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Insects and arachnids associated with rapeseed, Brassica napus ssp. oleifera, in western Tennessee

Michael Lynn Boyd

To the Graduate Council:

I am submitting herewith a thesis written by Michael Lynn Boyd entitled "Insects and arachnids associated with rapeseed, Brassica napus ssp. oleifera, in western Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

Gary L. Lentz, Major Professor

We have read this thesis and recommend its acceptance:

Jerome F. Grant, Charles D. Pless

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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INSECTS AND ARACHNIDS ASSOCIATED WITH RAPESEED, *Brassica napus* ssp. *oleifera*, IN WESTERN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Michael Lynn Boyd

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ABSTRACT

Rapeseed is a member of the crucifer genus Brassica (Cruciferae: Brassiceae), a genus with more than 50 plant species utilized for fodder, food, oilseed, or vegetable production (Fribourg et al. 1989). Rapeseed represents both summer and winter forms of rape, Brassica napus ssp. oleifera L., and turnip rape, Brassica campestris ssp. oleifera L., and both species frequently occur in common geographical areas (Appelqvist 1972). Rape, a native to Europe and Northwestern Africa, was first introduced into Canada in 1942, where cultivation is limited to summer forms due to extreme climatic conditions. Until the mid-1980's, rapeseed cultivation in the United States was limited to the Pacific Northwest and the Northern Great Plains (Fribourg et al. 1989).

Usage of rapeseed is dependent upon the level of unsaturated erucic acid and sulfur-containing glucosinolates (Ohlson 1972). High erucic acid rapeseed (HEAR) is a plant cultivar with an oil content of >50% erucic acid and >30 μmol glucosinolates per gram of meal (Fribourg et al. 1989). HEAR oil cultivars are desirable because the oil is used for rubber stabilization, machine lubrication, and textile manufacturing (Ohlson 1972). From 1986 to 1988, field trial experiments were conducted at the Milan Experiment Station in western Tennessee to determine the suitability of local environmental conditions for rapeseed production (Fribourg et al. 1989).

This research demonstrated that the rapeseed species, winter rape, Brassica napus ssp. oleifera forma biennis, could be cultivated in western Tennessee to produce HEAR oil. Because rapeseed is a new crop in western Tennessee, the species composition and seasonal incidence of arthropods are unknown; therefore, a two-year study beginning in the spring of 1990 was initiated to address these research areas.

Rapeseed and other crucifers are hosts to more than 150 insect species, with many pest species representing the orders Coleoptera, Diptera, Hemiptera, Homoptera, and Lepidoptera (Hill 1987). Most homopteran and lepidopteran pests attack the foliage tissues of crucifers; whereas, many coleopteran and hemipteran pests attack the reproductive tissues of crucifers, including rapeseed (Bonnemaison 1965). Dipteran pests are primarily root and foliage feeders (Hill 1987).

During this study, approximately 111 species or groups were collected from rapeseed in western Tennessee. Forty-seven families representing ten insect orders, including Coleoptera, Diptera, Hemiptera, Homoptera, and Lepidoptera, and five families representing one arachnid order were collected and identified. The most extensive diversity of arthropods occurred during the flowering and ripening stages of rapeseed.

The turnip aphid, Lipaphis erysimi (Kaltenbach) (Homoptera: Aphididae), was the predominant aphid species. The turnip aphid was present on the first sampling date (March

9 and 19) in 1990 and 1991, respectively. Turnip aphid populations increased most rapidly during the flowering stage of rapeseed, with population peaks coinciding with rapeseed flowering. Feeding damage in heavily-infested fields caused stunted growth, reduced pod production, and delayed seed maturity. Perhaps due to heavy spring rains, turnip aphid populations in 1991 were 78.8% lower than populations in 1990 as estimated by sweep-net sampling.

In all fields sampled in 1990 and 1991, turnip aphids were frequently attacked by a wasp parasitoid [Diaeretiella rapae (M'Intosh) (Hymenoptera: Aphidiidae)]. Wasp populations in 1991 were 95.8% lower than in 1990, reflecting the reduced level of aphid infestation. Parasitized aphids ceased feeding, attached themselves to plant stems, and became brown mummies.

The coleopteran species, the cabbage seedpod weevil, Ceutorhynchus assimilis (Paykull) (Curculionidae), was collected in sweep-net samples in 1990 and 1991 and was the most common (98.8%) curculionid species collected. Adults were first collected as rapeseed began to flower in early April, when adults were observed to feed and mate on flowers. Damaged seedpods were characterized by the presence of a small, black puncture, with larvae later damaging three to five seeds per pod. During both years of this study, overwintering adult populations peaked during or shortly after the peak flowering of rapeseed. The summer generation (F_1)

adults emerged three to four weeks later during the ripening (5.1 to 5.5) stage of rapeseed, and were observed to feed on any remaining green tissue.

Several thysanopterans attracted to rapeseed flowers included flower thrips, Frankliniella tritici (Fitch), tobacco thrips, F. fusca (Hinds), and soybean thrips, Neohydatothrips variabilis (Beach) (all Thripidae). Flower thrips was the most abundant species (87.8%) in 1990 and (97.9%) in 1991. Flower thrips were most abundant during the flowering (4.1 to 4.4) and early ripening (5.1) stages, and numbers of flower thrips decreased rapidly after flowering terminated. No visual damage to infested plants was observed, and plants appeared to develop normally. The implication of thrips infestation in rapeseed is that the crop may serve as an early-season host for later infestation of other crops (e.g., cotton).

In western Tennessee, the tarnished plant bug, Lygus lineolaris (Palisot de Beauvois) (Miridae), was the most frequently (>95%) collected pod-feeding hemipteran. During both years of this study, tarnished plant bug populations peaked during the ripening (5.1 to 5.3) stage of rapeseed. The tarnished plant bug is believed to utilize rapeseed as an early-season host in western Tennessee; therefore, the tarnished plant bug may build up populations in rapeseed, and later infest other crops (e.g., cotton).

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Chapter 1

INTRODUCTION

The crucifer genus Brassica (Cruciferae: Brassiceae) contains rapeseed and more than 50 plant species used for fodder, food, oilseed, or vegetable production (Fribourg et al. 1989). Rapeseed represents both annual and biennial forms of rape, Brassica napus ssp. oleifera L., and turnip rape Brassica campestris ssp. oleifera L., that have overlapping geographical areas (Appelqvist 1972). Rape, native to Europe and Northwestern Africa, was introduced into Asia in the early 1900's. Cultivation of rapeseed in India dates back as far as 2000 to 1300 B.C. as indicated by Sanskrit writings; whereas, cultivation of rapeseed in Europe did not begin until the thirteenth century. Rapeseed was first introduced into Canada in 1942, and cultivation is limited to summer forms due to the severe winter climate. Until recently, cultivation in the United States had been limited to the Pacific Northwest and the Northern Great Plains (Fribourg et al. 1989).

Crucifers are characterized by yellow flowers with four sepals and petals (Bengtsson et al. 1972). Upon emergence of the cotyledons, a low and level rosette is formed that requires exposure to freezing temperatures to continue development in biennial forms (Fribourg et al. 1989). The fruiting structure is an elongated pod composed of two carpels separated by a false septum (Bengtsson et al. 1972). At

maturity, the two carpels separate from the false septum and expel the seeds to the soil (Bengtsson et al. 1972).

European cultivation of rapeseed first became important during the sixteenth century in several northern countries where oil obtained from seeds was used for illumination and soap production (Appelqvist 1972). In the nineteenth century, petroleum oils replaced rapeseed oil as lighting fuel. In Canada, rapeseed cultivation began during World War II to provide lubricants for marine engines; in the 1950's, manufactering was switched to producing oil for edible purposes (Daun 1984). The development of the low-erucic acid rapeseed (LEAR) variety 'Oro' in 1968 helped to increase the marketability of rapeseed oil.

Usage of rapeseed oil is dependent upon the level of long chain, unsaturated erucic acid and sulfur-containing glucosinolates (Ohlson 1972). High-erucic acid rapeseed (HEAR) are those plant cultivars with an oil content of >50% erucic acid and >30 μmol glucosinolates per gram of meal (Fribourg et al. 1989). The long-chain or double bond molecules in HEAR oil cultivars are desirable for use in the production of fatice (a rubber stabilizer), lubricants for the cold rolling of steel, and manufacture of textile products (Ohlson 1972). Rapeseed oil was not approved for dietary uses until the development of low-erucic acid rapeseed (Daun 1984). Oil produced from LEAR or canola cultivars must have <2% erucic acid and <30 μmol glucosinolates per gram of meal. The dietary presence of

erucic acid causes improper fat utilization in human heart and skeletal muscles and glucosinolates negatively affect livestock growth (Fribourg et al. 1989).

Glucosinolates serve as antifeedants for many polyphagous herbivores, but through selection and adaptation many insect pest species now utilize these compounds or fission products as feeding attractants and stimulants (Lamb 1989). Bonnemaison (1965) documented pests of crucifers prior to the classification of rapeseed as an important cash crop in Europe and North America. Many of these pest species originated in Europe or Asia, and only a few indigenous oligophages were present in North America.

Crucifers, including rapeseed, are hosts to more than 150 insect pest species (Hill 1987). Many of these insect pest species belong to the orders Homoptera, Coleoptera, Lepidoptera, Hemiptera, and Diptera. Most homopteran pest species belong to the Aphididae and feed on the developing tissue of crucifers. Many coleopteran pest species, belonging to Curculionidae, Nitidulidae, and Chrysomelidae, among others damage, photosynthetic or reproductive tissues of crucifers (Bonnemaison 1965). The summer and winter diapauses of these specialist coleopteran families are closely adapted to crucifer life cycles. Numerous lepidopteran pest species, belonging to the Yponomeutidae, Pieridae, and Noctuidae, among others, are primarily foliage feeders. Hemipteran pest species are represented by the Lygaeidae, Miridae, and

Pentatomidae (Hill 1987). Numerous dipterans, including noxious species belonging to Anthomyiidae, Cecidomyiidae, Muscidae (Hylemya spp.), and Agromyzidae, also infest crucifers.

The cabbage aphid, Brevicoryne brassiceae (L.), green peach aphid, Myzus persicae (Sulzer), and turnip aphid, Lipaphis erysimi (Kaltenbach) (all Homoptera: Aphididae), are pests of rapeseed that attack leaf, stem, bud, flower, and pod structures (Lamb 1989). Infestation by cabbage aphid causes yellowing of plant tissue and eventually leads to plant mortality (Hill 1987). The distinct colonies of cabbage aphids attack either in fall, when damage to rosettes reduces plant vigor to cold weather, or in spring, when damage to flower heads causes stunting and reduces yield (Blackman and Eastop 1984). Damage by the cabbage aphid is restricted to cruciferous species, but rapeseed is only moderately infested (Blackman and Eastop 1984). Cabbage aphids excrete a white mealy wax that eventually covers the entire colony, and this wax production helps to deter attacks by parasitoids (George 1957).

The green peach aphid is a general feeder with peach, Prunus persica (L.) Batsch, as its primary host and more than 110 other plant species in 35 families as alternative hosts (Hill 1987). Green peach aphids are important pests because of their direct feeding damage and their ability to transmit 100 or more viral pathogens. Loose and diverse colonies feed

on leaf undersides, causing foliage to curl. Populations of green peach aphid increase most rapidly between 5 to 15°C, with peak net production occurring at 20°C (DeLoach 1974). Even though 200 or more species of predators and parasitoids of the green peach aphid are reported, the value of these insects is difficult to determine because this aphid species is scarce on crops (van Emden et al. 1969).

The turnip aphid is a second crucifer specialist that utilizes many species of Cruciferae as hosts (Blackman and Eastop 1984). The turnip aphid feeds on leaf undersides and reduces plant vigor and setting in the fall, and causes stunting and reduces fruit production in the spring (Hill 1987). Maximum incidence of turnip aphids occurs at approximately 17°C and when relative humidity is between 61 and 83% (Srivastava and Srivastava 1972). When the turnip aphid coexists with green peach aphid and cabbage aphid at 25°C, and other environmental factors are equal, the turnip aphid will become the dominant species (DeLoach 1974).

Many primary parasitoids of aphids are members of the family Aphidiidae (Hymenoptera) (George 1957). An important parasitoid of the cabbage aphid is Diaeretiella rapae (M'Intosh) (George 1957). This photopostive parasitic wasp is attracted to the mustard oil, allyl isothiocyanate, produced by cruciferous plants (Tamaki et al. 1981). Diaeretiella rapae will attack other aphid species when cabbage aphids are

rare, but parasitism is limited to aphid species that feed on cruciferous plants (Read et al. 1970).

The cabbage seedpod weevil, Ceutorhynchus assimilis (Paykull) (Coleoptera: Curculionidae), is a major pest of rapeseed in Europe and North America (Hill 1987). The main host of this weevil is rapeseed, with other crucifers serving as alternate hosts (Doucette 1947). Overwintering adults do not emerge until air temperatures reach 15°C and hibernation sites are humid (Bonnemaison 1965). After first feeding on wild crucifers in spring to supply energy for ovarial development and to replenish energy reserves, adults move into rapeseed fields where they feed and oviposit (Doucette 1947, Free and Williams 1978b). As adult numbers increase, the number of pods, seed production, and seed weight decrease; adult populations between 2.6 to 5.5 per plant result in 57 to 61% pod infestation (Free et al. 1983). One egg is typically oviposited into a pod 2 to 40mm in length, and the larva emerges in 8 to 10 days (Hill 1987). The larva feeds 4 to 5 weeks and consumes 25 to 100% of the seeds per pod before pupating in the soil. The summer generation emerges in approximately 12 days, and adults feed 10 to 15 days on any green tissue of Brassica and Raphanus (e.g., radish, R. sativus L.) plants before entering diapause (Doucette 1947, Bonnemaison 1965).

Cabbage seedpod weevils are parasitized by species of Pteromalidae and Eulophidae (Hymenoptera) that were imported

from Europe (Walz 1957). In Idaho, three species of hymenopterous ectoparasitoids [the pteromalids, Trichomalus fasciatus (Thomson) and Xenocrepis pura Mayr, and the eulophid, Necremnus duplicatus Gahan], were shown to parasitize cabbage seedpod weevils. Emerging prior to rapeseed blossoming, T. fasciatus adults were the most abundant. Xenocrepis pura and N. duplicatus were the second and third most abundant species, respectively. The presence of parasitoids in rapeseed fields is indicated by rough and jagged edges of pod emergence holes, as compared to weevil pod emergence holes that have a smooth edge.

Blossom beetles, Meligethes spp. (Coleoptera: Nitidulidae), are major pests of rapeseed in Europe, but are minor pests on other crucifers (Hill 1987). In England, blossom beetles also are found on plant species in Labiatae, Compositae, and Rosaceae (genus Potennilla) (Free and Williams 1978a). Surveys in England indicate that Meligethes aeneus F. is a severe pest of summer rapeseed but not of winter forms (Free and Williams 1978b). Podless stalks are frequently attributed to M. aeneus damage; however, not all stalk damage is due to adult feeding but may be caused by a variety of physiological factors.

Blossom beetle adults overwinter in leaf litter and emerge in spring to feed on flower pollen within the corolla tube (Hill 1987, Williams and Free 1978). Adults later move onto buds where they feed and oviposit into unopened green

buds, and 2 or 3 eggs are laid within each bud (Hill 1987). Larvae hatch in 3 to 10 days and feed on flower pollen and nectaries. Because blossom beetles feed on green buds, low populations of Meligethes spp. may be beneficial by feeding on flowers and decreasing the shading of photosynthetic surfaces. Infestation levels of 15 to 20 beetles per plant may require treatment with insecticides prior to flowering. On spring rapeseed, insecticides are recommended when 3 or more beetles per plant are present at early bud stage. Because Meligethes spp. are univoltine, the effectiveness of many hymenopteran parasitoids is limited because many wasps have multivoltine life cycles; thus, they cannot reproduce continuously on blossom beetles and parasitoid populations are low (Bonnemaison 1965).

Several flea beetles in the genus Phyllotreta (Coleoptera: Chrysomelidae) are major pests of Brassica spp. and other Cruciferae (Hill 1987). Adults overwinter in leaf litter and soil crevices and emerge from hibernation when warm weather persists. Adults feed on cotyledons and young leaves, causing a shot-hole appearance due to enlargement of feeding pits by developing leaf tissue. This type of feeding damage slows plant development, causes nonuniform stand height, and reduces seed yield and quality (Lamb 1984). Eggs are laid in groups of 3-40. Larvae emerge in one to two weeks and burrow into the soil to feed upon host roots (Hill 1987).

Important North American species of Phyllotreta that attack crucifers include the cabbage flea beetle, Phyllotreta cruciferae (Goeze), striped flea beetle, P. striolata (F.), and P. zimmermanni (F.) (Hill 1987). The cabbage flea beetle was first discovered in the United States in 1923 after its importation from Europe (Bonnemaison 1965). Adult beetles overwinter in hedgerows, topsoil, or other sheltered areas (Feeny et al. 1970). After emergence on warm, sunny days, the adults disperse to hosts with foliage exposed to bright sunlight or crops planted in widely spaced rows (Burgess 1977). Eggs are laid in late May and early June and require 75 to 85 degree days to hatch (Kinoshita et al. 1979). First-instar cabbage flea beetles feed on root hairs; whereas, second- and third-instars often tunnel and feed on seeds and roots (Kinoshita et al. 1979). Based on the Brassica campestris and B. napus growth-stage key (Harper and Berkenkamp 1975), most of the yield reduction caused by the cabbage flea beetle occurs during the seedling and rosette (1.0 to 2.2) growth stages (Bracken and Bucher 1986).

The striped flea beetle, another Eurasian species, was introduced into the United States prior to 1801. This species has biological and host preferences similar to those of the cabbage flea beetle, except that large adult populations of the striped flea beetle utilize noncruciferous plants as hosts. Striped flea beetles also differ as they prefer plants situated in shady areas (Hicks and Tahvanainen 1974). The

striped flea beetle appears prior to the cabbage flea beetle, and the adult striped flea beetle flies closer to the ground (<0.5m), compared to the adult cabbage flea beetle that flies higher than 7m (Lamb 1983).

Phyllotreta zimmermanni is a native flea beetle species that occurs from New England to Georgia and west to Manitoba and Missouri (Hicks and Tahvanainen 1974). Adults, collected in large numbers on crucifers, prefer species of the genera Arabis (e.g., tower mustard, A. glabra (L.) Bernhardi) and Lepidium (e.g., field peppergrass, L. campestre (L.) R. Brown). This species differs from the previous two species as P. zimmermanni larvae are leafminers and not root feeders (Chittenden 1923). Adults prefer to feed in open field situations, but they rarely compete with P. striolata (Hicks and Tahvanainen 1974).

Flea beetles in the genera Psylliodes and Chaectonema also occur on Cruciferae (Frost 1949). The hop flea beetle, Psylliodes punctulata Melsheimer, is a native polyphagous pest recorded from Solanaceae, Chenopodiaceae, and Cruciferae (Hill 1987). The hop flea beetle is most frequently found in open field habitats (Burgess 1977). Adults overwinter in leaf litter and turf beneath hedges and shelterbelts. The hop flea beetle is the first flea beetle to appear in the spring. The corn flea beetle, Chaectonema pulicara Melsheimer, is infrequently found on Cruciferae in sweep samples (Frost 1949).

Thrips are of minor importance on rapeseed as adults may infest and cause speckling of foliage (Hill 1987). Species in the genus Frankliniella (Thysanoptera: Thripidae) are cosmopolitan, polyphagous species that occur on 300 or more host species. Direct damage consists of leaf and flower distortion and reduction in seedling growth and crop yield. Upon emergence in the spring, adults insert eggs into host tissues, such as buds, flowers, or unfurled leaves. Adult thrips will frequently feed on pollen to supply protein for adult fertility, egg production, and larval growth (Kirk 1984).

Several species of Lepidoptera defoliate many crucifers, including rapeseed (Hill 1987). The diamondback moth, Plutella xylostella (L.) (Yponomeutidae), is a major cosmopolitan pest of crucifers, particularly Brassica spp. Upon emergence in the spring, adults lay eggs singly or in small groups on the upper leaf surface. Larvae emerge after 3 to 8 days and begin to mine the lower epidermis leaf surface. Pupation occurs in silken cocoons attached to plant foliage and adults emerge 5 to 10 days later.

The family Pieridae includes many important species in the genus Pieris that are cosmopolitan pests of crucifers, especially Brassica spp. The imported cabbageworm, Pieris rapae (L.), is a Eurasian species that was introduced into Canada in 1956 (Bonnemaison 1965). Larvae develop between 15 and 32°C and measure 25mm at maturity. A second generation emerges from July to September, and P. rapae overwinters as

pupae (Hill 1987). Another species, the green-veined white butterfly, P. napi (L.), is more common on wild crucifer hosts.

The bertha armyworm, Mamestra configurata Walker (Noctuidae), is an important pest in Canada and the United States (Hill 1987). This species is a defoliator of rapeseed in Canada and reduces pod production by defoliating plants at flower initiation (Lamb 1989). Fifth-instar M. configurata will attack developing pods; an infestation of 10 larvae per 0.836 m^2 may cause a crop loss of 33.87 kg per ha (0.69 bu per acre) (Bracken and Bucher 1977). Larvae feed on flowering shoots and pods during the 5.1 to 5.3 growth stage. Several other noctuid species in the genera Agrotis, Mythimna, and Spodoptera, and the cabbage looper, Trichoplusia ni (Hübner), are pests of crucifers, including rapeseed (Hill 1987). The cabbage looper, a serious cosmopolitan pest, is a polyphagous species that may cause complete defoliation of infested plants.

Species in the genus Lygus (Hemiptera: Miridae) are important crop pests, with 34 species present in Canada and the United States (Kelton 1975). Overwintering adults emerge in March and April and begin to oviposit in unopened flower buds and stems (Hill 1987). Adults and nymphs feed on plant tissues and cause deformation of fruits, and death of flower buds and stems. Injection of toxic saliva by adults during feeding also causes speckling and tattering on leaves.

Continous generations occur in southern climates; however, in northern regions, adults overwinter in foliage or leaf litter.

Three species of Lygus [the pale legume bug, Lygus elisus Van Duzee, the tarnished plant bug, L. lineolaris (Palisot de Beauvois), and L. borealis (Kelton)] have been identified as pests of rapeseed in Canada and the Pacific Northwest (Butts and Lamb 1990). Pale legume bug adults feed on dividing raceme terminals, and 3 or 4 days of feeding cause buds to yellow (Getzin 1983). In western Washington in 1981 and 1982, pale legume bug adults destroyed 1.7 fruiting structures per plant on oilseed cabbage, Brassica oleracea L. Even though crucifers are not preferred hosts of L. elisus, an average density of one adult per plant during a 30-day bloom period would exceed the economic injury level.

The tarnished plant bug attacks more than 169 host species representing 30 plant families (Snodgrass et al. 1984). In Canada, the frequency of tarnished plant bug was significantly higher on B. napus than on B. campestris (Butts and Lamb 1990). Even though glucosinolates are a feeding deterrent, no significant ($P > 0.05$) differences in nymph densities were observed between low glucosinolate rape and high glucosionlate rape. Lygus spp. are uncommon in rapeseed until the crop reaches bud (3.1 to 3.3) growth stage; population peaks coincide with early flowering stages of 4.1 and 4.2 (Butts and Lamb 1991). Most crop injury occurs during

ripening stages of 5.1 to 5.2, when fourth or fifth instar and adult Lygus bugs feed on developing pods and seeds.

Species in the genus Delia (Diptera: Anthomiidae) are important crop pests of crucifers, including rapeseed (Hill 1987). The cabbage root fly, Delia radicum L., is a major cosmopolitan pest of crucifers, particularly Brassica spp. and radish. The larvae eat into the lateral roots, and sometimes tunnel into the taproot and kill plants (Hill 1987, Lamb 1989). Eggs are laid on the soil adjacent to the plant, and larvae hatch in 3 to 7 days (Hill 1987). Larvae feed for three weeks and pupate in 15 to 35 days. This species overwinters as a pupa until warm weather sets in during spring.

The rapeseed species, winter rape, Brassica napus ssp. oleifera forma biennis, is cultivated in western Tennessee to supply high erucic acid oil for use in industrial processes (Fribourg et al. 1989). Rapeseed is a relatively new crop to western Tennessee, where cultivated hectarages are low. From 1986 to 1988, several field trial experiments were conducted in western Tennessee at the Milan Experiment Station in Milan, Tennessee, to determine whether local environmental conditions were suitable for rapeseed cultivation (Fribourg et al. 1989). During the two cropping seasons, yields differed little from those obtained in Canada and Europe; therefore, rapeseed could be a competitive winter crop in Tennessee. Commercial rapeseed cultivation has been limited to ca. 1,620 to 4,860

hectares annually since production began in 1988 (Flinchum 1990, personal communication).

Because rapeseed is a new crop in Tennessee, its ecological relationships and seasonal incidence of insects and arachnids are unknown. Thus, a two-year study was conducted to address these research areas. Information obtained in this study would be useful to develop management strategies for potential pest species, and to determine the extent that rapeseed serves as a host to populations of Lygus species, with implications for later infestation of other crops. The objectives of this research were to:

1. identify pest and beneficial species on winter rape in western Tennessee,
2. determine the seasonal incidence of species, and
3. observe if rapeseed serves as an early-season host for Lygus species.

Chapter 2

MATERIALS AND METHODS

Above-ground arthropods were observed on and collected from commercial rapeseed fields in four counties in western Tennessee. Arthropod populations were monitored in seven commercial fields of rapeseed in 1990 and eight commercial fields in 1991. In 1990, fields in Fayette (1), Haywood (2), and Lake (4) Counties were sampled from March 9 to June 4, and in 1991, four fields in both Henry and Lake Counties were sampled from March 19 to June 4 (Figure 1). On each sampling date arthropod activity, such as location and mating activities, on plants was observed. Feeding damage was rated as light or heavy, and the growth stage of rapeseed was recorded using the growth key for Brassica campestris L. and B. napus L. (Harper and Berkenkamp 1975) in each field.

Three sampling methods were utilized to assess the seasonal incidence of arthropods on rapeseed. Sampling methods included D-Vac, whole plant, and sweep-net sampling. A D-Vac vacuum net (D-Vac Co., Riverside, California USA) was held for 10 seconds over plants at six randomly selected sites per field. In 1990, the sampling was conducted on March 23 in Levee and Wagner fields, and on April 7 in the Lindamood field. Because of the difficulty involved in sampling rapeseed stands, D-Vac sampling was discontinued in 1990 and was not used in 1991. Specimens were placed into vials (20 ml)

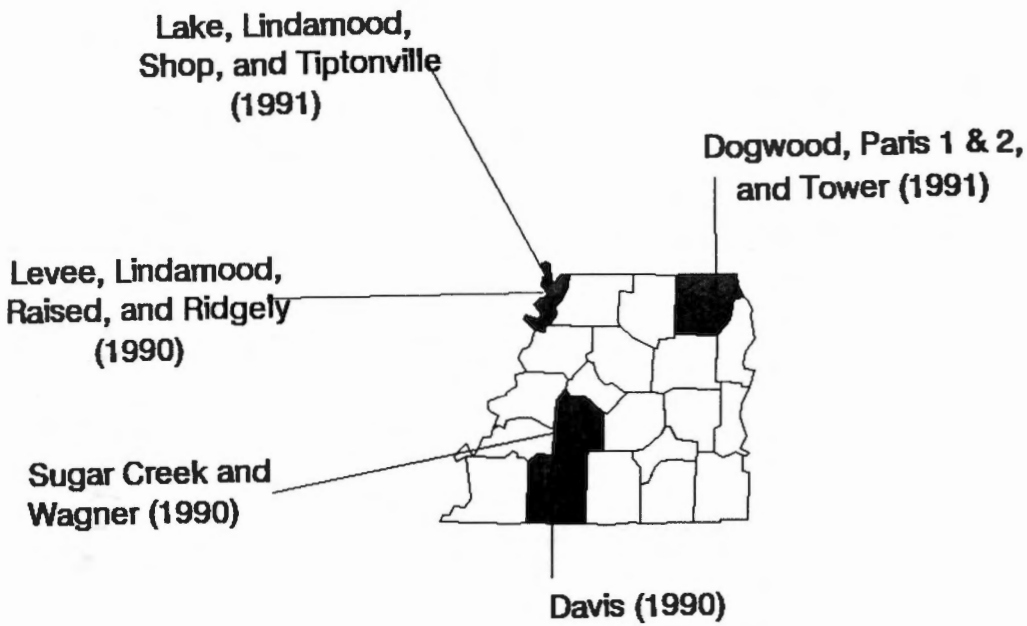

Figure 1. Location of rapeseed sampling sites (shaded counties) in western Tennessee during 1990 and 1991.

containing 70% ethyl alcohol and held for further identification.

Whole-plant sampling involved the uprooting or cutting of plants at ground level, and placing them into plastic bags. In 1990, four whole-plant samples (15-25 whole-plants per sample) were randomly collected in each field from March 9 to March 23, and in 1991, four whole-plant samples (10-20 whole-plants per sample) were randomly collected per sample on March 19 and March 28 in each field. Samples were placed into plastic bags, stored in a cooler (60.54 liter), and transported to the laboratory. Samples were then examined for arthropods and damage; collected specimens were placed into vials (20 ml) containing 70% ethyl alcohol and held for further identification.

Four sweep-net (38-cm-diameter) samples (50 sweeps per sample) with a 180° arc were taken randomly in each field on each sampling date and placed separately into ice cream containers (3.78 liter), with a single paper towel saturated with 95% ethyl acetate. Containers were taken to the laboratory and allowed to remain overnight to sufficently asphyxiate the specimens. In the laboratory, arthropods were partially hand separated from plant material and placed in vials (20 ml) containing 90% ethyl alcohol. This high concentration of alcohol was used due to its dilution caused by the water content of plant material and arthropod specimens. Samples

were later sorted, and specimens were counted and identified to family, genus, and species, when possible.

Voucher specimens were placed at the West Tennessee Experiment Station in Jackson, Tennessee, and in the University of Tennessee Insect Museum located on the Agriculture Campus, University of Tennessee, Knoxville.

Chapter 3

RESULTS AND DISCUSSION

Species Composition

During this two-year study, approximately 111 species or groups of arthropods were found on rapeseed in western Tennessee (Table 1). Forty-seven families representing ten orders of insects and five families from one order of arachnids, were collected from rapeseed.

The most extensive arthropod diversity was found during the flowering and ripening stages of rapeseed. The most frequently collected orders were Coleoptera, Hemiptera, Homoptera, and Hymenoptera (Table 1). The incidence of selected insects from eleven families representing five orders in 1990 (Table 2) and 1991 (Table 3) is discussed further in this chapter.

Seasonal Incidence

Several species of aphids were present on rapeseed during both years of this study. During 1990, two species of aphids [the turnip aphid, Lipaphis erysimi (Kaltenbach), and the green peach aphid, Myzus persicae (Sulzer) (Homoptera: Aphididae)] were collected from both whole-plant and sweep-net samples. During 1991, however, three aphid species [the turnip aphid, the green peach aphid, and the cabbage aphid, Brevicoryne brassicae (L.)] were collected. The cabbage aphid was collected only from whole-plant samples in one field. The turnip aphid and green

Table 1. Arthropods associated with rapeseed, Brassica napus ssp. oleifera, in western Tennessee, in 1990 and 1991.

Order/ Family	Genus	Species	Author	ST[a]	Field Sites[b]
Collembola/ Isotomidae	--	--	--	D,WP	4,9,15
Orthoptera/Acrididae	--	--	--	S	1,2,3,6,8,10-15
Tettigoniidae	--	--	--	S	15
Diptera/Chloropidae	--	--	--	S	1-15
Muscidae	--	--	--	S	1-15
Muscidae	--	--	--	S	1-15
Ottidae	--	--	--	S	1
Ottidae	--	--	--	S	1-15
Psychodidae	--	--	--	S	1-15
Syrphidae	--	--	--	S	1-15
Tipulidae	--	--	--	S	1-15
Neuroptera/Chrysopidae	*Chrysopa*	sp.	--	S,WP	1-15
Lepidoptera/Noctuidae	--	--	--	S	1-15
	--	--	--	S	8
Pieridae	*Pieris*	*napi*	(L.)	S	4,9
	Pieris	*rapae*	(L.)	S	1-4,8-11,14,15
Pyralidae	*Evergestis*	sp.	--	S	4,9
Homoptera/Aphididae	*Brevicoryne*	*brassicae*	(L.)	WP	11,13
	Lipaphis	*erysimi*	(Kaltenbach)	D,S,WP	1-15
	Myzus	*persicae*	(Sulzer)	D,S,WP	1-4,6-8,10-15
Cicadellidae	--	--	--	S	1-6,9-11,13-15
Hymenoptera/Aphidiidae	*Diaeretiella*	*rapae*	(M'Intosh)	S,WP	1-15
Apidae	*Apis*	*mellifera*	(L.)	S	1-15
	Bombus	sp.	--	S	3
Formicidae	--	--	--	S	2,3,8,9,11-14
Ichneumonidae	--	--	--	S	2-15
Thysanoptera/Thripidae	*Frankliniella*	*fusca*	(Hinds)	S	1-3,5-15
	Frankliniella	*tritici*	(Fitch)	S	1-15
	Neohydatothrips	*variabilis*	(Beach)	S	1
Hemiptera/Corimelaenidae	--	--	--	S	13,14
Anthocoridae	*Orius*	*tristicolor*	(White)	S	1-3,6-10,12-15
Lygaeidae	*Geocoris*	sp.	--	S	3,6,10
	Nysius	sp.	--	D,S	1-15

Table 1. (Continued)

Order/Family	Genus	Species	Author	ST	Field Sites
Hemiptera/Miridae	*Lygus*	*lineolaris*	(Beauvois)	S,WP	1-15
Pentatomidae	*Acrosternum*	*hilare*	(Say)	S	2,7,8,14
	Euschistus	*servus*	(Say)	S	1-8,10-14
	Murgantia	*histrionica*	(Hahn)	S	1,2,5,12,14
	Podisus	*maculiventris*	(Say)	S	3-7,13,14
Coleoptera/Cantharidae	*Cantharis*	*bilneatus*	Say	S	7,8,11,14
	Cantharis	*carolinus*	F.	S	15
	Cantharis	*impressus*	LeConte	S	14
	Cantharis	*marginatus*	F.	S	8-10,12,15
	Chauliognathus	*marginatus*	F.	S	1-3,5-8,11,13,14
Carabidae	*Clivina*	sp.	--	S	12
	Harpalus	*erythropus*	Dejean	S	14
Cerambycidae	*Stenosphenus*	*notatus*	(Olivier)	S	12
	--	--	--	S,WP	3,7-9
Chrysomelidae	*Acalymma*	*vittatum*	(F.)	S	1-6,10,11,14
	Cerotoma	*trifurcata*	(Forster)	S	1-3,8,9,11,12,14,15
	Chaetocnema	*pulicaria*	Melsheimer	S,WP	1-15
	Chaetocnema	*confinis*	Crotch	S	7,8
	Chrysodina	*globosa*	(Olivier)	S	12
	Collops	*quadrimaculatus*	(F.)	S	2,3,6,11,14
	Crepidodera	*nana*	Say	S	1-15
	Diabrotica	*undecimpunctata*	Barber	S	1,3-12,14,15
	Disonycha	*xanthomelas*	(Dalman)	S	14
	Donica	*flavipes*	Kirby	S	15
	Donica	*pennsylvanica*	(Illiger)	S	12
	Galerucella	*nymphaeae*	(L.)	S	12
	Gastrophysa	*cyanea*	Melsheimer	S	1-15
	Hydrothassa	*vittata*	(Olivier)	S	6
	Lema	*collaris*	Say	D,S	5,7,14
	Lema	*trilinea*	White	S	7
	Lema	sp.	--	S	7
	Mantura	*floridana*	Crotch	S	2-15
	Paria	*canella*	(F.)	WP	15
	Phaedon	*viridus*	(Melsheimer)	S	5

Table 1. (Continued)

Order/Family	Genus	Species	Author	ST	Field Sites
Coleoptera/Chrysomelidae	*Phyllotreta*	*cruciferae*	(Goeze)	S,WP	1-15
	Phyllotreta	*striolata*	(F.)	S	1-12,14,15
	Phyllotreta	*zimmermanni*	(F.)	S	1-15
	Phyllotreta	sp.	--	S	1-15
Cleridae	*Placopterus*	*thoracicus*	(Olivier)	D,S	1
Coccinellidae	*Anatis*	*quidenimpunctata*	(Olivier)	S	2
	Chilocorus	*stigma*	Say	S	14
	Coccinella	*septempunctata*	L.	D,S	1,2,4,5,7-15
	Coleomegilla	*maculata*	Timberlake	s	1-15
	Cycloneda	sp.	--	S	2,4,5,7,9
	Hippodamia	*convergens*	Guerin-Meneville	S,WP	1,2,4-6,8-12,14,15
Curculionidae	*Apion*	*paturelm*	Smith	S	1
	Ceutorhynchus	*assimilis*	(Paykull)	D,S,WP	1-15
	Ceutorhynchus	sp.	--	S,WP	1-9,11,15
	Graphognathus	*leucoloma*	(Boheman)	S	12
	Lixus	*concavus*	Say	S	1
	Phytonomus	*nigriorostris*	(F.)	S	9
	Pseudobaris	*nigrina*	(Say)	S	15
	Sitona	sp.	--	S	12
Elateridae	--	--	--	WP	15
Lampyridae	*Lucidota*	*punctata*	LeConte	S	4,12
	--	--	--	S	14
Languriidae	*Languria*	*angustata*	(Beauvouis)	S	11
	Languria	*bicolor*	(F.)	S	11
	Languria	*mozardi*	Latreille	S	2,3,6,7,9-12,15
	Languria	*trifasciata*	Say	S	2
Meloidae	*Pomphopoea*	*sayi*	LeConte	S	12
Mordellidae	--	--	--	S	1,2,6-8,12,14,15
	Mordellistena	*marginalis*	(Say)	S	12
	Mordellistena	*pustulata*	(Melsheimer)	S	7
Mylabridae	*Bruchus*	*brachialis*	Fahraeus	S	1,3,4,6,10,12,15
	Mylabris	*pisorum*	Linne'	S	1-9,11-15

Table 1. (Continued)

Order/Family	*Genus*	*Species*	Author	ST	Field Sites
Coleoptera/Nitidulidae	*Meligethes*	*nigrescens*	Stephens	S	1-15
	Nitidula	*rufipes*	Linne'	S	15
Phalacridae	*Acylomus*	*ergoti*	Casey	S	2,9,11-14
Scarabaeidae	*Ataeinus*	*strigatus*	(Say)	WP	15
Staphylinidae	*Paederus*	*littoraarius*	Gravenhorst	WP	1,12
	Lobrathium	*collare*	Erichson	WP	12
Lycosidae	--	--	--	D,S	1-3,5-10,12-15
Salticidae	--	--	--	S	1,4,5,12,15
Tetragnathidae	*Tetragnatha*	sp.	--	S	1-15
Theridiidae	--	--	--	S	1-15
Thomisidae	*Misumena*	sp.	--	S	1-15
	Misumenops	sp.	--	S	1-8,10,11,12-15

[a]ST = Sample Type; D = D-Vac, S = Sweep, WP = Whole Plant.

[b]Field Sites: 1 = Davis, 2 = Dogwood, 3 = Lake, 4 = Levee, 5 = Lindamood 1990, 6 = Lindamood 1991, 7 = Paris1, 8 = Paris2, 9 = Raised, 10 = Ridgely, 11 = Shop, 12 = Sugar Creek 13 = Tiptonville, 14 = Tower, 15 = Wagner. Locations of field sites are presented in Figure 1.

Paris1 and Paris2 were treated with insecticides on April 17, 1991.

Table 2. Selected insect species collected in sweep-net samples from rapeseed, Brassica napus ssp. oleifera, in western Tennessee from seven commercial fields in 1990 (+ = present, - = not present).

	Field						
Insect	Davis	Levee	Lindamood	Raised	Ridgely	Sugar Cr.	Wagner
cabbage aphid	-	-	-	-	-	-	-
turnip aphid	+	+	+	+	+	+	+
green peach aphid	+	+	-	-	+	+	+
wasp parasitoid	+	+	+	+	+	+	+
cabbage seedpod weevil	+	+	+	+	+	+	+
Ceutorhynchus sp.	+	+	+	+	-	+	+
corn flea beetle	+	+	+	+	+	+	+
crucifer flea beetle	+	+	+	+	+	+	+
striped flea beetle	-	+	+	+	+	+	+
Mantura floridana	-	+	+	+	+	+	+
Phyllotreta zimmermanni	+	+	+	+	+	+	-
ninespotted lady beetle	-	-	-	-	-	+	-
sevenspotted lady beetle	+	+	+	+	+	+	+
pink lady beetle	+	+	+	+	+	+	+
convergent lady beetle	+	+	+	+	+	+	+

Table 2. (Continued)

	Field						
Insect	Davis	Levee	Lindamood	Raised	Ridgely	Sugar Cr.	Wagner
twicestabbed lady beetle	-	-	-	-	-	-	-
Meligethes nigrescens	+	+	+	+	+	+	+
tobacco thrips	+	-	+	+	+	+	+
flower thrips	+	+	+	+	+	+	+
minute pirate bug	+	-	-	+	+	+	+
tarnished plant bug	+	+	+	+	+	+	+
brown stink bug	+	+	+	-	+	+	-
harlequin bug	+	-	-	-	-	+	-
southern green stink bug	-	-	-	-	-	-	-
spined soldier bug	-	+	-	-	-	-	-

Table 3. Selected insect species collected in sweep-net samples from rapeseed, Brassica napus ssp. oleifera, in western Tennessee from eight commercial fields in 1991 (+ = present, - = not present).

	Field							
Insect	Dogwood	Lake	L'mood[a]	Paris I	Paris II	Shop	T'ville[b]	Tower
cabbage aphid	-	-	-	-	-	-	+	-
green peach aphid	+	+	+	+	+	+	+	+
turnip aphid	+	+	+	+	+	+	+	+
wasp parasitoid	+	+	+	+	+	+	+	+
cabbage seedpod weevil	+	+	+	+	+	+	+	+
Ceutorhychus sp.	+	+	+	-	-	+	+	+
corn flea beetle	+	+	+	+	+	+	+	+
crucifer flea beetle	+	+	+	+	+	+	+	+
striped flea beetle	+	+	+	+	+	+	-	+
Phyllotreta zimmermanni	+	+	+	+	+	+	+	+
Mantura floridana	+	+	+	+	+	+	+	+
ninespotted lady beetle	+	-	-	-	-	-	-	-
7-spotted lady beetle	+	-	-	+	+	+	+	+
pink lady beetle	+	+	+	+	+	+	+	+
convergent lady beetle	+	+	+	+	+	+	+	+

Table 3. (Continued)

Insect	Field							
	Dogwood	Lake	L'mood[a]	Paris I	Paris II	Shop	T'ville[b]	Tower
twicestabbed lady beetle	-	-	-	-	-	-	-	+
Meligethes nigrescens	+	+	+	+	+	+	+	+
tobacco thrips	+	+	+	+	+	+	+	+
flower thrips	+	+	+	+	+	+	+	+
minute pirate bug	-	+	+	+	+	-	-	+
tarnished plant bug	+	+	+	+	+	+	+	+
brown stink bug	+	+	+	+	+	+	+	+
harlequin bug	+	-	-	-	-	-	-	+
southern green stink bug	+	-	-	-	-	-	-	+
spined soldier bug	-	+	+	+	+	-	+	-

[a] L'mood = Lindamood
[b] T'ville = Tiptonville

peach aphid were present on the first sampling date (March 9 and 19) in 1990 and 1991, respectively. The cabbage aphid also was present on the first sampling date in 1991. All three aphid species infested the foliage and buds during the budding (3.2 and 3.3) stage; however, populations in 1991 were 40.9% lower than in 1990. No visible damage was observed, and infested plants continued to grow.

During both years of this study, the turnip aphid was the predominant species collected in most (7 of 7 in 1990 and 6 of 8 in 1991) of the fields sampled. Turnip aphid populations as estimated by whole plant sampling varied among fields and different plant growth stages in 1990 (Table 4) and in 1991 (Table 5). In 1990 in the Davis Field, turnip aphids infested 15.0% of the plants (n = 100) sampled on March 9; whereas, two weeks later 46.7% of the plants (n = 60) sampled were infested. The density of turnip aphids per plant on March 23 was 13.6 times greater than the density on March 9. In 1991 in the Shop Field, the density of turnip aphids had risen from zero per plant (n = 40) on March 19 to approximately three per plant (n = 40) on March 28.

Turnip aphids were collected in sweep-net samples from flowering (4.1 to 4.4) to the ripening (5.1 to 5.5) stages of rapeseed. Turnip aphid populations increased most rapidly during flowering for both Raised Field, Lake County (Figure 2) in 1990, and Tower Field, Henry County (Figure 3)

Table 4. Infestation of rapeseed by the turnip aphid, Lipaphis erysimi, in selected fields in western Tennessee on March 9, 16, and 23, 1990.

Location[a]	No. of Whole Plants Collected	Growth Stage[b] of Rapeseed	% of Plants Infested	Avg. No. (±SD) Aphids per Plant
		March 9, 1990		
Davis (F.C.)	100	3.1	15.0	0.30± 0.92
Ridgely (L.C.)	100	3.1	1.0	0.01± 0.10
Wagner (H.C.)	100	3.2	20.0	1.12± 3.59
		March 16, 1990		
Davis (F.C.)	100	3.1	52.0	2.87± 5.77
Ridgely (L.C.)	100	3.1	7.0	0.76± 3.29
Wagner (H.C)	60	3.2	50.0	2.22±14.01
		March 23, 1990		
Davis (F.C.)	60	3.2	46.7	4.08±10.77
Ridgely (L.C.)	60	3.2	8.4	0.67± 3.39

[b]F.C. = Fayette County, H.C. = Haywood County, L.C. = Lake County

[b]Plant growth stage was determined based on Harper and Berkenkamp (1975) growth-stage key for Brassica campestris and B. napus.

Table 5. Infestation of rapeseed by the turnip aphid (TA), Lipaphis erysimi, and the green peach aphid (GPA), Myzus persicae, in selected fields in Lake County in western Tennessee on March 19 and 28, 1991.

Location	No. of Whole Plants Collected	Growth Stage[a] of Rapeseed	% of Plants Infested	Mean No. (±SD) TA per Plant	Mean No. (±SD) GPA per Plant
		March 19, 1991			
Tiptonville	40	3.2	27.5	0.10± 0.62	1.88±6.04
Shop	40	3.2	0.0	0.00± 0.00	0.00±0.00
		March 28, 1991			
Tiptonville	40	3.3	7.5	0.43± 2.49	0.75±0.35
Shop	40	3.3	52.5	3.23±10.07	2.18±5.26

[a]Plant growth stage was determined based on Harper and Berkenkamp (1975) growth-stage key for Brassica campestris and B. napus.

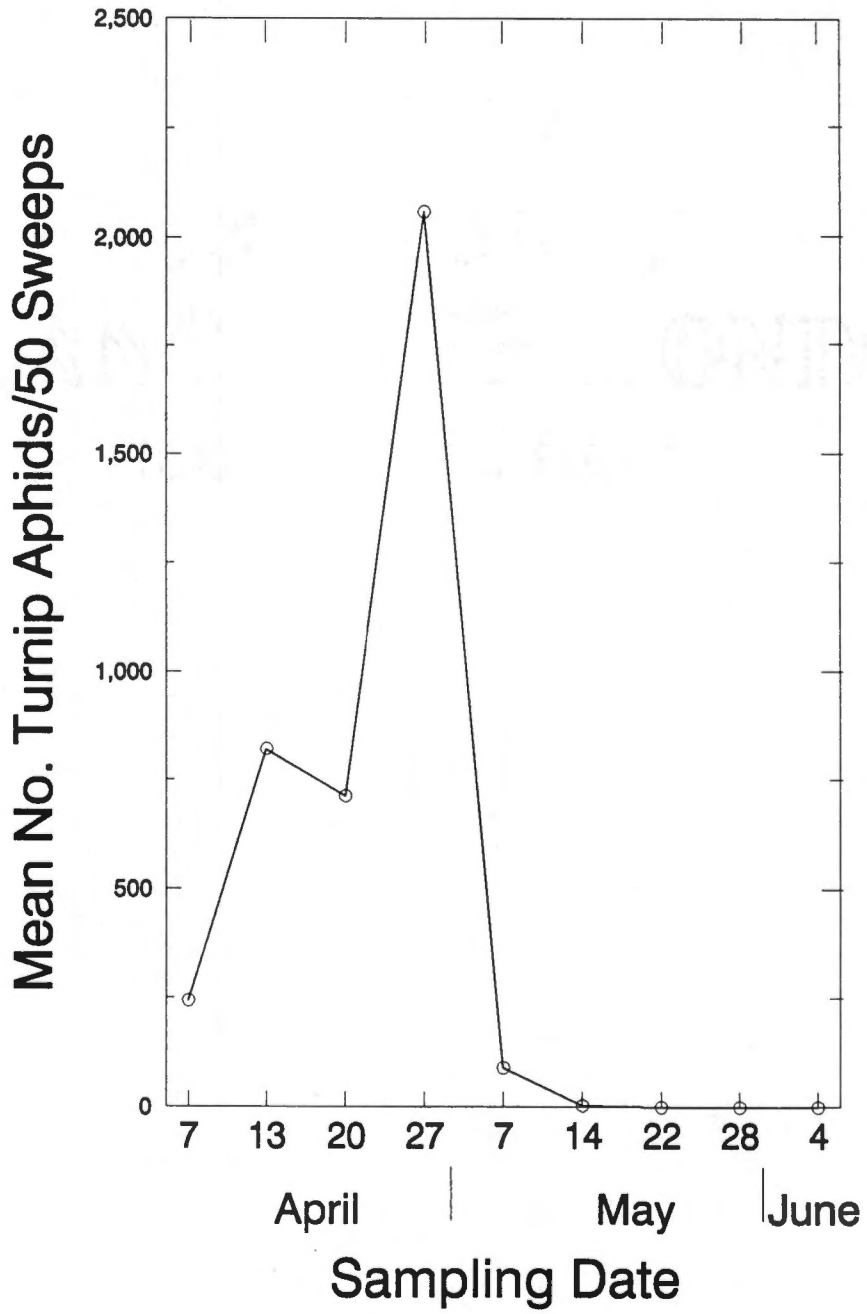

Figure 2. Infestation of the turnip aphid, Lipaphis erysimi, during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Raised Field, Lake County, Tennessee, 1990.

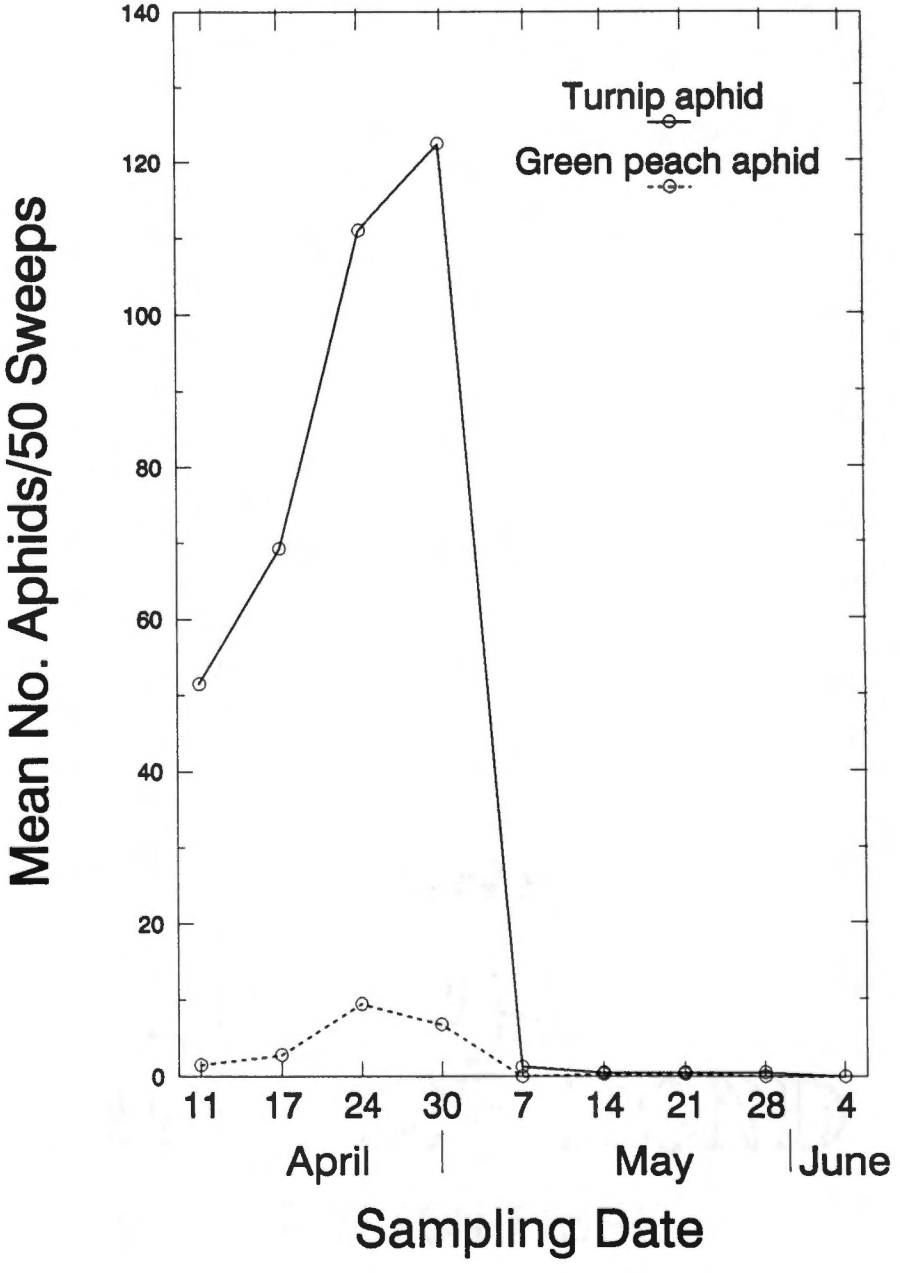

Figure 3. Infestation of the turnip aphid, Lipaphis erysimi, and the green peach aphid, Myzus persicae, during the flowering (April 11 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Tower Field, Henry County, Tennessee, 1991.

in 1991. The highest level of turnip aphid infestation in Raised Field ($\bar{x}$ = 2060/50 sweeps) and Tower Field ($\bar{x}$ = 122.5/50 sweeps) occurred after peak flowering. Visual observations noted that feeding damage resulted in reduced plant growth, fewer seedpods, and delayed seed maturity. Damage of this type is characteristic of turnip aphid infestation (Hill 1987). These factors later resulted in uneven stand maturity in heavily-infested fields.

Green peach aphid populations, as estimated by whole plant sampling, were higher than the turnip aphid populations in the Tiptonville (March 19 and 28) Field (Table 5) in 1991. On March 19, the density of green peach aphids per plant (n = 40) was 18.8 times greater than the turnip aphid density, and on March 28, the density of green peach aphids was still greater than the turnip aphid density. Green peach aphids were collected in sweep-net samples from flowering (4.1 to 4.4) to the ripening (5.1 to 5.5) stages of rapeseed. In Tower Field (Figure 3) in 1991, the green peach aphid population peak ($\bar{x}$ = 9.5/50 sweeps) coincided with peak flowering. The cabbage aphid was collected only in Tiptonville Field on March 19, 1991, with 2 of 20 plants (nine and two aphids per plant, respectively) infested, as estimated by whole plant sampling.

In all seven and eight fields sampled in 1990 and 1991, respectively, turnip aphids were frequently attacked by a wasp parasitoid [Diaeretiella rapae (M'Intosh) (Hymenoptera:

Aphidiidae)]. Visual observations noted that the level of parasitism varied among fields, and parasitism levels were highest in fields with heavy aphid infestations. Wasp populations peaked at lower densities and on later sampling dates than turnip aphid populations. For example, in 1990 in the Ridgely Field, Lake County, wasp populations peaked ca. 2.5 weeks after turnip aphid populations peaked, and the peak density was ca. 67.1% less than that of the turnip aphid population peak (Figure 4). In 1991, in the Dogwood Field, Henry County, the wasp population peak density was 93.8% less than that of the turnip aphid population peak (Figure 5). Wasp populations in all fields were 95.8% lower in 1991 than in 1990. Aphids parasitized in the field ceased feeding and attached themselves to plant stems. Parasitized aphids became brown mummies and were easily recognized.

Several common species of Coleoptera, representing the families Curculionidae, Chrysomelidae, Nitidulidae, and Coccinellidae, were present in sweep-net samples. The curculionid species, the cabbage seedpod weevil, Ceutorhynchus assimilis (Paykull), was collected in all seven and eight fields in 1990 and 1991, respectively, on each sampling date. A second unidentified Ceutorhynchus sp. was collected in only six fields in 1990 and 1991 on each sampling date.

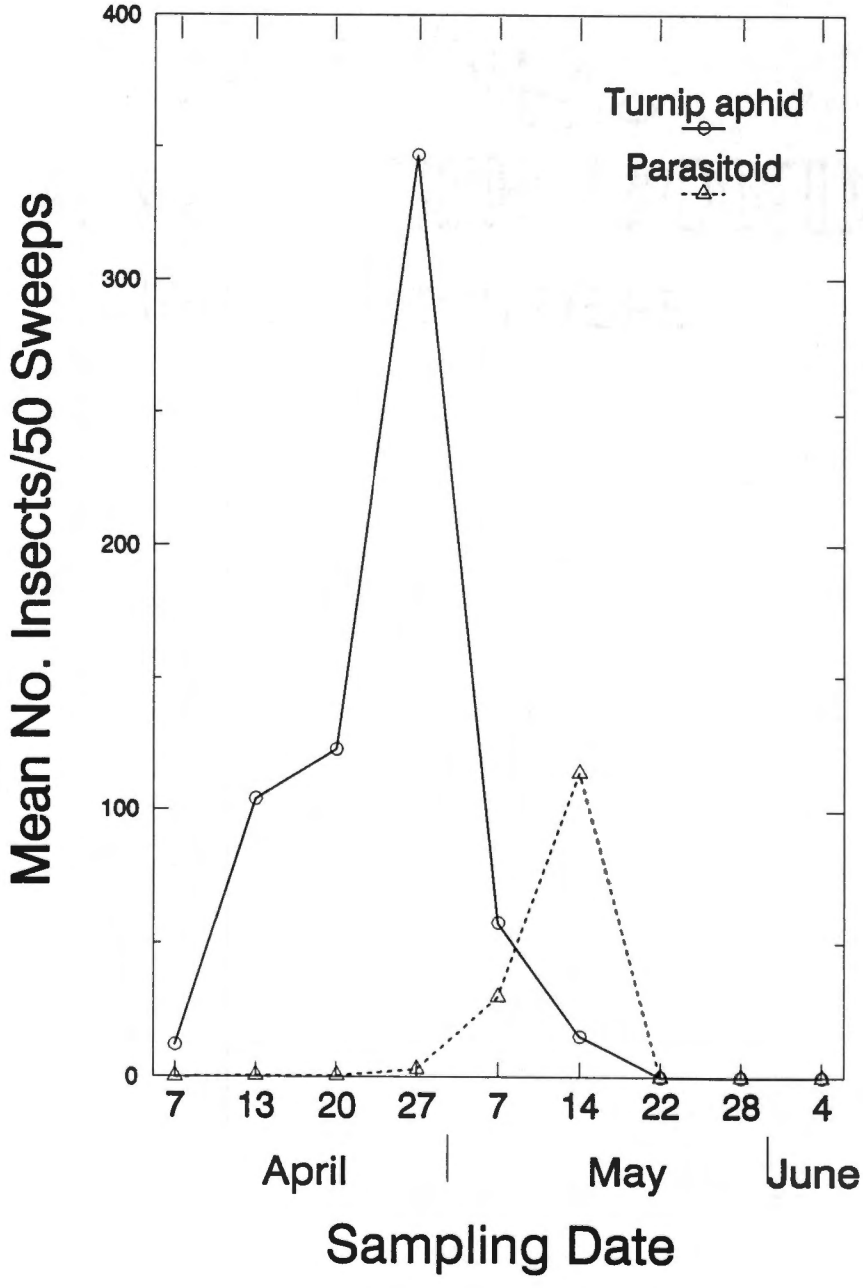

Figure 4. Seasonal incidence of the turnip aphid, Lipaphis erysimi, and a wasp parasitoid, Diaeretiella rapae, during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Ridgely Field, Lake County, Tennessee, 1990.

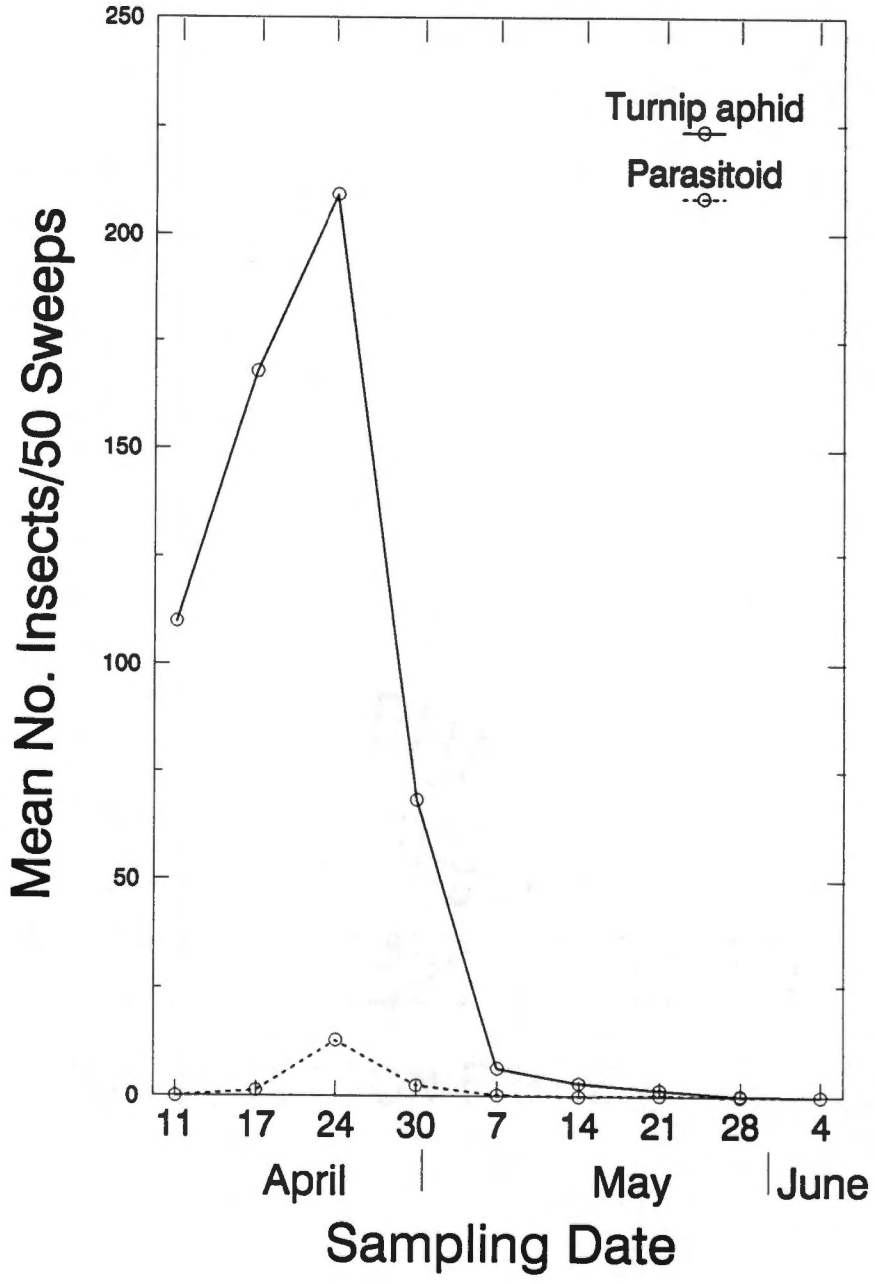

Figure 5. Seasonal incidence of the turnip aphid, Lipaphis erysimi, and a wasp parasitoid, Diaeretiella rapae, during the flowering (April 11 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Dogwood Field, Henry County, Tennessee, 1991.

The cabbage seedpod weevil was the most common curculionid (98.8%) species collected in sweep-net samples. Cabbage seedpod weevil adults began to emerge from overwintering sites and were first collected as rapeseed began to flower in early April. These adults were observed to feed and mate on plant terminals, and in some cases to feed within individual flowers.

Two distinct population peaks of the cabbage seedpod weevil were observed for the Sugar Creek Field, Haywood County (Figure 6) in 1990 and in the Tower Field, Henry County (Figure 7) in 1991. The population peak of overwintering adults ($\bar{x}$ = 4.3/50 sweeps) in the Sugar Creek Field occurred on April 20 when flowering terminated; whereas, the population peak ($\bar{x}$ = 168.8/50 sweeps) in the Tower Field coincided with peak flowering on April 11. Pods were visually examined for ovipositional punctures; and damaged pods were characterized by the presence of a small, black puncture wound. Damaged pods averaged three to five damaged seeds per pod. Three to four weeks after the peak of the overwintering population, the first summer generation (F_1) adults were collected around May 28, 1990, in the Sugar Creek Field, and in the Tower Field the first F_1 adults were collected around May 14, 1991. In 1990, the F_1 adult population peaked ($\bar{x}$ = 4.0/50 sweeps) on June 4 in the Sugar Creek Field; whereas, in 1991, the population peaked ($\bar{x}$ = 173.5/50 sweeps) in the Tower Field on May 21. The F_1

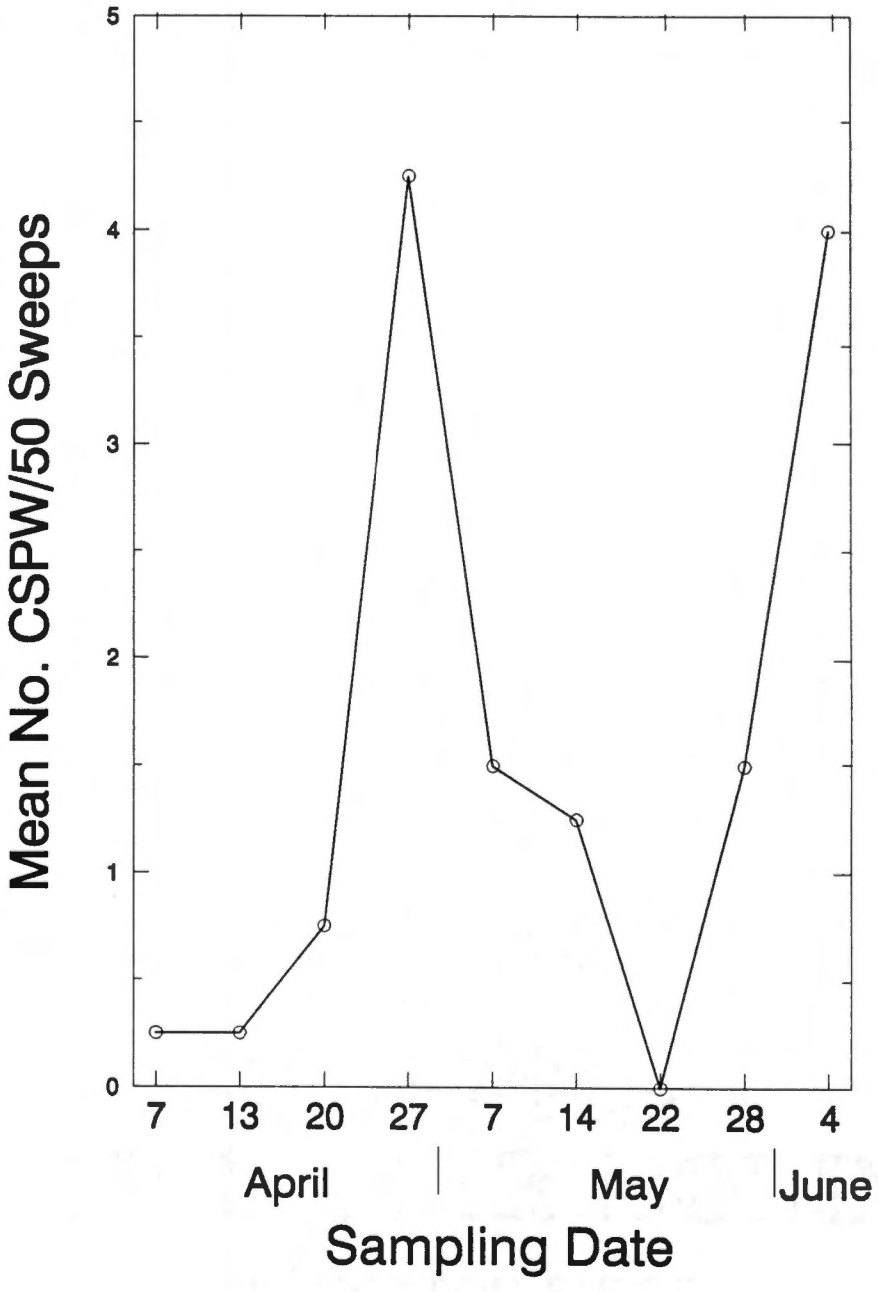

Figure 6. Infestation of the cabbage seedpod weevil (CSPW), Ceutorhynchus assimilis, adults during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Sugar Creek Field, Haywood County, Tennessee, 1990.

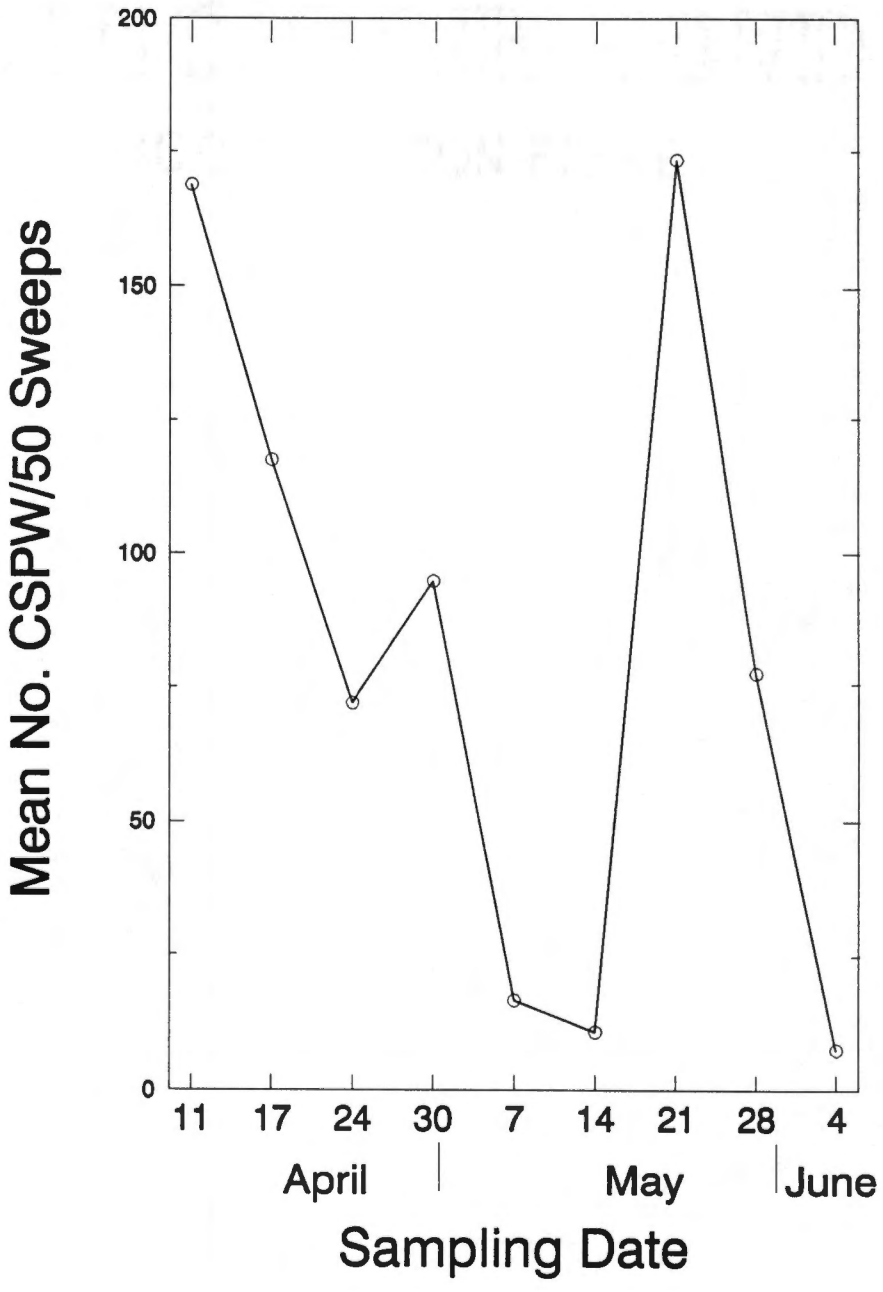

Figure 7. Infestation of the cabbage seedpod weevil (CSPW), Ceutorhynchus assimilis, adults during the flowering (April 11 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Tower Field, Henry County, Tennessee, 1991.

adults were observed to feed on the few flowers and green pods that remained in the field.

Five species of flea beetles [the corn flea beetle, Chaetocnema pulicaria Melsheimer, Mantura floridana Crotch, the crucifer flea beetle, Phyllotreta cruciferae (Goeze), the striped flea beetle, P. striolata (F.), and P. zimmermanni (F.)] (Coleoptera: Chrysomelidae) were identified from sweep-net samples collected in 1990 and 1991. Flea beetles, especially C. pulicaria, were collected during the flowering (4.1 to 4.4) and ripening (5.1 to 5.5) stages of rapeseed. Because flea beetles are primarily seedling pests, occurrence of significant damage at these stages of plant growth is unlikely. In 1990, two of the three Phyllotreta species (P. cruciferae and P. zimmermanni) were the most abundant flea beetles present, and accounted for 97.8% of all flea beetles collected. The first flea beetles were collected on May 14 in the Lindamood Field, Lake County (Figure 8). The maturity of the rapeseed stand at this location was two weeks later as compared to the other fields sampled, and more flowers were present on this sampling date. The density of P. cruciferae peaked ($\bar{x}$ = 291.0/50 sweeps) on May 28, when rapeseed was in its ripening (5.2) stage. The density of P. zimmermanni was lower than that of P. cruciferae, but its population increased on each sampling date after May 7.

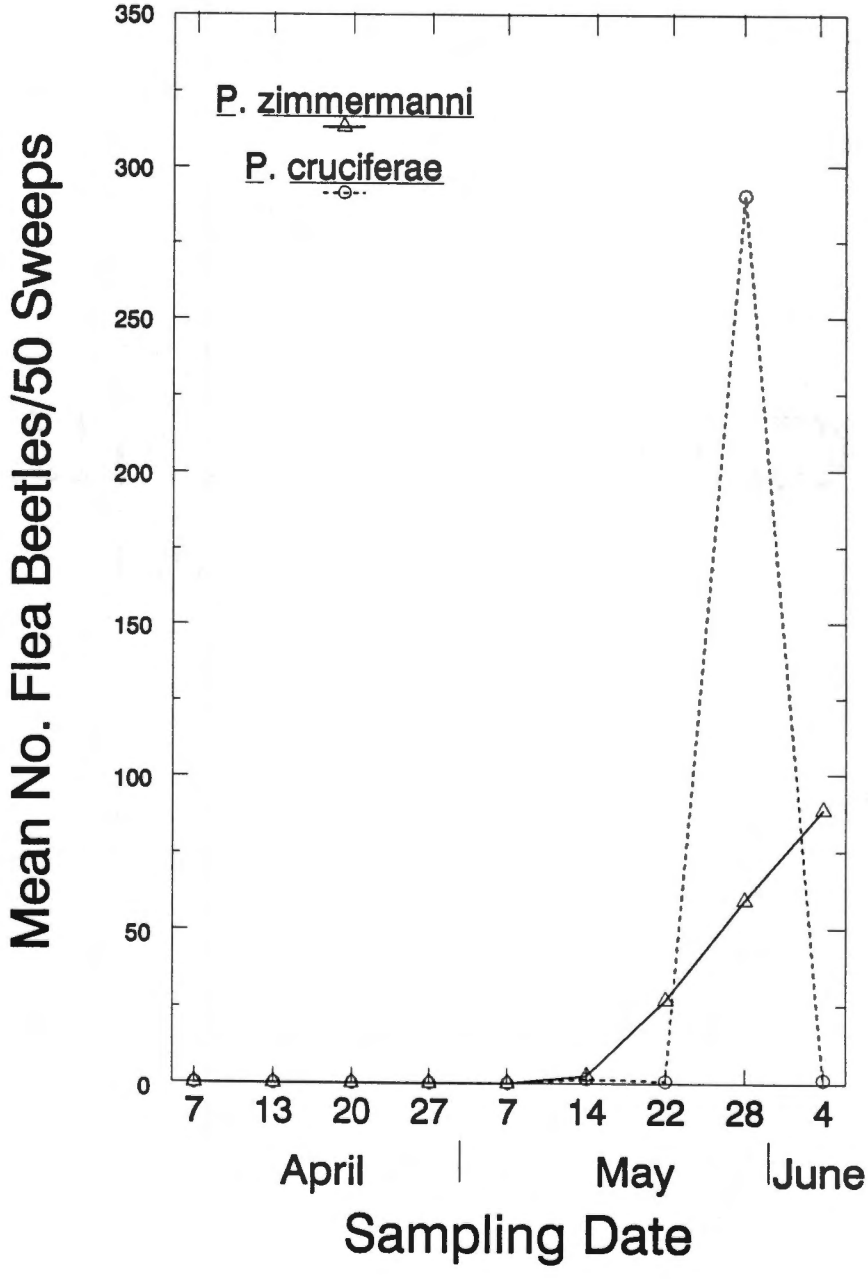

Figure 8. Seasonal incidence of Phyllotreta cruciferae and P. zimmermanni adults during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Lindamood Field, Lake County, Tennessee, 1990.

In 1991, Chaetocnema pulicaria, Mantura floridana, and P. zimmermanni were the three most abundant flea beetles collected and accounted for 73.4% of all flea beetles encountered. The first flea beetles (C. pulicaria) were collected on April 10 in the Lake Field, Lake County (Figure 9). The density of C. pulicaria peaked ($\bar{x}$ = 1.8/50 sweeps) on May 21. Mantura floridana and P. zimmermanni species had higher population densities, but were frequently collected during the ripening stage at this location. Phyllotreta zimmermanni was the second most abundant flea beetle species in all eight fields sampled, and accounted for 26.8% of all flea beetles collected in 1991. The peak density of P. zimmermanni occurred on May 14 at 11.0 adults per 50 sweeps. The density of M. floridana was higher than P. zimmermanni but was collected on fewer sampling dates. Mantura floridana was the most abundant (32.3%) flea beetle species collected in 1991.

The nitidulid species, Meligethes nigrescens Stephens, was collected in all fields sampled during both years of this study. Meligethes nigrescens adults were first collected in 1990 on April 7 in the Wagner Field, Haywood County (Figure 10), and in 1991 on April 10 in the Tiptonville Field, Lake County (Figure 11). Beetles were collected throughout the flowering (4.1 to 4.4) and into the early ripening (5.1) stages at both locations. When plants were at peak flowering (4.2) and lower pods were beginning

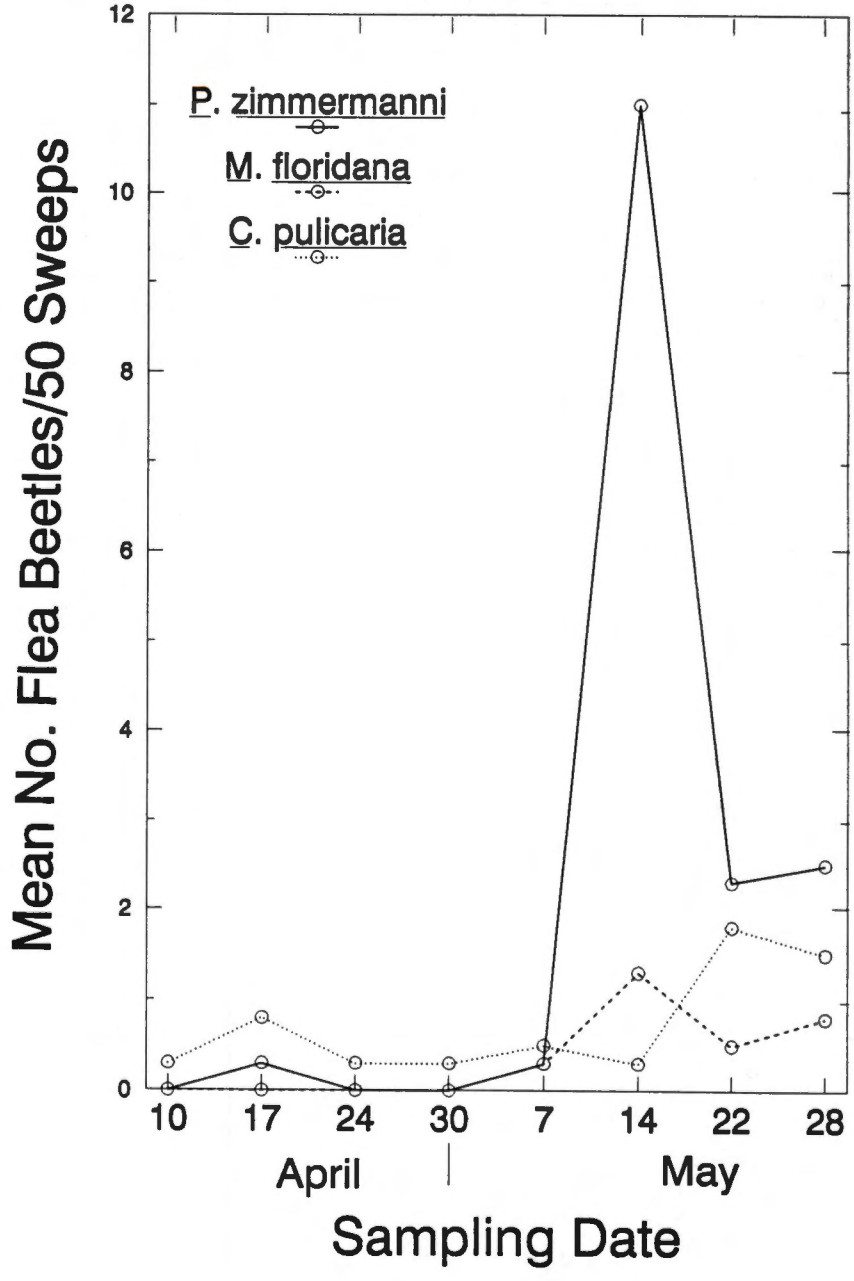

Figure 9. Seasonal incidence of Chaetocnema pulicaria, Phyllotreta zimmermanni, and Mantura floridana adults during the flowering (April 10 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Lake Field, Lake County, Tennessee, 1991.

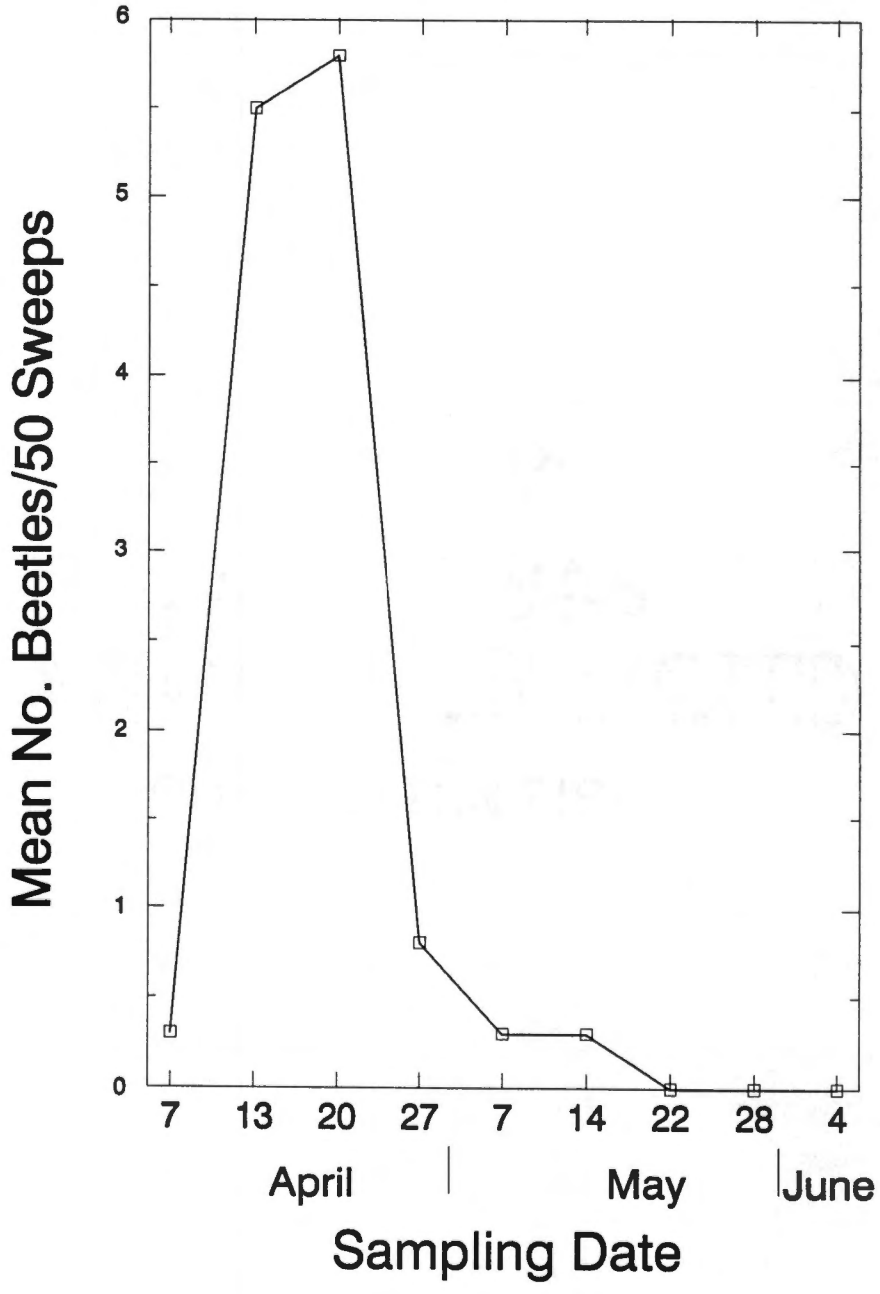

Figure 10. Seasonal incidence of nitidulid adults during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Wagner Field, Haywood County, Tennessee, 1990.

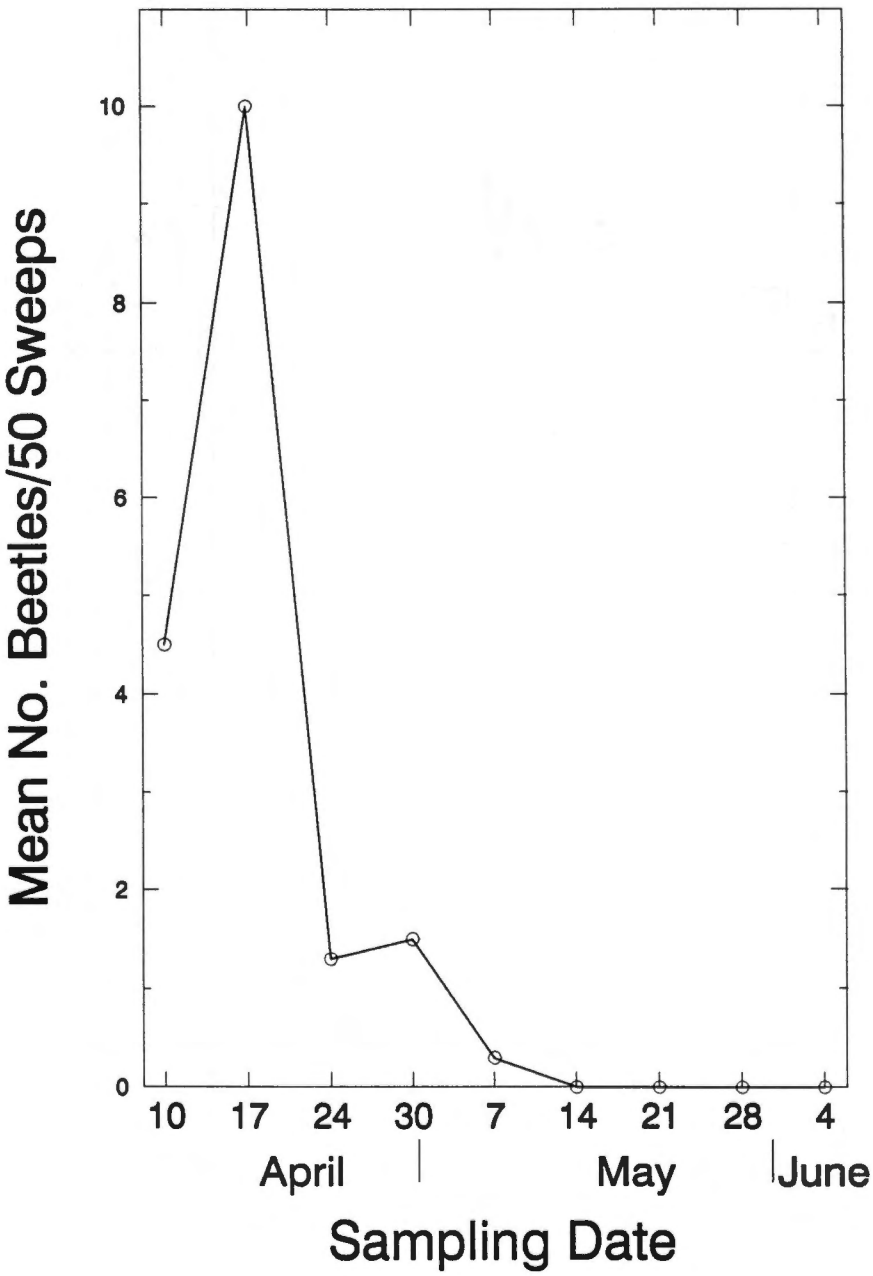

Figure 11. Seasonal incidence of nitidulid adults during the flowering (April 10 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Tiptonville Field, Lake County, Tennessee, 1991.

to fill (4.3), the adult beetle population peaked ($\bar{x}$ = 5.8/50 and 10.0/50 sweeps) in the Wagner Field on April 20, 1990 and in the Tiptonville Field on April 17, 1991, respectively. Due to the small size (<2 mm) of the beetle, no visual observations were noted of feeding damage or of ovipositional sites on plants.

Several species of Coccinellidae were present on rapeseed during both years of this study. During 1990, four species of Coccinellidae [the ninespotted lady beetle, Anatis quidenimpunctata (Oliver), the sevenspotted lady beetle, Coccinella septempunctata L., pink lady beetle, Coleomegilla maculata lengi Timberlake, and the convergent lady beetle, Hippodamia convergens Guerin-Meneville] were collected and identified. During 1991, however, five lady beetle species [the ninespotted lady beetle, the sevenspotted lady beetle, the pink lady beetle, the convergent lady beetle, and the twicestabbed lady beetle, Chilocorus stigma Say] were collected. Adult lady beetles were observed to search on rapeseed, and larvae were observed to feed on aphids during the ripening stage (5.1 to 5.5) of rapeseed.

In 1990, the sevenspotted, pink, and convergent lady beetle adults were the most frequently collected (99.1%) lady beetles in sweep-net samples from April 27 to June 4. The incidence of these three species in the Levee Field, Lake County, is presented in Figure 12. Sevenspotted lady

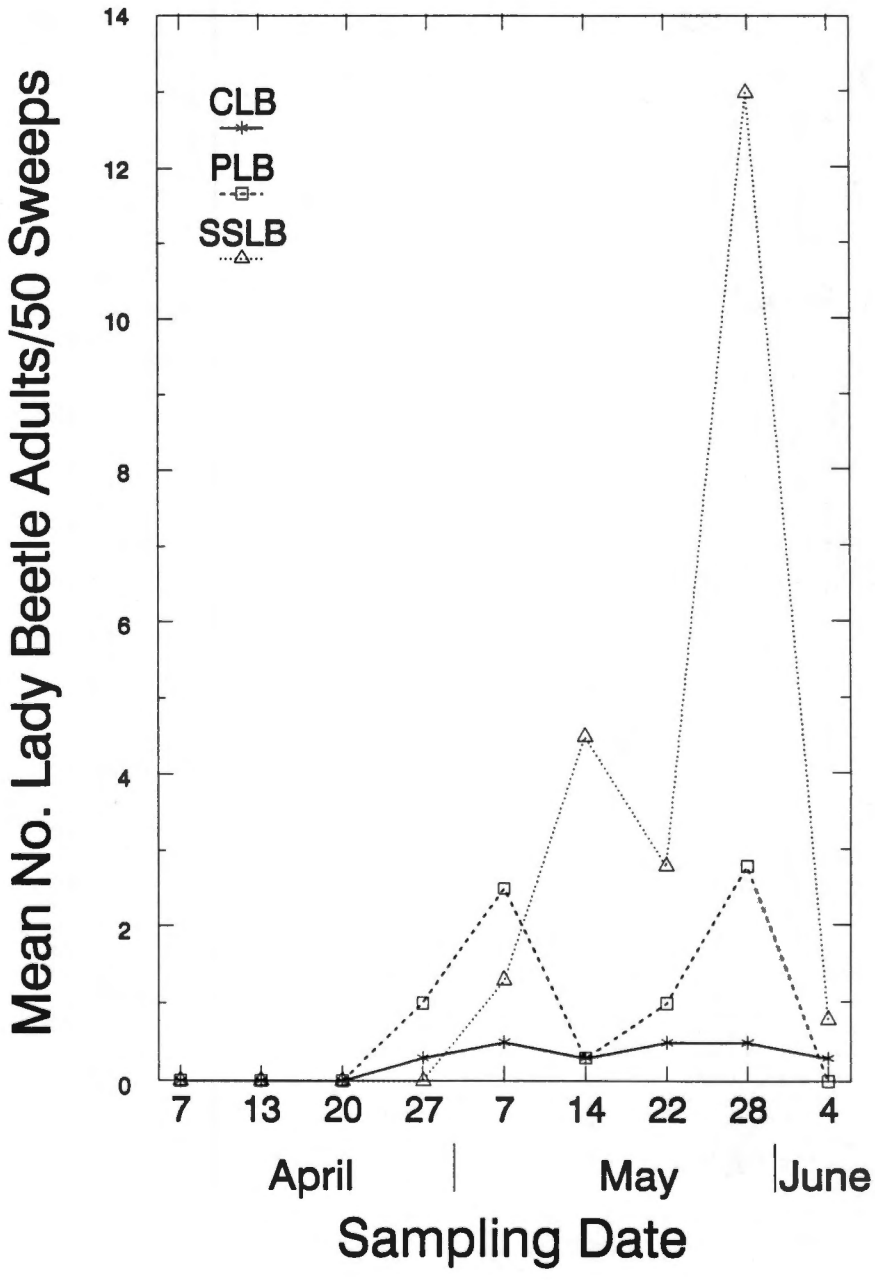

Figure 12. Seasonal incidence of the convergent lady beetle (CLB), Hippodamia convergens, pink lady beetle (PLB), Coleomegilla maculata lengi, and sevenspotted lady beetle (SSLB), Coccinella septempunctata, adults during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Levee Field, Lake County, Tennessee, 1990.

beetle adults were the most common (62.0%) species, followed by the pink lady beetle (26.8%), and the convergent lady beetle (10.3%). In 1991, the pink and sevenspotted lady beetle adults were the most frequently collected (94.7%) species during the flowering (4.1 to 4.4) and ripening (5.1 to 5.5) stages of rapeseed. The occurrence of these two species and lady beetle larvae in the Tiptonville Field, Lake County, is presented in Figure 13. The first adults were not collected until April 17, and the first larvae were not collected until three weeks later (May 7). The pink lady beetle was the most common (78.5%) species, with the sevenspotted lady beetle the second most common (16.2%) species.

Thysanopterans attracted to rapeseed flowers included flower thrips, Frankliniella tritici (Fitch), tobacco thrips, F. fusca (Hinds), and soybean thrips, Neohydatothrips variabilis (Beach) (all Thripidae). Both winged and nonwinged thrips were frequently collected from flower heads and later on developing pods. The population densities of thrips peaked at various plant growth stages among the fields sampled. Populations of flower thrips peaked during the flowering (4.2 to 4.3) and ripening (5.1 to 5.3) stages, while populations of tobacco thrips peaked during the ripening (5.1 to 5.5) stage. In 1990, the earliest population peak was observed in the Raised Field, Lake County, on April 27 following peak flowering, and the

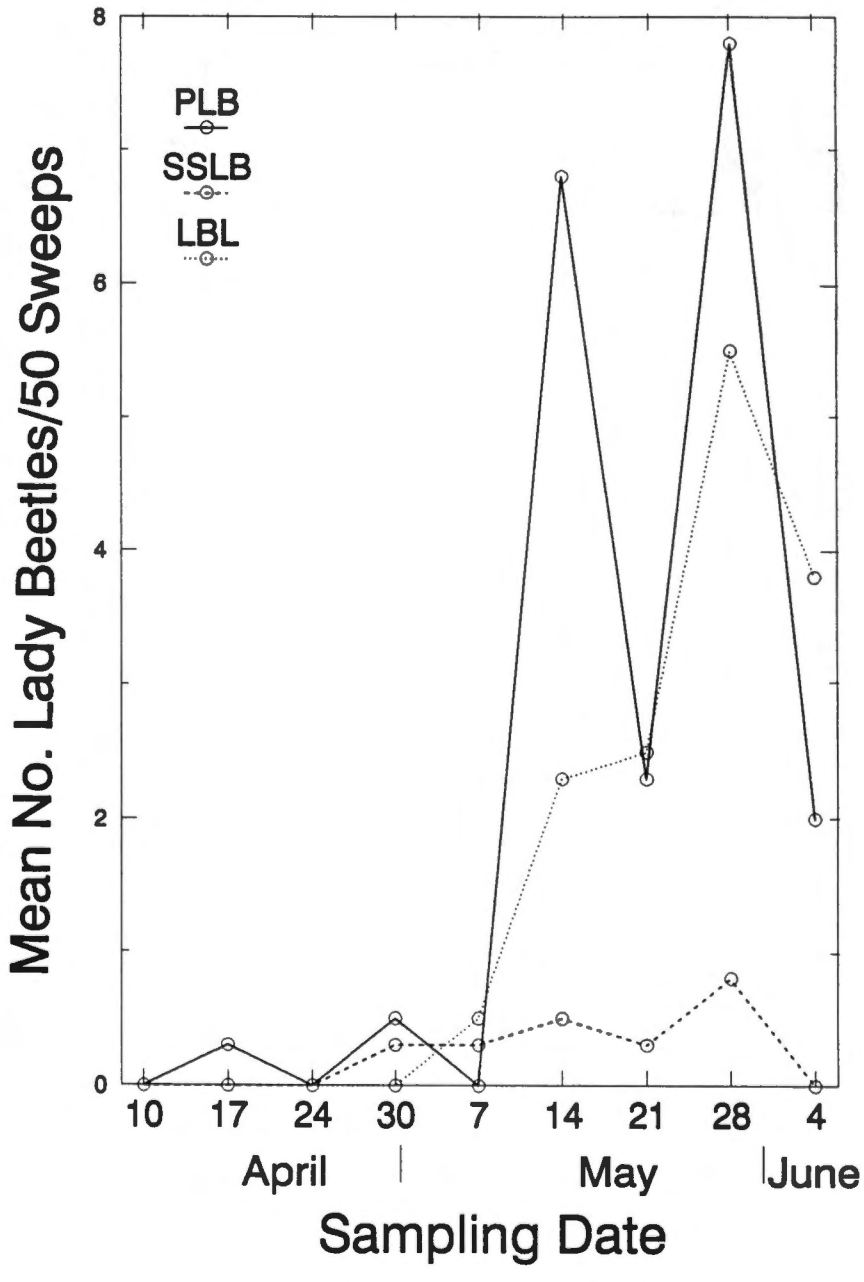

Figure 13. Seasonal incidence of the pink lady beetle (PLB), Coleomegilla maculata lengi, and sevenspotted lady beetle (SSLB), Coccinella septempunctata, adults and lady beetle larvae (LBL) during the flowering (April 10 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Tiptonville Field, Lake County, Tennessee, 1991.

latest thrips population peak occurred in the Davis Field, Fayette County, on May 14. In 1991, the earliest peak was in the Lake Field, Lake County, on April 17, and the latest population peak was on May 21.

Flower thrips were the most abundant species (87.8 and 97.9%) in 1990 and 1991, respectively, throughout the entire sampling period. The incidence of flower thrips and tobacco thrips, the second most common species (11.0 and 2.1%), in 1990 and 1991, respectively, is illustrated for the Davis Field, Fayette County (Figure 14), in 1990 and for the Tiptonville Field, Lake County (Figure 15), in 1991. In 1990, flower thrips were initially encountered on April 20, and the first tobacco thrips were collected on May 7; whereas, in 1991, both species were initially encountered on April 10. In 1990, in the Davis Field, density of flower thrips increased rapidly after the initial infestation, with one distinct population peak ($\bar{x}$ = 167.0/50 sweeps) after flowering terminated. In 1991, in the Tiptonville Field, a population level of more than 200 flower thrips per 50 sweeps was sustained during the flowering (April 17 to 30) and early ripening (May 7) stages. Flower thrips populations decreased rapidly after flowering terminated. In 1991, tobacco thrips population peaked on April 30 at 3.8 thrips per 50 sweeps.

Visual observations detected no damage to infested plants, with thrips likely feeding on flower pollen and

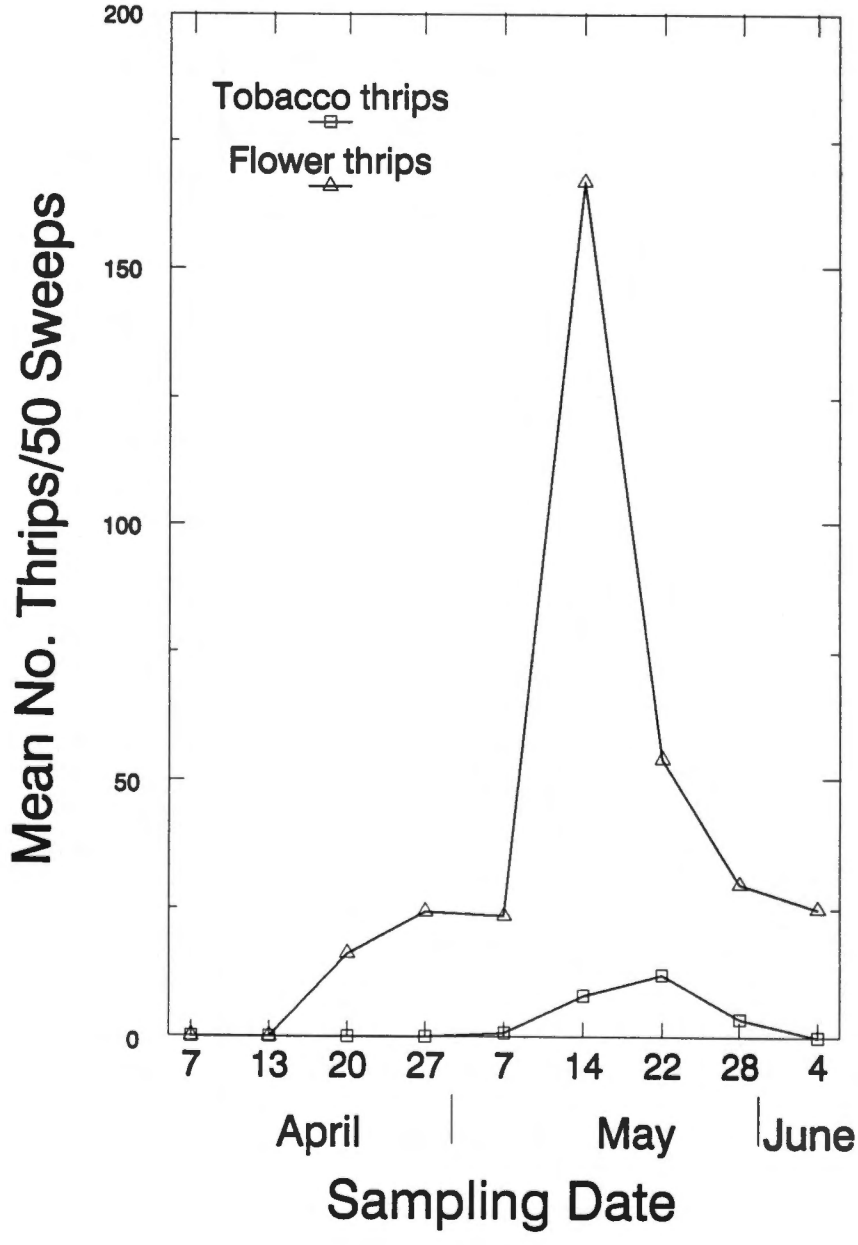

Figure 14. Infestation of the tobacco thrips, Frankliniella fusca, and flower thrips, F. tritici, during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Davis Field, Fayette County, Tennessee, 1990.

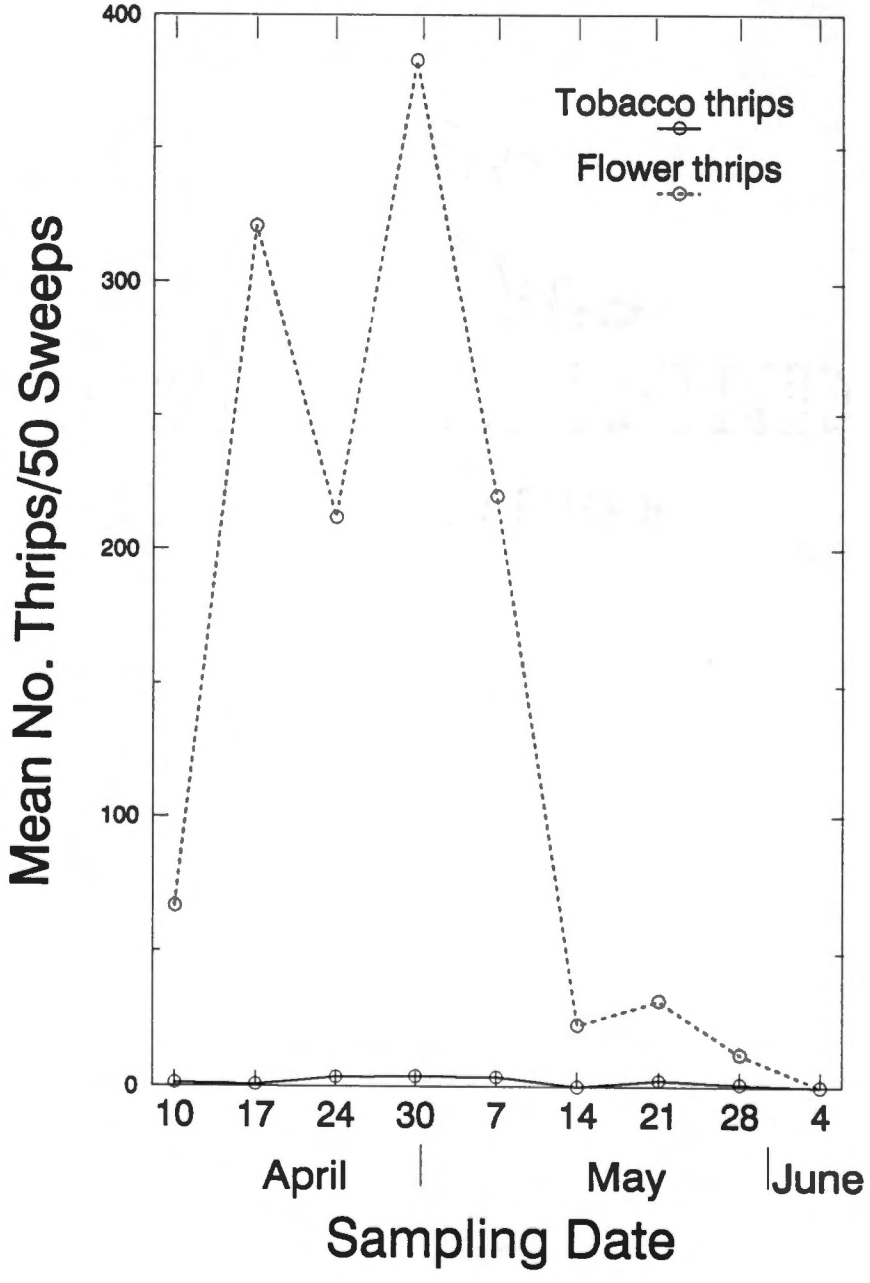

Figure 15. Infestation of the tobacco thrips, Frankliniella fusca, and the flower thrips, F. tritici, during the flowering (April 10 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Tiptonville Field, Lake County, Tennessee, 1991.

later on developing pod tissue. The importance of thrips to rapeseed during late flowering and ripening stages is minimal; however, rapeseed may serve as an early-season host for thrips pests of other crops. Because western Tennessee is an important cotton-growing region, thrips may move into adjacent cotton fields to feed on cotton seedlings that are susceptible to thrips damage.

In 1990 (Table 2) and 1991 (Table 3), hemipterans collected on rapeseed included the minute pirate bug, Orius insidiosus (Say) (Anthocoridae), the tarnished plant bug, Lygus lineolaris (Palisot de Beauvois) (Miridae), the brown stink bug, Euschistus servus (Say), the harlequin bug, Murgantia histrionica (Hahn), the southern green stink bug, Acrosternum hilare (Say), and the spined soldier bug, Podisus maculiventris (Say) (all Pentatomidae). In addition, several other homopteran species [e.g., leafhoppers (Cicadellidae)] also were encountered. Hemipterans and homopterans were generally encountered during the flowering and ripening stages of rapeseed. The most frequently (>95%) collected hemipteran observed to feed on developing pods was the tarnished plant bug.

The tarnished plant bug was first encountered in 1990 on April 7 in the Davis Field, Fayette County (Figure 16), and in 1991, on April 11 in Tower Field, Henry County (Figure 17). Adults were observed on buds, in flowers, and feeding on developing seedpods. In 1990, tarnished plant

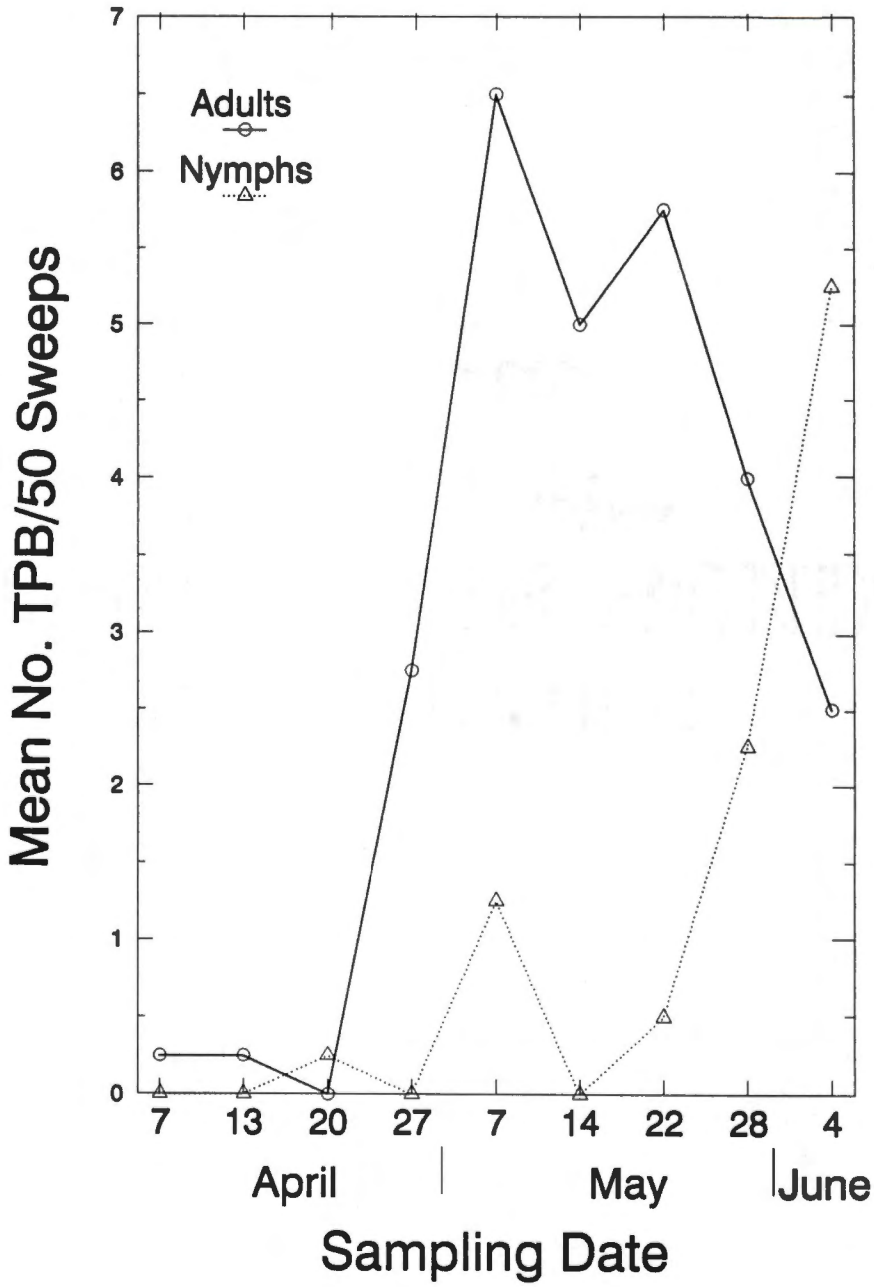

Figure 16. Seasonal incidence of the tarnished plant bug, Lygus lineolaris, adults and nymphs during the flowering (April 7 to 27) and the ripening (May 7 to June 4) stages of rapeseed, Davis Field, Fayette County, Tennessee, 1990.

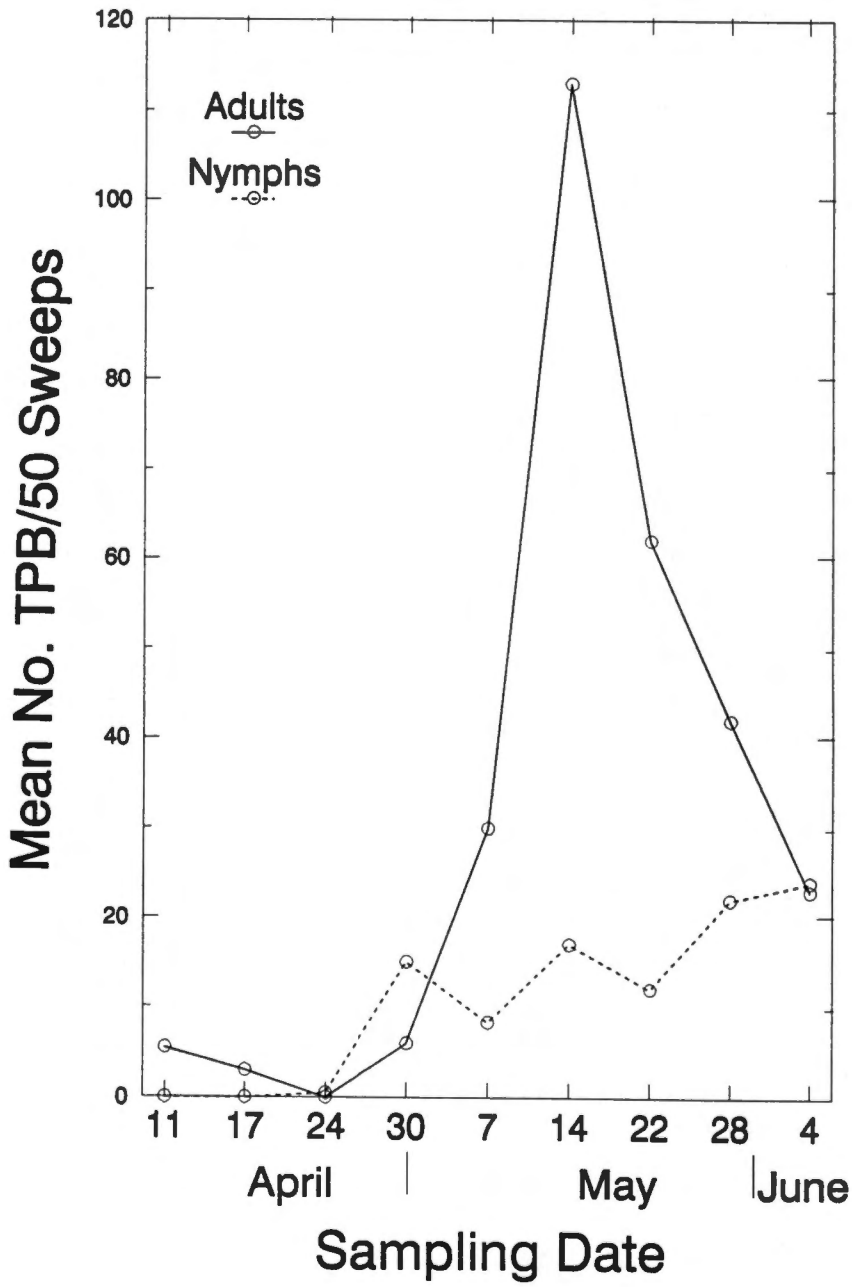

Figure 17. Seasonal incidence of the tarnished plant bug, Lygus lineolaris, adults and nymphs during the flowering (April 11 to 30) and the ripening (May 7 to June 4) stages of rapeseed, Tower Field, Henry County, Tennessee, 1991.

bug nymphs were first collected on April 20 in the Davis Field, and in 1991, on April 24 in the Tower Field. In 1990, adult populations peaked at 6.5 adults per 50 sweeps on May 7, when rapeseed was beginning its ripening (5.1) stage, and adult tarnished plant bugs were still collected on the last sampling date (June 4). In 1990, populations of tarnished plant bug nymphs rose to 1.25 nymphs per 50 sweeps on May 7, declined slightly, and increased steadily to 5.25 nymphs per 50 sweeps on the last sampling date (June 4). In 1991 in the Tower Field, adult populations peaked at 113.0 adults per 50 sweeps on May 14, when rapeseed was in its ripening (5.3) stage, and adult densities were greater than 20 adults per 50 sweeps until June 4. Three weeks after the adult population peaked, the nymphal population peaked on June 4 in the Tower Field. Because tarnished plant bug adults were observed to feed on pods and nymphs were collected from plants, the tarnished plant bug is believed to utilize rapeseed as an early-season host in western Tennessee.

Chapter 4

CONCLUSIONS

Rapeseed is a crucifer crop in the genus Brassica (Cruciferae: Brassiceae) that is cultivated for oilseed production (Fribourg et al. 1989). Rapeseed represents both annual and biennial forms of rape, Brassica napus ssp. oleifera L., and turnip rape, Brassica campestris ssp. oleifera L., in areas where rapeseed is cultivated (Appelqvist 1972). Cultivation of rapeseed in North America began in 1942 in Canada, where the crop was initially grown as a source of lubricants for marine engines. Until recently, cultivation in the United States has been limited to the Pacific Northwest and the Northern Great Plains (Fribourg et al. 1989). Because rapeseed has been commercially cultivated in Tennessee only since 1988, the associated arthropods and seasonal incidence of these species are unknown. Thus, a two-year project was initiated to address these research areas in West Tennessee.

Crucifers, including rapeseed, are hosts to more than 150 insect species, with many pest species representing the orders Homoptera, Coleoptera, Lepidoptera, Hemiptera, and Diptera (Hill 1987). Many of the homopteran pests belong to the family Aphididae that attack foliage and flower tissues. Several coleopteran pests in the families Nitidulidae, Chrysomelidae, and Curculionidae are crucifer specialists closely adapted to their host's life cycle (Bonnemaison

1965). Lepidopteran pests are primarily foliage feeders that affect plants early in their life cycle. Several Hemiptera, such as members of the families Lygaeidae, Miridae, and Pentatomidae, may attack the fruiting structures of crucifers (Lamb 1989). Numerous dipterans in the families Anthomyiidae, Cecidomyiidae, Muscidae, and Agromyzidae attack the roots and foliage of crucifers, including rapeseed (Hill 1987).

In 1990 and 1991, the turnip aphid, Lipaphis erysimi (Kaltenbach) (Homoptera: Aphididae), was the predominant aphid species. The turnip aphid is a crucifer specialist that reduces plant vigor and setting in the fall, and causes stunting and reduced fruit production in the spring (Hill 1987). Turnip aphid populations increased most rapidly during the flowering stage of rapeseed, with a population peak of 2,060 aphids per 50 sweeps on April 27, 1990, in Raised Field, Lake County (Table A9). Heavily-infested plants had stunted growth, reduced seedpod and seed production, and delayed seed maturity. Turnip aphid populations in 1991 were 78.8% lower than in 1990, as estimated by sweep-net sampling. The lower populations in 1991 may have been partially attributed to continuous, heavy, spring rains in western Tennessee.

During both years of this study, turnip aphids were frequently attacked by a wasp parasitoid [Diaeretiella rapae (M'Intosh) (Hymenoptera: Aphidiidae)]. Visual

observations noted that parasitism levels varied among fields. Wasp populations, as estimated by sweep-net sampling, were 95.8% lower in 1991 than 1990. Parasitized aphids ceased feeding, attached themselves to stems, and became brown mummies. Because parasitized aphids were not easily dislodged by utilizing sweep-nets, a quantitative measurement of parasitism levels could not be assessed.

The cabbage seedpod weevil, Ceutorhynchus assimilis (Paykull) (Coleoptera: Curculionidae), is a major rapeseed pest in Europe and North America (Hill 1987). Female adults oviposit into developing pods, and larva emerge to feed on the developing seeds. In western Tennessee, the cabbage seedpod weevil was the most common curculionid (98.8%) species collected in sweep-net samples. Adults were first collected as rapeseed began to flower, and adults were observed to feed and mate on flowers. Pods were examined for ovipositional punctures, and damaged pods were characterized by a small, black puncture wound. Damaged pods averaged three to five damaged seeds per pod. In 1991, cabbage seedpod weevil populations were 98.3% higher in Henry County than populations in Lake County, as estimated by sweep-net sampling. Henry County has a long history of crucifer cultivation and also has more overwintering sites (e.g., woodlots and fencerows) available than Lake County. Thus, Henry County may be able to support higher cabbage seedpod weevil populations.

Several flea beetle (Coleoptera: Chrysomelidae) species are pests of crucifers (Hill 1987). Adults feed on cotyledons and young leaves, and this feeding may result in slowed plant development, nonuniform stand height, and reduced seed yield and quality (Lamb 1984). Five species of flea beetles [the corn flea beetle, Chaetocnema pulicaria Melsheimer, Mantura floridana Crotch, the crucifer flea beetle, Phyllotreta cruciferae (Goeze), the striped flea beetle, P. striolata (F.), and P. zimmermanni (F.)] were identified from sweep-net samples in 1990 and 1991. In 1990, P. cruciferae and P. zimmermanni were the most abundant flea beetles present, and accounted for 97.8% of all flea beetles; whereas, in 1991, C. pulicaria, Mantura floridana, and P. zimmermanni were the three most abundant flea beetles collected, and accounted for 73.4% of all flea beetles collected. Flea beetles were collected during the flowering, especially C. pulicaria, and ripening stages of rapeseed. Because flea beetles are primarily seedling pests, the occurrence of significant damage at these stages of plant growth is unlikely.

Blossom beetles, Meligethes spp. (Coleoptera: Nitidulidae), are major pests of rapeseed in Europe (Hill 1987). In England, surveys indicate the pollen beetle, M. aeneus F., is a severe pest of summer rapeseed, but less so of winter rapeseed (Free and Williams 1978b). Adults that feed on green buds may cause the formation of podless

stalks. In 1990 and 1991, the nitidulid species, M. nigrescens Stephens, was collected in western Tennessee. Beetles were collected throughout the flowering (4.1 to 4.4) and into the early ripening (5.1) stages. Because of their small size (<2mm) and low infestation (<5.8 adults per 50 sweeps), no visual observations were noted of feeding damage or of ovipositonal sites on plants.

Several species of coccinellids [the ninespotted lady beetle, Anatis quidenimpunctata (Oliver), the twicestabbed lady beetle, Chilocorus stigma Say, the sevenspotted lady beetle, Coccinella septempunctata L., the pink lady beetle, Coleomegilla maculata lengi Timberlake, and the convergent lady beetle, Hippodamia convergens Guerin-Meneville] were identified from rapeseed in 1990 and 1991. In 1990, the sevenspotted lady beetle was the most common (62.0%) species; whereas, the pink lady beetle was the most common (78.5%) species in 1991. Lady beetle adults and larvae were observed to move among and feed on aphids in rapeseed fields.

Thrips in the genus Frankliniella (Thysanoptera: Thripidae) are cosmopolitan, polyphagous species that occur on 300 or more hosts, including rapeseed (Hill 1987). During the two years of this study, thysanopterans attracted to rapeseed included flower thrips, Frankliniella tritici (Fitch), tobacco thrips, F. fusca (Hinds), and soybean thrips, Neohydatothrips variabilis (Beach). Flower thrips

was the most abundant species (87.8 and 97.8%) in 1990 and 1991, respectively. Adult thrips frequently feed on flower pollen to supply protein for adult fertility and egg production (Hill 1987). Populations of flower thrips in western Tennessee were highest during the flowering (4.1 to 4.4) and early ripening (5.1) stages, and thrips populations decreased rapidly once flowering terminated. Visual observations detected no damage to infested plants; however, rapeseed may serve as an early-season host for thrips pests of other crops (e.g., cotton).

Three species of Lygus [the pale legume bug, L. elisus Van Duzee, the tarnished plant bug, L. lineolaris (Palisot de Beauvois), and L. borealis (Kelton)] (Hemiptera: Miridae) have been identified as pests of rapeseed in Canada (Butts and Lamb 1990). In western Tennessee, the tarnished plant bug was identified from rapeseed samples collected in 1990 and 1991. Lygus spp. cause most crop injury to rapeseed during the ripening (5.1 and 5.2) stage, when nymphs and adults feed on developing pods and seeds (Butts and Lamb 1991). In 1990 and 1991, adult populations peaked at 6.5 and 113.0 adults per 50 sweeps, respectively, during the ripening (5.1 to 5.3) stage of rapeseed in western Tennessee. Because tarnished plant bug adults were observed to feed on pods and nymphs were collected, the tarnished plant bug is believed to utilize rapeseed as an early-season host in western Tennessee.

Rapeseed is a relatively new crop to the agronomic system in western Tennessee and the South; therefore, more research is needed to define the interrelationships between the crop and its associated insects. Economic thresholds for aphid species, the cabbage seedpod weevil, Lygus spp., and other important pest species are needed to efficiently manage these insects. Because several species (e.g. thrips and Lygus spp.) may utilize rapeseed as an early-season host, studies are needed to determine the movement of these insects from rapeseed into other agronomic important crops (e.g., cotton and soybeans).

REFERENCES CITED

REFERENCES CITED

Appelqvist, L.-A. 1972. Historical background, pp. 1-8. In L.-A. Appelqvist and R. Ohlson (eds.), Rapeseed Cultivation, Composition, Processing, and Utilization. Elsevier Publishing Co., Amsterdam. 391 pp.

Bengtsson, L., A. von Hofsten and B. Loof. 1972. Botany of rapeseed, pp. 36-48. In L.-A. Appelqvist and R. Ohlson (eds.), Rapeseed Cultivation, Composition, Processing, and Utilization. Elsevier Publishing Co., Amsterdam. 391 pp.

Blackman, R. L. and V. F. Eastop. 1984. Aphids on the world's crops: an identification guide. Wiley-Interscience Publication, Chichester. 466 pp.

Bonnemaison, L. 1965. Insect pests of crucifers and their control. Ann. Rev. Entomol. 10:232-256.

Bracken, G. K. and G. E. Bucher. 1977. An estimate of relation between density of bertha armyworm and yield loss on rapeseed, based on artificial infestations. J. Econ. Entomol. 70:701-705.

Bracken, G. K. and G. E. Bucher. 1986. Yield losses in canola caused by adult and larval flea beetles, Phyllotreta cruciferae (Coleoptera: Chrysomelidae). Can. Entomol. 118:319-324.

Burgess, L. 1977. Flea beetles (Coleoptera: Chrysomelidae) attacking rape crops in Canadian Prairie Provinces. Can. Entomol. 109:21-32.

Butts, R. A. and R. J. Lamb. 1990. Comparison of oilseed Brassica crops with high or low levels of glucosinolates and alfalfa as hosts for three species of Lygus (Hemiptera: Heteroptera: Miridae). J. Econ. Entomol. 83:2258-2262.

Butts, R. A. and R. J. Lamb. 1991. Seasonal abundance of three Lygus species (Heteroptera: Miridae) in oilseed rape and alfalfa in Alberta. J. Econ. Entomol. 84:450-456.

Chittenden, F. H. 1923. Notes on the distribution and habits of North American Phyllotreta (Coleop.). Proc. Entomol. Soc. Wash. 25:131-139.

Daun, J. K. 1984. Composition and use of canola seed, oil, and meal. Cereal Foods World 29:291-296.

DeLoach, C. J. 1974. Rate of increase of populations of cabbage, green peach, and turnip aphids at constant temperatures. Ann. Entomol. Soc. Am. 67:332-340.

Doucette, C. F. 1947. Host plants of the cabbage seedpod weevil. J. Econ. Entomol. 40:838-840.

Feeny, P., K. L. Paauwe and N. J. Demong. 1970. Flea beetles and mustard oils: host plant specificity of Phyllotreta cruciferae and P. striolata adults (Coleoptera: Chrysomelidae). Ann. Entomol. Soc. Am. 63:832-841.

Free, J. B. and I. H. Williams. 1978a. A survey of the damage caused to crops of oil-seed rape (Brassica napus L.) by insect pests in south-central England and their effect on seed yield. J. Agric. Sci. 90:417-424.

Free, J. B. and I. H. Williams. 1978b. The responses of the pollen beetle, Meligethes aeneus, and the seed weevil, Ceuthorhynchus assimilis, to oil-seed rape, Brassica napus, and other plants. J. Appl. Biol. 15:761-774.

Free, J. B., A. W. Ferguson and S. Winfield. 1983. Effect of various levels of infestation by the seed weevil (Ceutorhynchus assimilis Payk.) on the seed yield of oilseed rape (Brassica napus L.). J. Agric. Sci. 101:589-596.

Fribourg, H. A., C. R. Graves, G. N. Rhodes, J. F. Bradley, E. C. Bernard, G. M. Lessman, M. A. Mueller, R. B. Graves, M. L. Thornton, B. A. Latka and A. M. Plouy. 1989. Rapeseed-a potential new crop of Tennessee. The University of Tennessee Agricultural Experiment St. Bull. No. 669. June, 1989. 40 pp.

Frost, S. W. 1949. Flea beetles attacking Cruciferae. J. Econ. Entomol. 42:144-145.

George, K. S. 1957. Preliminary investigations on the biology and ecology of the parasites and predators of Brevicoryne brassicae (L.). Bull. Entomol. Res. 48:619-629.

Getzin, L. W. 1983. Damage to inflorescence of cabbage seed plants by the pale legume bug (Heteroptera: Miridae). J. Econ. Entomol. 76:1083-1085.

Harper, F. R. and B. Berkenkamp. 1975. Revised growth-stage key for Brassica campestris and B. napus. Can J. Plant Sci. 55:657-658.

Hicks, K. L. and J. O. Tahvanainen. 1974. Niche differentiation by crucifer-feeding flea beetles (Coleoptera: Chrysomelidae). Amer. Midland Naturalist 91:406-423.

Hill, D. S. 1987. Agricultural insect pests of temperate regions and their control. Cambridge University Press, Cambridge. 659 pp.

Kelton, L. A. 1975. The lygus bugs (genus Lygus Hahn) of North America (Heteroptera: Miridae). Mem. Entomol. Soc. Can. 95:1-101.

Kinoshita, G. B., H. J. Svec, C. R. Harris and F. L. McEwen. 1979. Biology of the crucifer flea beetle, Phyllotreta cruciferae (Coleoptera: Chrysomelidae), in southwestern Ontario. Can. Entomol. 111:1395-1407.

Kirk, W. D. J. 1984. Pollen-feeding in thrips (Insecta: Thysanoptera). J. Zool. Lond. 204:107-117.

Lamb, R. J. 1983. Phenology of flea beetle (Coleoptera: Chrysomelidae) flight in relation to their invasion of canola fields in Manitoba. Can. Entomol. 115:1493-1502.

Lamb, R. J. 1984. Effects of flea beetles, Phyllotreta spp. (Chrysomelidae: Coleoptera), on the survival, growth, seed yield and quality of canola, rape and yellow mustard. Can. Entomol. 116:269-280.

Lamb, R. J. 1989. Entomology of oilseed Brassica crops. Ann. Rev. Entomol. 34:211-229.

Ohlson, R. 1972. Non-nutritional uses of rapeseed oil and rapeseed fatty acids, pp. 274-287. In L.-A. Appelqvist and R. Ohlson (eds.), Rapeseed Cultivation, Composition, Processing, and Utilization. Elsevier Publishing Co., Amsterdam. 391 pp.

Read, D. P., P. P. Feeny and R. B. Root. 1970. Habitat selection by the aphid parasite Diaeretiella rapae (Hymenoptera: Braconidae) and hyperparasite Charips brassicae (Hymenoptera: Cynipidae). Can. Entomol. 102:1567-1578.

Snodgrass, G. L., W. P. Scott and J. W. Smith. 1984. Host plants and seasonal distribution of the tarnished plant bug (Hemiptera: Miridae) in the Delta of Arkansas, Louisiana, and Mississippi. Environ. Entomol. 13:110-116.

Srivastava, A. S. and J. L. Srivastava. 1972. Ecological studies on the aphid, painted bug and sawfly attacking mustard and rape in India. FAO Plant Protection Bull. 20:136-140.

Tamaki, G., B. Annis and M. Weiss. 1981. Response of natural enemies to the green peach aphid in different plant cultures. Environ. Entomol. 10:375-378.

van Emden, H. F., V. F. Eastop, R. D. Hughes and M. J. Way. 1969. The ecology of Myzus persicae. Ann. Rev. Entomol. 14:197-270.

Walz, A. J. 1957. Observations on the biologies of some hymenopterous parasites of the cabbage seedpod weevil in northern Idaho. Ann. Entomol. Soc. Am. 50:219-220.

Williams, I. H. and J. B. Free. 1978. The feeding and mating behaviour of pollen beetles (Meligethes aeneus Fab.) and seed weevils (Ceutorhynchus assimilis Payk.) on oil-seed rape (Brassica napus L.). J. Agric. Sci. 91:453-456.

APPENDIX

Table A1. Seasonal incidence of selected insects on rapeseed, Davis Field, Fayette County, Tennessee, 1990.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	7	13	20	27	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	0.8	0	0.3	0.5	0.8	0.3	1.3	0.5	0.8
turnip aphid	151	30	70	14.5	3.5	2.8	0	0	0
wasp parasitoid	6.8	6.8	2.3	1.3	7.8	14	0.5	0	0
cabbage seedpod weevil	0.3	0.3	0.3	0.5	0.5	0	0	0.8	1.3
Ceutorhynchus sp.	0	0	0.3	0	0.3	0.3	0.3	0.3	0
Phyllotreta zimmermanni	0	0	0	0	0	2	6	1.3	1.3
striped flea beetle	0	0	0	0	0.3	0.5	0	0.8	0
crucifer flea beetle	0	0	0	0	0	4.8	5.3	0.5	0.5
Mantura floridana	0	0	0	0	0	0	0	0	0
corn flea beetle	0	0.3	0	0	0.3	0.8	0	0	0
convergent lady beetle	0	0	0	0	0	0.5	0	0	0
pink lady beetle	0	0	0	0	0.3	0	0.3	0.5	0.5
sevenspotted lady beetle	0	0	0	0	0.3	1	0.3	2.5	0.3
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0.8	0	0	4	2	0.3	0.3
Meligethes nigrescens	1.8	3	5.5	0.8	0.3	1.5	0.5	0	0
tobacco thrips	0	0	0	0	0.8	8	12	3.5	0
flower thrips	0	0	16	24.3	23.5	167	54.3	29.8	25
minute pirate bug	0	0	0	0	0.3	0.8	0.5	0	1.5
tarnished plant bug adults	0.3	0.3	0	2.8	6.5	5	5.8	4	2.5
tarnished plant bug nymphs	0	0	0.3	0	1.3	0	0.5	2.3	5.3
brown stink bug	0	0	0	0	0	0.3	0	0	0
harlequin bug	0	0	0	0	0	0	0	0.5	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0	0

Table A2. Seasonal incidence of selected insects on rapeseed, Dogwood Field, Henry County, Tennessee, 1991.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	11	17	24	30	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	1	3.3	1.8	4.3	2	1	3.8	4	0
turnip aphid	110	168	209	68.3	6.5	3	1.5	0.3	0
wasp parasitoid	0	1.3	13	2.5	0.3	0	0.3	0	0
cabbage seedpod weevil	429	54	44	217	26	9	17	20	0.3
Ceutorhynchus sp.	0	0	0	0	0	0	0.3	0	0
Phyllotreta zimmermanni	1	0	0.3	0	0	0	1	0.5	0
striped flea beetle	0	0	0	0	0	0	1	0	0
crucifer flea beetle	0	0	0.3	0	2	0	0	0	0
Mantura floridana	0	0.3	0	0	0	0.8	7	6.3	0
corn flea beetle	0	0	0.3	0	1	0.3	0	0	0
convergent lady beetle	0	0.5	0	0	0	0	0	0	0
pink lady beetle	0	0.3	0	0	0.3	0.3	1.3	4.3	1.3
sevenspotted lady beetle	0	0.3	0	0	0	0.3	0.8	0.5	0
ninespotted lady beetle	0	0	0.3	0	0	0	0	0	0
lady beetle larvae	0	0	0	4	0.8	5.5	12	13	0.3
Meligethes nigrescens	5	7	4	3.3	0	0	0.5	0	0
tobacco thrips	1	0.5	0	2.3	1	2	9.8	5.5	0
flower thrips	67	93	134	88.8	18.8	11	31.3	22.8	0.3
minute pirate bug	0	0	0	0	0	0	0	0.5	0
tarnished plant bug adults	4	2.3	1.5	3.8	10	48	46	33	0.3
tarnished plant bug nymphs	0	0	0	3	1.3	11	12	30	0
brown stink bug	0	0	0	0.3	0	0.3	0	0.3	0.3
harlequin bug	0	0.3	0	0	0	1	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0.3	0
spined soldier bug	0	0.3	0	0	0	0	0	0	0

Table A3. Seasonal incidence of selected insects on rapeseed, Lake Field, Lake County, Tennessee, 1991.

	Average Number Per 50 Sweeps							
	DATE							
	April				May			
Insect	10	17	24	30	7	14	22	28
cabbage aphid	0	0	0	0	0	0	0	0
green peach aphid	5.3	6.5	5.5	0.8	1.3	2.3	0.5	0
turnip aphid	31	23	15	3	11.5	1.5	0.3	0
wasp parasitoid	0.8	0.8	0	0	0.3	0	0	0
cabbage seedpod weevil	1.5	5	0.3	1.8	1.3	1.3	1	0.8
Ceutorhynchus sp.	0.5	0.5	0.3	0.5	0	1.3	1	0.3
Phyllotreta zimmermanni	0	0.3	0	0	0.3	11	2.3	2.5
striped flea beetle	0	0	0	0	0	0	0.3	0
crucifer flea beetle	0	0	0	0	0	4.3	5.3	0
Mantura floridana	0	0	0	0	0.3	1.3	0.5	0.8
corn flea beetle	0.3	0.8	0.3	0.3	0.5	0.3	1.8	1.5
convergent lady beetle	0	0	0	0	0	0	0	0
pink lady beetle	0	3.5	0	0.8	0.8	1.5	1.3	1.5
sevenspotted lady beetle	0	0	0	0	0	0	0	0
ninespotted lady beetle	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0	0.8	7	5	16
Meligethes nigrescens	4.5	5.3	2	2	0.3	0.3	0.8	0
tobacco thrips	0.5	0.3	0	0.3	1.5	0	2.5	1.3
flower thrips	406	963	848	341	334	2.8	26.3	3
minute pirate bug	0	0	0	0	0.5	0	0	0
tarnished plant bug adults	3	0.5	0.3	1.5	8.3	24	16	5.5
tarnished plant bug nymphs	0	0.3	0	3.8	6.8	16	3.3	17
brown stink bug	0.3	0	0	0	0	0	0	0
harlequin bug	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0

Table A4. Seasonal incidence of selected insects on rapeseed, Levee Field, Lake County, Tennessee, 1990.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	7	13	20	27	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	0	0	0	0.5	0	0	0	0	0
turnip aphid	649	206	244	14.5	27.8	0.8	0	0	0
wasp parasitoid	0.3	0.3	9.3	14	28	10	0	0	0
cabbage seedpod weevil	0	0	0	0.5	0	0.3	0	0.8	0.8
Ceutorhynchus sp.	0	0	0	0	0	0.5	0	0	0
Phyllotreta zimmermanni	0.3	0	0	0	0	0.3	1	0.3	1.5
striped flea beetle	0	0	0.3	0	0	0.5	0	0	0
crucifer flea beetle	0	0	0	0	0	0.8	1.5	2.3	0
Mantura floridana	0	0	0	0	0	0.3	0	0	0
corn flea beetle	0	0	0	0	0	0.3	0	0.5	0
convergent lady beetle	0	0	0	0.3	0.5	0.3	0.5	0.5	0.3
pink lady beetle	0	0	0	1	2.5	0.3	1	2.8	0
sevenspotted lady beetle	0	0	0	0	1.3	4.5	2.8	13	0
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0.5	0.8	4	0.8	0.5	0.3
Meligethes nigrescens	2.3	0.5	2.3	0.8	0.3	0	0	0	0
tobacco thrips	0	0	0	0	0	0	0	0	0
flower thrips	0	0	27	24.3	1.5	0	1.5	0.5	0
minute pirate bug	0	0	0	0	0	0	0	0	0
tarnished plant bug adults	0	0.3	0	2.8	1.3	2.5	3	3.8	0.3
tarnished plant bug nymphs	0	0	0	0	0.5	0	0	0.3	0.5
brown stink bug	0	0	0.3	0	0	0	0	0	0
harlequin bug	0	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0.3	0	0	0	0	0

Table A5. Seasonal incidence of selected insects on rapeseed, Lindamood Field, Lake County, Tennessee, 1990.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	7	13	20	27	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	0	0	0	0	0	0	0	0	0
turnip aphid	5.5	6	22	88	11.3	3.8	0	0	0
wasp parasitoid	0	0	0	0.5	0	144	0.3	0	0
cabbage seedpod weevil	0	0.3	0.3	0.3	0.3	0	0.5	1.3	5.5
Ceutorhynchus sp.	0	0	0	0	0	0	0	0.3	0
Phyllotreta zimmermanni	0	0	0	0	0	0.3	27.3	59.8	89.3
striped flea beetle	0	0	0	0	0	1.5	1.3	0.8	2.3
crucifer flea beetle	0	0	0	0	0	1.5	0.8	291	1.3
Mantura floridana	0	0	0.5	0.5	1.3	0	0	0	0
corn flea beetle	0	0	0	0	0	0.8	0	0	0
convergent lady beetle	0	0	0	0.3	0	0.3	0	2.5	0
pink lady beetle	0	0	0	0	0	0	0.3	1.5	0
sevenspotted lady beetle	0	0	0	0	0	3	5.3	9	0
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0	0	0	0	0	0
Meligethes nigrescens	0.8	0	16	0.8	0.3	0.5	0	0	0
tobacco thrips	0	0	0	0	0	0	0	0.3	0
flower thrips	0	0	0	21.8	23.5	127	149	44.8	0.5
minute pirate bug	0	0	0	0	0	0	0	0	
tarnished plant bug adults	0	0	0	0	2.3	4.5	2.5	5.8	0.5
tarnished plant bug nymphs	0	0	0	0	0.3	0	0	0	0.8
brown stink bug	0	0	0	0	0	0	0.3	0	0
harlequin bug	0	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0	0

Table A6. Seasonal incidence of selected insects on rapeseed, Lindamood Field, Lake County, Tennessee, 1991.

	Average Number Per 50 Sweeps							
	DATE							
	April				May			
Insect	10	17	24	30	7	14	22	28
cabbage aphid	0	0	0	0	0	0	0	0
green peach aphid	1.5	1.5	1.3	1.3	0	0	0	0
turnip aphid	0	7.8	4	2.5	1	0	1	0
wasp parasitoid	0	0	0.5	0	0	0	0	0
cabbage seedpod weevil	0	1	0.5	0.5	2.3	0.8	0.3	0.8
Ceutorhynchus sp.	0.3	0	0	0.5	0	0.3	0.8	0.5
Phyllotreta zimmermanni	0.3	0.3	0	0	0.3	1	1	0
striped flea beetle	0.3	0	0	0	0	0	0	0
crucifer flea beetle	0	0	0	0	0.3	1.8	0.8	0
Mantura floridana	0	0.5	0	0	0	0	0.5	0.3
corn flea beetle	1.3	0.3	0	0	0	0.3	0	0
convergent lady beetle	0	0	0	0	0	0	0.3	0
pink lady beetle	0	0.3	0	0.3	0.8	3.5	1.8	2.8
sevenspotted lady beetle	0	0	0	0	0	0	0	0
ninespotted lady beetle	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0	1	9.3	11	20
Meligethes nigrescens	2.3	5	3	0.3	0	0.3	0	0
tobacco thrips	0	0	0.3	0.5	0.3	0	1.8	0.3
flower thrips	171	606	405	108	86.3	4	71.8	3.5
minute pirate bug	0	0.3	0	0	0.3	0	1.8	0.3
tarnished plant bug adults	0.5	0.3	0.5	0.5	1.8	21	23	5.3
tarnished plant bug nymphs	0	0	0	2.3	2.8	4.3	3	8.3
brown stink bug	0.3	0	0	0	0	0	0	0
harlequin bug	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0
spined soldier bug	0	1	0	0	0	0	0	0.3

Table A7. Seasonal incidence of selected insects on rapeseed, Paris 1, Henry County, Tennessee, 1991.

	Average Number Per 50 Sweeps							
	DATE							
	April			May				June
Insect	10	24	30	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0
green peach aphid	2	1.5	4.5	9.3	26	1	0	0
turnip aphid	4.3	6.8	10.5	4.5	10.3	1.3	0.5	0
wasp parasitoid	0	1.3	1.3	0.8	2.3	0	0	0
cabbage seedpod weevil	258	1.3	3.8	2	6	28	28	1.5
Ceutorhynchus sp.	0	0	0	0	0	0	0	0
Phyllotreta zimmermanni	0	0	0	0	0	2.3	2.3	0.3
striped flea beetle	0	0	0	0	0.3	1	2	0.3
crucifer flea beetle	0	0	0.3	0	1	0.3	0	0
Mantura floridana	0	0	0	0	0.3	1.3	2.8	0.8
corn flea beetle	0	0	1.5	0.8	2.3	0.3	0	0.3
convergent lady beetle	0	0	0	0	0	0	0	0
pink lady beetle	0	0	0.3	0	0	1	0.5	2.5
sevenspotted lady beetle	0	0	0	0	1	0.5	2.5	0.3
ninespotted lady beetle	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0	5.3	1.5	4.3	1.3
Meligethes nigrescens	3.5	1.8	0	0.3	0	0	0	0
tobacco thrips	1.3	0.5	11	4.5	8.8	19	17	0.3
flower thrips	5.5	5.8	21	57.3	71	44.8	36	1.3
minute pirate bug	0	0	0	0	0	0.5	0.3	0
tarnished plant bug adults	6	0.3	0	2.8	7.3	60	18	17
tarnished plant bug nymphs	0	0	0.3	0.5	16	4.5	19	17
brown stink bug	0	0	0.3	0	0	0.3	0.3	0.5
harlequin bug	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	.5
spined soldier bug	0	0	0	0	0.5	0.3	0.5	0

Table A8. Seasonal incidence of selected insects on rapeseed, Paris 2, Henry County, Tennessee, 1991.

	Average Number Per 50 Sweeps						
	DATE						
	April			May			
Insect	10	24	30	7	14	22	28
cabbage aphid	0	0	0	0	0	0	0
green peach aphid	1.5	4	22	26	8	0.5	0.3
turnip aphid	33.8	17	14.3	17.5	7.8	0	0
wasp parasitoid	0	3.8	1	0.8	1.3	0	0
cabbage seedpod weevil	399	2.8	4	3	5.8	38.5	49.3
Ceutorhynchus sp.	0	0	0	0	0	0	0
Phyllotreta zimmermanni	0	0	0	0	0	0.3	0.8
striped flea beetle	0	0	0	0	0	0.3	2.8
crucifer flea beetle	0	0	0	0	0.3	0	0
Mantura floridana	0	0	0	0	0.3	1.3	2.5
corn flea beetle	0.5	0	3.5	0.3	0	0.3	0
convergent lady beetle	0	0	0.3	0	0	0	0
pink lady beetle	0	0	0	0	0.3	0	11
sevenspotted lady beetle	0.5	0	0	0	0.5	0.3	0.5
ninespotted lady beetle	0	0	0	0	0	0	0
lady beetle larvae	0	0	0.3	1	7	3.3	4.5
Meligethes nigrescens	1.8	3	0.8	0.8	1	0.5	0
tobacco thrips	0.8	0.3	23	2	4	7.8	14
flower thrips	5.8	5.8	27	57.8	92	19.5	19.3
minute pirate bug	0	0	0	0	0	0	0.5
tarnished plant bug adults	4.5	0	0	0.3	3.5	69	15
tarnished plant bug nymphs	0	0	0.3	0.3	19	16	7.8
brown stink bug	0	0	0.3	0	0	0.8	0.5
harlequin bug	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0.3
spined soldier bug	0	0	0	0	0	0	0

Table A9. Seasonal incidence of selected insects on rapeseed, Raised Field, Lake County, Tennessee, 1990.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	7	13	20	27	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	0	0	0	0	0	0	0	0	0
turnip aphid	243	821	713	2060	89.5	3.3	0	0	0
wasp parasitoid	0	0	16	17	232	123	0.5	0	0
cabbage seedpod weevil	0	0	0	0	0.3	0.5	0.3	0	0.8
Ceutorhynchus sp.	0	0	0	0	0	0.3	0	0.3	0.3
Phyllotreta zimmermanni	0	0	0	0	0	1.3	11	16.8	0
striped flea beetle	0	0	0	0	0	1	2.3	0.5	0
crucifer flea beetle	0	0	0	0	0	5.5	5	18.5	0
Mantura floridana	0	0	0	0.5	0	0	0.3	0	0
corn flea beetle	0	0	0	0.3	0.5	0	0	0	0
convergent lady beetle	0	0	0	0	0.3	0	0	0.5	0
pink lady beetle	0	0	0	0.3	0	0	0	6.3	0.5
sevenspotted lady beetle	0	0	0	0.3	1.8	4.8	3.3	5	0
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	1.3	1.5	3.8	3	0	0
Meligethes nigrescens	0.8	0	8	1	0.3	0	0	0	0
tobacco thrips	0	0	0	0	0	0.5	0	0	0
flower thrips	0	0.3	3.3	70.5	4.5	20.3	8.8	1.3	1.5
minute pirate bug	0.3	0	0	0	0	0	0	0	0
tarnished plant bug adults	0.5	0	0	0.3	1	6	2.3	6	0.5
tarnished plant bug nymphs	0	0	0	0	0.5	0.8	1.5	0.8	0
brown stink bug	0	0	0	0	0	0	0	0	0
harlequin bug	0	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0	0

Table A10. Seasonal incidence of selected insects on rapeseed, Ridgely Field, Lake County, Tennessee, 1990.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	7	13	20	27	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	0	0	0	0.3	0	0	0	0	0
turnip aphid	121	104	123	347	57.5	15.3	0	0	0
wasp parasitoid	0	0.5	0.5	3	30	114	0	0	0
cabbage seedpod weevil	0	0	0.3	0.3	0.3	0.3	0	0.3	3.3
Ceutorhynchus sp.	0	0	0	0	0	0	0	0	0
Phyllotreta zimmermanni	0.3	0	0.3	0	0	0.3	2.25	1.8	1
striped flea beetle	0	0	0	0	0	0.3	0	1.25	0
crucifer flea beetle	0	0	0	0	0	0.5	1.3	0.5	0.3
Mantura floridana	0	0	0	0.3	0.3	0.3	0	0	0
corn flea beetle	0	0	0	0	0.3	0	0	0	0.3
convergent lady beetle	0	0	0	0	0.3	0	0	0.3	0
pink lady beetle	0	0	0	0	0.3	0.8	0	0.5	0
sevenspotted lady beetle	0	0	0	0	0.5	1	0.3	4	0
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0	0	0	0	0	0
Meligethes nigrescens	0.3	0	7	2	0.3	0	0	0	0
tobacco thrips	0	0	0	0	0	0	0.3	0.3	0.3
flower thrips	0	0	7	72.8	59	100	9.8	1.5	0
minute pirate bug	0.3	0	0	0	0	0	0	0	0
tarnished plant bug adults	0	0	0.5	0	4.3	2.5	1.3	4.8	0.5
tarnished plant bug nymphs	0	0	0	0	0	0.5	0	0	0
brown stink bug	0	0	0.3	0	0	0	0	0	0
harlequin bug	0	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0	0

Table A11. Seasonal incidence of selected insects on rapeseed, Shop Field, Lake County, Tennessee, 1991.

	Average Number Per 50 Sweeps							
	DATE							
	April				May			
Insect	10	17	24	30	7	14	22	28
cabbage aphid	0	0	0	0	0	0	0	0
green peach aphid	6.3	1.3	3.3	3	1.3	0	0	0
turnip aphid	26.5	23	44	11	1.3	0	0.25	0
wasp parasitoid	0	0	1.3	0	0.3	0	0	0
cabbage seedpod weevil	0.5	0.3	0	0	0.5	1.5	0.3	0
Ceutorhynchus sp.	0.8	0	0	0.3	0	3.8	1.5	3.5
Phyllotreta zimmermanni	0.5	0	0	0	0.3	4.8	4	1.3
striped flea beetle	0.3	0	0	0	0.8	0.5	0.3	0
crucifer flea beetle	0.3	0	0	0	0	1.5	0	0
Mantura floridana	1	0.8	0	0	0	0.5	0.3	0
corn flea beetle	0.3	0.3	0	0	0.3	0.3	0.3	0.3
convergent lady beetle	0.3	0.3	0	0	0	0.3	0.3	0
pink lady beetle	0.3	1.5	0	0.5	0.3	1.5	2.8	2.5
sevenspotted lady beetle	0	0.3	0	0	0	0.3	0	0.5
ninespotted lady beetle	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	1.8	5.3	13	3.3	6.8
Meligethes nigrescens	1	0.5	0.8	0.5	0	0	0	0
tobacco thrips	0	0.3	0	0	0.5	0	0.8	1.3
flower thrips	321	420	613	132	34.5	1	3	3
minute pirate bug	0	0	0	0	0	0	0	0
tarnished plant bug adults	1	1	0.3	11	21	48	9	5.8
tarnished plant bug nymphs	0	0.5	2.5	11	12	13	5	20
brown stink bug	0	0	0	0	0	0	0	0.3
harlequin bug	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0

Table A12. Seasonal incidence of selected insects on rapeseed, Sugar Creek Field, Haywood County, Tennessee, 1990.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	7	13	20	27	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	0	0	0	0	0	0	0	0	0.3
turnip aphid	180	98	90	52.8	0.3	0.5	0	0	0
wasp parasitoid	2.3	9	2.8	5	7.5	12	0	0	0
cabbage seedpod weevil	0.3	0.3	0.8	4.3	1.5	1.3	0	1.5	4
Ceutorhynchus sp.	0	0	0.8	0.3	0.5	0.8	0	0	0.3
Phyllotreta zimmermanni	0	0	0	0	0	3.5	2.3	0.5	0.8
striped flea beetle	0	0	0	0	0	0	0	0	0.3
crucifer flea beetle	0	0	0	0	0	7.5	1.3	0.3	0
Mantura floridana	0	0	0.3	0	0	0	0	0	0
corn flea beetle	0	0	0.3	0	0.5	0.3	0	0	0
convergent lady beetle	0	0	0	0	1.5	2.8	0	0	0
pink lady beetle	0	0	0	0.3	0.8	0.5	0	4.8	2.3
sevenspotted lady beetle	0	0	0	1.3	3.5	2.5	0.3	1.3	0
ninespotted lady beetle	0	0	0	0	0.3	0	0	0	0
lady beetle larvae	0	0	0	1.8	1.3	9.8	0	0.5	0.8
Meligethes nigrescens	0	11	0.8	1	0	0	0	0	0
tobacco thrips	0	0	0	0	0	1.3	0.3	4.3	0
flower thrips	0	0	1.5	14.8	5	192	9.8	14.8	2
minute pirate bug	0.3	0	0	0	0	0.3	0	0.3	0
tarnished plant bug adults	0.3	3.3	1.3	7.3	4.5	16.3	1.3	9	1.5
tarnished plant bug nymphs	0	0	0	0.3	0.5	5.3	0	2.3	0.8
brown stink bug	0	0	0	0	0	0.3	0	0	0.3
harlequin bug	0	0	0	0	0	0.3	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0	0

Table A13. Seasonal incidence of selected insects on rapeseed, Tiptonville Field, Lake County, Tennessee, 1991.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	10	17	24	30	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	14	1.8	0.8	3.5	0	0	0	0	0
turnip aphid	34	28	37	23.8	10.8	1.3	1	0.8	0
wasp parasitoid	0	0	1	0	0	0.3	0	0	0
cabbage seedpod weevil	0.5	0.5	0	1.5	2.3	1.8	1.5	2.5	1.8
Ceutorhynchus sp.	0	0.8	0	0	0	0.5	0.3	0.5	0
Phyllotreta zimmermanni	0.3	0	0	0	0.3	0.8	12	3.3	0
striped flea beetle	0	0	0	0	0	0	0	0	0
crucifer flea beetle	0	0.3	0	0	0.3	0	1	0.8	0
Mantura floridana	0	0.3	0	0	0	0.8	20	9	0
corn flea beetle	1	0	0	0.3	0	0	0.3	0	0
convergent lady beetle	0	0	0	0	0	0	0	0	0
pink lady beetle	0	0.3	0	0.5	0	6.8	2.3	7.8	0
sevenspotted lady beetle	0	0	0	0.3	0.3	0.5	0.3	0.8	0
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0	0.5	2.3	2.5	5.5	3.8
Meligethes nigrescens	4.5	10	1.3	1.5	0.3	0	0	0	0
tobacco thrips	1.3	0.8	3.5	3.8	3.5	0	2.3	1	0
flower thrips	66.5	321	212	383	220	23	32	12.3	0
minute pirate bug	0	0	0	0	0	0	0	0	0
tarnished plant bug adults	3.5	1.5	0	5.3	8	17	19	17	16
tarnished plant bug nymphs	0	0	0.3	2.3	1.5	4	4.8	24	15
brown stink bug	0	0	0	0	0	0	0.3	0.3	0.3
harlequin bug	0	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0.3	0	0	0	0.8	0	0	0.3

Table A14. Seasonal incidence of selected insects on rapeseed, Tower Field, Henry County, Tennessee, 1991.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	10	17	24	30	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	1.5	2.8	9.5	6.8	0	0.3	0.3	0	0
turnip aphid	51.8	69	111	122	1.3	0.5	0.5	0.5	0
wasp parasitoid	0	0.5	0	0.8	0	0	0	0	0
cabbage seedpod weevil	168	118	72	95	16.5	10.8	173	77.5	7.5
Ceutorhynchus sp.	0	0.3	0	0	0	0	0.3	0	0
Phyllotreta zimmermanni	0	0.3	0	0.3	0	0	6	0.5	0
striped flea beetle	0	0.5	0	0.3	0	1	4.5	1.5	0
crucifer flea beetle	0	0	0	0	0	1.3	4	0	0
Mantura floridana	0	0	0	0	0	0.8	11	5	0.5
corn flea beetle	0	1.3	0	3	2.5	1	0.8	0	0
convergent lady beetle	0.3	0	0	0	0.3	3	0.8	0	0.5
pink lady beetle	0	1	0	1	0.3	0	2.8	3.5	2.3
sevenspotted lady beetle	0	0.3	0.3	0	0.3	2	0.8	0	0
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	9.5	4	10	2	1.5	7.8
Meligethes nigrescens	1.8	1.5	2.5	1.8	0.8	0	0	0	0
tobacco thrips	1.3	0.8	0	1.3	0.3	2	2	8.8	0
flower thrips	8	26	36	44.8	23	9.8	35.5	10.3	0.8
minute pirate bug	0	0	0	0	0	0	0.3	0	0
tarnished plant bug adults	5.5	3	0	6	30	113	62	42	23
tarnished plant bug nymphs	0	0	0.5	15	8.3	17	12	22	24
brown stink bug	0	0.5	0	0.3	0	0.3	0	0.3	1
harlequin bug	0	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0.3	0	0
spined soldier bug	0	0	0	0	0	0	0	0	0.5

Table A15. Seasonal incidence of selected insects on rapeseed, Wagner Field, Haywood County, Tennessee, 1990.

	Average Number Per 50 Sweeps								
	DATE								
	April				May				June
Insect	7	13	20	27	7	14	22	28	4
cabbage aphid	0	0	0	0	0	0	0	0	0
green peach aphid	0	0	0	0	0	0.25	0	0	0
turnip aphid	413	102	69	5.5	2.3	1	0	0	0
wasp parasitoid	26	16	3.3	3	4.5	8.3	1	0	0
cabbage seedpod weevil	0	0.3	0.3	0	0.5	0	0.5	0.5	1.3
Ceutorhynchus sp.	0	0.3	0.3	0.3	0	0.5	0.3	0.3	0
Phyllotreta zimmermanni	0	0	0	0	0	0.5	0.3	0.8	0.3
striped flea beetle	0	0	0	0	0.3	0.3	0	0	0
crucifer flea beetle	0	0	0	0	1.5	4.8	1	0.3	0
Mantura floridana	0	0	0	0	0	0	0	0.3	0
corn flea beetle	0	0	0.3	0	1.3	0.8	0.3	0	0.3
convergent lady beetle	0	0	0	0	0	0.5	0	0	0
pink lady beetle	0	0	1.5	0.3	0.3	0	0.5	1	0.3
sevenspotted lady beetle	0	0	0	0	0.5	0	0.3	1	0
ninespotted lady beetle	0	0	0	0	0	0	0	0	0
lady beetle larvae	0	0	0	0.3	0	0.8	0.3	1	2.8
Meligethes nigrescens	0.3	5.5	5.8	0.8	0.3	0.3	0	0	0
tobacco thrips	0.3	0	0	0	0	4	5.3	10	1.5
flower thrips	0.3	0.3	5.5	51	37.8	457	22	3.5	4.3
minute pirate bug	0	0.3	0	0	0	0.5	0	0.3	0.5
tarnished plant bug adults	0.5	0.3	0.8	0.8	4	3.8	2.8	1.3	3
tarnished plant bug nymphs	0	0	0	0	0	0	0.3	0.3	2
brown stink bug	0	0	0	0	0	0	0	0	0
harlequin bug	0	0	0	0	0	0	0	0	0
southern green stink bug	0	0	0	0	0	0	0	0	0
spined soldier bug	0	0	0	0	0	0	0	0	0

VITA

Michael L. Boyd was born in Humboldt, Tennessee, on November 3, 1965. He received a Bachelor of Science Degree in Wildlife and Fisheries Science from the University of Tennessee at Knoxville in May, 1989. He reentered the University of Tennessee at Knoxville in January, 1990, and accepted a research assistantship in the Department of Entomology and Plant Pathology. He began study toward a Master's degree under the supervision of Dr. Gary L. Lentz in Jackson, Tennessee. In December of 1991, he received his Master of Science Degree with a major in Entomology and Plant Pathology. Michael Boyd is a member of the Tennessee Entomological Society, the Entomological Society of America, and Gamma Sigma Delta, the Honor Society of Agriculture.