields into the NO INSECTICIDE strips.

Insect Sample Collection

The numbers of insects collected from foliage using vacuum, sweep-net, and sticky card sampling techniques during 2005 are summarized in Table 5. Sticky cards remained in the field for a week before evaluation, compared with real-time sampling with the vacuum and sweep-net techniques, thus results of sticky cards cannot be directly compared with those of the other sample methods. Sticky cards proved to be very good for sampling highly mobile insects like flea beetles, click beetles, and tortoise beetles. The number of cucumber beetles collected in sweep-net samples was similar to the number collected on sticky cards. Although white-fringed beetles were collected in sweep-net samples, few white-fringed beetles were collected with any sampling method.

Insect species recognized as damaging to sweetpotatoes collected from strip-plots during 2004–2007

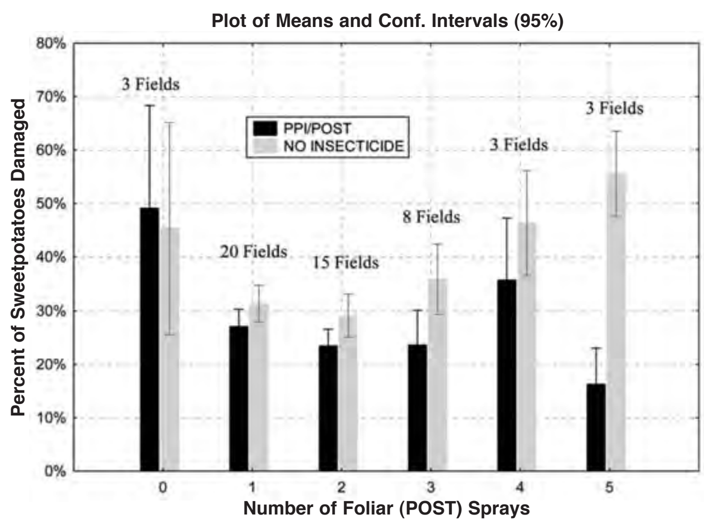

Figure 5. Mean percentage of sweetpotatoes damaged by insects in strip plots with PPI/POST treatment and NO INSECTICIDE treatment for fields with 0–5 POST spray applications.

Table 5. Mean number of insects per sample (x100) from vacuum samples, sticky cards, and sweep-net samples for 2005 averaged across all fields and sample dates.						
	Vacuum		Sticky card		Sweep-net	
	Mean	SD	Mean	SD	Mean	SD
12-spotted cucumber beetle	02.2	17.5	08.2	28.7	09.5	41.5
All click beetles	00.3	05.3	17.8	56.7	0.6	08.5
All cucumber beetles	02.2	17.5	09.9	35.1	10.8	44.7
All tortoise beetles	04.7	25.3	105.7	169.4	19.9	77.7
Banded cucumber beetle	00.0	00.0	01.7	19.7	01.3	16.4
Red-headed flea beetle	05.9	25.6	71.1	143.7	20.7	61.5
Sweetpotato flea beetle	87.6	165.5	1037.5	1257.0	325.9	691.2
Systena flea beetles	09.4	63.9	81.3	151.3	24.2	65.4
Tobacco wireworm	00.3	05.3	17.7	56.6	0.6	08.5
White-fringed beetle	00.3	05.3	00.0	0.0	0.5	08.3

include those listed in Table 6. The number of insects collected over time in sweep-net samples is illustrated in Figure 6. Sweetpotato flea beetles and *Systena* flea beetles were present from planting until harvest in every field and increased slightly toward the end of the season. This finding supports grower consensus that spray applications from midseason to late season are likely more effective for reducing damage from cucumber beetles and *Systena* flea beetles, even though considerable "early-season" damage (identified as damage that has healed over with a new sweetpotato skin) to sweetpotato roots may occur from both of these species. Sweetpotato flea beetles have the potential to reach large populations. Sweep-net counts ranged from zero to 120 per sample, but they averaged 3.2 insects per sample in NO INSECTICIDE strips from 2004–2007. Sweetpotato flea beetles were the most numerous damaging insect species collected, followed by the red-headed flea beetle and tortoise beetles. Table 7 presents the relative numbers of commonly collected insects per sweep-net sample from NO INSECTICIDE plots averaged across the growing season for each year of the study.

Most of the click beetles that were collected as adults were tobacco wireworm (*Conoderus vespertinus* [Fabricious]) (Figure 6). These insects were more numerous overall during the early part of the growing season and occurred only sporadically from mid-July until harvest. The corn wireworm, *Melanotus communis* (Gyllenhal), is a major pest of sweetpotatoes in North Carolina but has received little attention in Mississippi. Only one specimen of adult corn wireworm was collected in weekly insect samples from strip-plots in Mississippi fields during the study, and four were collected on sticky cards in a sweetpotato field late in 2007.

In 2004 and 2005, a total of 55 wireworm larvae were collected in bait traps. Due to the low numbers recovered compared with the many baits placed, sample collection was not continued in 2006. Thirty-two of the 55 larvae were identified as tobacco wireworms, four

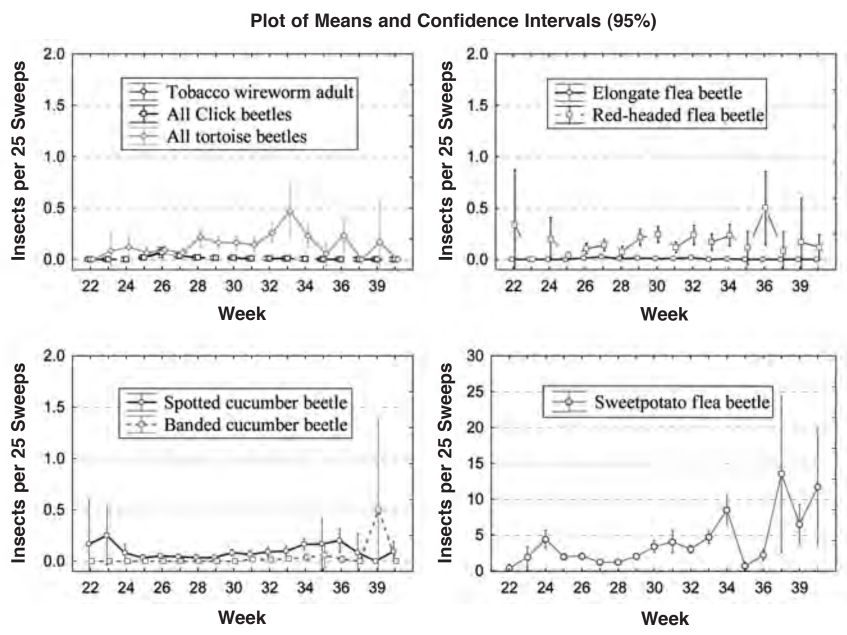

Figure 6. Mean number of insects per sweep-net sample from NO INSECTICIDE plots based on week of the year. Note that the scale for insect numbers for sweetpotato flea beetle is 15 times that of the other species.

were identified as *Melanotus pilosus* Blatchley (no common name), seven were probably corn wireworms (these larvae cannot be separated from *M. dietrichi* Quate), 10 were identified only to the genus *Melanotus*, one was a *Conoderus* species, and one was of the genus *Glyphonyx*. In 2005, a field not included in the RAMP project in Chickasaw County was abandoned at harvest because of wireworm damage. Wireworms collected from this field were identified as either corn wireworm (probable) or *Melanotus dietrichi*. If corn acreage continues to increase, corn wireworm may become a much more common pest in sweetpotatoes. Although adult beetles of the southern potato wireworm (*Heteroderes falli*) were collected in sweep-net samples, no larvae were identified as that species.

Cucumber beetles with capability of damaging roots were collected in samples from the strip-plots. The banded cucumber beetle, *D. balteata*, accounted for 12% of the cucumber beetles from sweep-net samples in 2004; 11% in 2005; and 2.5% in 2006. The spotted cucumber beetle, *Diabrotica undecimpunctata howardi,* was the dominant species.

Root Injury

The percentage of roots damaged by insects was extremely variable among fields, ranging from 0–100%. Although some of the insects (wireworms, white-fringed beetles, and sugarcane beetles) have the potential to render a field unprofitable, percentage of roots damaged in NO INSECTICIDE plots was 24.9% in 2004, 35% in

Table 6. Species of insects collected from sweetpotato fields with potential for direct damage to the crop.

General grouping	Genus Species[1]	Common name
Tortoise beetles	*Agroiconota bivittata* (Say)	—
	Charidotella sexpunctata bicolor (Fabricius)	Gold bug
	Chelymorpha cassidea (Fabricius)	Argus tortoise beetle
	Deloyala guttata (Olivier)	Mottled tortoise beetle
Cucumber beetles	***Diabrotica balteata* LeConte**	**Banded cucumber beetle**
	***Diabrotica undecimpunctata howardi* Barber**	**Spotted cucumber beetle**
Flea beetles	***Chaetocnema confinis* Crotch**	**Sweetpotato flea beetle**
	Chaetocnema denticulata	**Toothed flea beetle**
	***Systena elongata* (Fabricius)**	**Elongate flea beetle**
	***Systena frontalis* (Fabricius)**	**Red-headed flea beetle**
Sugarcane beetle	***Eutheola humilis* (LeConte)**	**Sugarcane beetle**
June beetles	***Phylophaga* Various species**	**White grubs**
Click beetles (Wireworm adults)	***Aeolus species***	
	***Conoderus bellus* (Say)**	
	***Conoderus vespertinus* (Fabricius)**	**Tobacco wireworm**
	***Heteroderes falli* (Lane)**	**Southern potato wireworm**
	***Melanotus communis* (Gyllenhal)**[2]	**Corn wireworm**
	***Melanotus pilosus* Blatchley**	
White-fringed beetles	***Naupactus leucoloma* (Boheman)**	
Sweetpotato weevil	***Cylas formicarius elegantulus***[3]	**Sweetpotato weevil**
Misc. beetles	*Acalymma vittatum* (Fabricius)	Striped cucumber beetle
	Cerotoma trifurcata (Förster)	Bean leaf beetle
	Epicauta various species	Blister beetles
	Leptinotarsa decemlineata (Say)[4]	Colorado potato beetle
	Myochrous denticollis (Say)	Corn leaf beetle
Lepidoptera	*Agrius cingulata* (Fabricius)	Sweetpotato hornworm
	Agrotis subterranean (Fabricius)[5]	Granulate cutworm
	Helicoverpa zea (Boddie)	Bollworm
	Psuedoplusia includens (Walker)	Soybean looper
	Spodoptera ornothogalli (Guenée)[5]	Yellow striped armyworm
	Spodoptera frugiperda (J. E. Smith)[5]	Fall armyworm
	Spodoptera exigua (Hübner)[5]	Beet armyworm
	Spoladea recurvalis (Fabricius)[5]	Hawaiian beet webworm
	Trichoplusia ni (Hübner)	Cabbage Looper

[1]**Bold lettering** indicates root-damaging pest. Insects not in bold or otherwise marked, are generally leaf feeders.
[2]Absolute identification of corn wireworm larvae and adults has not been obtained.
[3]Not collected in fields associated with this study, but collected from one research field in the area in 2003.
[4]Species collected rarely and probably incidentally in sweetpotato.
[5]Indicates potential for root damage if soil is cracked or roots are visible above the soil line.

Table 7. Mean number and standard deviation (SD) of common insects per sweep-net sample (x100) for years 2004–2007 from NO INSECTICIDE plots.[1]								
	2004		2005		2006		2007	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Banded cucumber beetle	**1.07**	**15.77**	**0.95**	**14.41**	**0.21**	**4.60**	**3.13**	**20.22**
Click beetles	**1.66**	**18.17**	**0.76**	**9.71**	**3.18**	**21.87**	**4.17**	**20.03**
Elongate flea beetle	**0.36**	**5.96**	**0.95**	**9.69**	**2.12**	**14.42**	**1.56**	**12.43**
Mottled tortoise beetle/gold bug[2]	9.14	32.71	16.10	71.98	3.60	20.81	11.98	39.79
Red-headed flea beetle	**17.10**	**83.14**	**18.09**	**55.29**	**17.37**	**45.56**	**23.96**	**68.25**
Southern Corn Leaf Beetle	0.36	7.70	0.19	4.35	1.91	15.16	0.00	0.00
Spotted cucumber beetle	**7.84**	**31.38**	**9.09**	**31.29**	**4.24**	**22.17**	**6.25**	**26.34**
Sweetpotato flea beetle	**476.72**	**1236.28**	**337.41**	**647.25**	**160.59**	**300.77**	**139.06**	**290.31**
Two-striped tortoise beetle	4.51	27.65	5.21	23.47	6.57	36.56	9.90	36.27
White-fringed beetle	**0.00**	**0.00**	**0.28**	**5.32**	**1.06**	**12.14**	**18.23**	**62.50**

[1]Bold letters indicate common, root-damaging species.
[2]Not counted as individual species.

2005, 32.5% in 2006, and 76.2% in 2007. Types of root damage were ranked based on the occurrence of scar injury. From the most damaging to the least damaging, root injuries were ranked in this order: small holes, pinholes, deep holes, shallow gouges, channels, and deep gouges. This ranking indicates that most sweet-potato root damage was caused by injury from the WSD insect complex. However, insect species with the greatest potential to cause major loss of marketable pota-toes appear to be wireworms, white-fringed beetles, and sugarcane beetles because a small amount of injury by these insects can render the potato unmarketable. Conversely, potatoes slightly injured by *Systena* flea beetles and cucumber beetles may still be acceptable in the marketplace. Table 8 summarizes the percentage of potatoes sustaining damage according to different scar types during the study, as well as the data based on severity of the damage (number of holes or scars) per 100 potatoes. In almost all of these data, the standard deviation is nearly the same as the average, indicating great variance in the data and a very large range between minimum and maximum amount of damage.

Table 8. Mean percentage and standard deviation (SD) of potatoes damaged with small holes, deep holes, pinholes, tracks, channels, and deep and shallow gouges; mean number of scars per potato in NO INSECTICIDE plots, 2004–2007.[1]								
Damage type	2004		2005		2006		2007	
	Pct. damage	Scars[2]	Pct. damage	Scars[2]	Pct. damage	Scars[2]	Pct. damage	Scars[2]
Small Holes (Cucumber beetle)	9.97 (12.95)	24.60 (45.20)	13.89 (15.37)	34.40 (46.50)	7.77 (9.23)	14.00 (20.20)	41.83 (29.08)	180.00 (210.30)
Deep Holes (Wireworms)	4.67 (8.25)	10.50 (24.50)	7.40 (11.39)	17.60 (42.60)	10.12 (17.03)	21.10 (42.70)	17.33 (18.11)	34.50 (47.30)
Pinholes (Flea beetles)	4.34 (6.92)	9.30 (18.20)	10.74 (14.14)	22.60 (39.20)	3.01 (5.78)	5.60 (11.60)	14.17 (14.05)	34.50 (42.80)
Tracks (Sweetpotato flea beetle)	2.61 (7.49)	2.90 (8.70)	3.45 (6.01)	3.70 (7.00)	2.07 (3.76)	2.10 (3.80)	1.50 (2.84)	1.50 (2.80)
Channels (White-fringed beetle)	0.52 (2.00)	0.60 (2.20)	2.02 (4.54)	2.70 (7.00)	2.94 (9.85)	4.40 (15.40)	8.67 (9.92)	11.30 (14.20)
Deep Gouge (Sugarcane beetle)	0.77 (2.33)	0.90 (2.60)	0.35 (1.58)	0.50 (2.20)	3.22 (9.85)	5.10 (17.90)	5.83 (7.27)	7.00 (8.80)
Shallow Gouge (White grub)	5.04 (7.17)	6.50 (10.60)	2.96 (4.85)	3.50 (6.20)	1.10 (2.76)	1.40 (3.90)	0.50 (1.35)	0.50 (1.40)
Smooth Holes (Caterpillar)	22.0 (41.6	0.77 (2.50)	25.7 (43.8)	1.40 (2.70)	40.1 (49.2)	3.10 (4.80)	37.5 (49.4)	3.33 (6.50)

[1]The best estimate of probable causal insect is listed in parentheses below the damage type.
[2]Channels and gouges are based on the estimated percent of the potato covered with scars. Other types of damage are mean numbers of scars per potato.

Table 9. Mean number and standard deviation (SD) of new and old insect scars per 100 potatoes from PPI/POST and NO INSECTICIDE plots averaged across years 2004-2007.[1]					
Type of damage[2]	NO INSECTICIDE		PPI/POST		prob. F.
	Mean[3]	SD	Mean[3]	SD	
Deep holes (Wireworms) – New	4.27 a	16.74	1.94 a	6.68	0.0598
Deep holes (Wireworms) – Old	8.78 a	23.80	4.92 b	14.91	0.0237
Smooth holes (Caterpillars) – New	0.96 a	2.69	0.65 a	1.92	0.0643
Smooth holes (Caterpillars) – Old	0.48 a	1.66	0.25 b	1.00	0.0220
Pinholes (*Systena* flea beetles) – New	7.73 a	20.72	7.14 a	17.99	0.7698
Pinholes (*Systena* flea beetles) – Old	2.95 a	9.60	2.74 a	8.06	0.1248
Deep gouge (Sugarcane beetle) – New	1.04 a	4.80	0.84 a	3.10	0.5997
Deep gouge (Sugarcane beetle) – Old	0.78 a	5.61	0.24 a	1.51	0.2437
Small hole (Cucumber beetle) – New	11.52 a	30.06	13.74 a	42.78	0.1742
Small hole (Cucumber beetle) – Old	11.81 a	37.82	10.39 b	36.03	<0.0001
Tracks (Sweetpotato flea beetle) – Old	0.86 a	2.61	0.71 a	2.59	0.4988
Tracks (Sweetpotato flea beetle) – New	1.04 a	3.38	0.52 a	1.84	0.0660
Channels (White-fringed beetles) – New	1.69 a	6.66	0.79 a	3.33	0.2091
Channels (White-fringed beetles) – Old	0.86 a	4.02	0.28 a	1.52	0.1759
Shallow gouge (White grubs) – New	0.80 a	2.96	0.53 a	1.89	0.3414
Shallow gouge (White grubs) – Old	0.80 a	2.77	0.39 a	1.71	0.5222

[1]The best estimate of probable insect cause is listed in parentheses.
[2]Old damage occurred earlier in the season and was healed over with a new skin. New damage occurred later in the season, and potatoes were harvested before insect wounds could develop new skin.
[3]Means within a row not sharing the same letter differ significantly (LSD, p=0.05).

During 2005 and 2006, insect damage was also categorized as "old" (healed over with a new skin) or "new" (fresh or not healed over with a new skin). Data for each damage type and causal insect is summarized in Table 9. Note that root damage from old deep hole, track, channel, deep gouge, and shallow gouge injuries and from new deep hole and channel injuries was significantly less in potatoes from the "farmer standard" insecticide treatment. This finding suggests that a PPI insecticide application may be effective in reducing numbers of insect larvae causing these types of damage.

The percentage of roots damaged as related to the number of days from the PPI application date to planting date is illustrated in Figure 7. Percentage of damage was positively correlated with days between PPI application and planting dates for all insect damage (r=0.2236; p<0.0001), small holes (r=0.1646; p=0.0001), pinholes (r=0.1400; p=0.0015), tracks (r=0.1166; p=0.0082), and channels (r=0.0970; p=0.0283). Although the r-values are small, the data still indicate trends for increased damage with increased time between PPI application and planting date. By using the equation of the regression line comparing days from PPI application to planting with percentage of damage of all types (Percentage = 0.2117 + 0.003 * Days to Planting) and subtracting percent damage for PPI at 1 day before planting from the percentage calculated for 10 days (0.2417-0.2117=0.030), a 3% increase in damage is calculated for the 10-day delay. Since this effect is cumulative, every subsequent 10-day delay increases the potential for root damage by an additional 3%. Therefore, a delay of 20 days would result in 6% of the sweetpotatoes being damaged. Results indicate that the percentage of potato roots with tracks, channels,

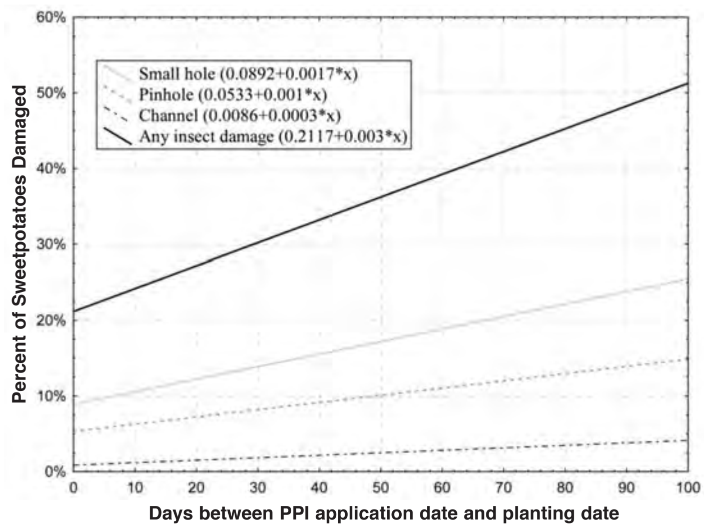

Figure 7. Linear regression lines for damage types showing the effect of time between PPI applications and planting on the percent of sweetpotatoes damaged by insects in PPI and PPI/POST strip plots. Only damage types with significant slopes (p≤0.05) are shown.

Table 10. Percent of damaged sweetpotatoes in NO INSECTICIDE plots following previous-year sweetpotato, soybean, corn, pasture, and cotton crops summarized over years 2004–2007.[1]

Type of damage	Sweetpotato	Cotton	Soybean	Corn	Pasture	All groups
Channels (White-fringed beetle)	1.3	8.8	1.5	0.4	2.0	2.2
Deep gouge (Sugarcane beetle)	1.1	1.0	3.2	0.3	1.7	1.5
Deep hole (Wireworms)	7.3	4.4	10.4	5.7	10.7	7.8
Pinhole (*Systena* flea beetles)	5.6	6.5	9.4	3.6	8.9	6.6
Shallow Gouge (White grubs)	3.1	2.7	3.1	1.7	7.0	3.2
Small hole (Cucumber beetles)	11.0	10.5	16.0	6.2	17.1	12.1
Tracks (Sweetpotato flea beetle)	2.0	3.7	3.9	3.2	1.0	2.7
Undamaged	71.4	65.7	58.3	81.0	60.4	67.7

[1]The best estimate of probable insect cause is parenthetically listed.

small holes, and pinholes can be reduced by planting soon after a PPI insecticide application. However, the reduction would be more obvious in damage types that occur in higher frequencies (small hole and pinhole damage) than in other types of damage. Wireworms and white-fringed beetles have the potential to invade fields in disastrous proportions. This did not occur in any of the fields within the 4-year study.

Other factors affecting insect damage include date of planting, date of harvest, and days to harvest. These factors are interrelated, and it is impossible to differentiate actual cause-and-effect scenarios. Percentage of insect-damaged potatoes correlated positively with days to harvest ($r=0.1603$; $p<0.0001$), indicating that delaying harvest leads to additional insect damage.

Crop rotation was once considered a cultural practice, but it is currently a consequence driven by market demand and land availability. Since cotton, corn, and soybeans are common crops in the sweetpotato production region of Mississippi, rotation of sweetpotatoes previously planted to these fields is common. However, it is not uncommon for sweetpotato production fields to remain in sweetpotatoes for several years due to limited quality land resources, and sweetpotatoes are less commonly planted in fields that were fallow or used for pasture. The percentage of fields in this study planted with sweetpotato following sweetpotato, soybeans, corn, pasture, and cotton for years 2004–2007 varies greatly from year to year. However, sweetpotato is the most common previous-year crop. The mean percent of insect-damaged potatoes averaged over 2004–2007 (Table 10) was significantly greater in sweetpotatoes following soybean and pasture than in sweetpotatoes following other previous-year crops [LSD, arcsin(square root) transformed data], (df:1138; F:390.6; $p<0.0001$).

The crop rotation trial completed at the Delta Research and Extension Center resulted in significant damage only in the small-hole category. The percentage of sweetpotatoes damaged by insects and the mean number of small holes per sweetpotato harvested the year after the rotation crops were not significantly different among the cotton, corn, soybeans, sweetpotato, and fallow rotational scenarios (Table 11).

Table 11. Percent of sweetpotatoes damaged and mean number of small holes per sweetpotato for potatoes planted after 2 years of sweetpotato and 1 year of rotation crops at Stoneville, Mississippi.[1]

	Soybean		Cotton		Sweetpotato		Fallow		Corn		Prob. F
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Mean percent of sweetpotatoes damaged	39.2	49.1	38.6	48.8	33.7	47.0	37.4	48.3	37.2	49.0	0.9611
Mean number of small holes per potato	0.99	2.05	1.14	2.74	0.48	2.02	0.91	2.15	0.60	1.30	0.2235

[1]Small hole damage was the only type of damage common enough to allow statistical analysis.

Summary

A very concise summary of findings is presented below for the Mississippi portion of the Southern Sweetpotato IPM project.

- Early-season insects: Corn leaf beetle, click beetle (wireworm) adults, cucumber beetles, and flea beetles.
- Midseason insects: White-fringed beetles, Phyllophaga (white grub adults), cucumber beetles, and flea beetles.
- Late-season insects: Flea beetles, cucumber beetles, sugarcane beetles, and white-fringed beetles (*Systena* flea beetles have about the same population all summer).
- Correlation data indicate that a threshold for triggering insecticide applications to control *Systena* flea beetles, sweetpotato flea beetles, and spotted cucumber beetles may be possible.
- Good sampling methods for flea and leaf beetles include sweep-net and sticky cards. Vacuum is good if properly used, but because vacuums clog easily with leaves, they require a diligent sampler to use it effectively.
- Rotation crops preceding sweetpotatoes ranked in order of most to least damage in sweetpotatoes are soybeans, pasture, cotton, sweetpotato, and corn.
- The shorter the interval between PPI insecticide application and planting, the less insect damage is found at harvest.
- PPI insecticide plus foliar applications of insecticide reduce damage from insects on average about 5%. However, there is always the potential for exceptional amounts of damage from these insects in an individual field if PPI and other insecticide applications are ignored.
- Planting date — In general, the later the planting, the more damage is likely to occur.
- Days to harvest — The longer the sweetpotatoes are in the ground, the more damage they will sustain from insects. Harvest as soon as possible.

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