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Insects and arachnids associated with musk thistle, Carduus thoermeri, in Tennessee

Steve Dennis Powell

To the Graduate Council:

I am submitting herewith a thesis written by Steve Dennis Powell entitled "Insects and arachnids associated with musk thistle, Carduus thoermeri, in 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.

Jerome F. Grant, Major Professor

We have read this thesis and recommend its acceptance:

Paris L. Lambdin, Harry Williams

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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C W Minkel

Associate Vice Chancellor
and Dean of the Graduate School

INSECTS AND ARACHNIDS ASSOCIATED WITH MUSK THISTLE, *Carduus thoermeri*, IN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Steve Dennis Powell

May 1991

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ABSTRACT

Musk thistle, Carduus thoermeri (Weinmann) (Compositae: Cynareae: Carduinae), is native to Europe and was introduced into North America in the late 1800's along the eastern seaboard of Canada and the United States and in Alabama (Batra et al. 1981). Musk thistle spread quickly from the mid-Atlantic States, where it was considered to be a weed by the early 1900's, to the Midwest, and became an economically important pest by 1950 (Batra et al. 1981).

Cultural controls, including mowing, reduced grazing, minimization of erosion, and periodic reseeding of grass, are important in maintaining low numbers of thistle seedlings (Trumble and Kok 1982). Although chemical herbicides achieve a measure of control against thistles, rough terrain and the potential of groundwater contamination limit their use. These two limitations, as well as the threat of reintroduction of thistle from untreated areas, provided the impetus for the evaluation of alternative control techniques (Trumble and Kok 1982).

In 1968, the head weevil, Rhinocyllus conicus (Froelich) (Coleoptera: Curculionidae), was introduced into the United States for biological control of thistles, particularly musk thistle (Hodgson and Rees 1976). Rhinocyllus conicus reduces the number of seeds produced by infested thistle plants

(Roberts and Kok 1979). Another biological control agent of musk thistle, the rosette weevil, Trichosirocalus horridus (Panzer) (Coleoptera: Curculionidae), was introduced into the United States in 1974 (Batra et al. 1981). Trichosirocalus horridus feeds on the crown tissue (Kok and trumble 1979).

In 1989, R. conicus and T. horridus were introduced into Tennessee to assess their potential for biological control of musk thistle (Lambdin and Grant 1989). The natural enemies of musk thistle that coexisted with and helped to suppress this plant pest in its native habitat are not present to help suppress the population of this weed in Tennessee (Lambdin and Grant 1989). A two-year study was initiated in conjunction with this research to better understand the diversity and specialization of the arthropod fauna that is associated with musk thistle in Tennessee. The specific objectives were to determine the species composition and seasonality of insects and arachnids associated with musk thistle and to observe the impact of selected arthropods on the plant. This introduced plant provides numerous established arthropod species with food or protection during its growing season. This research should provide preliminary information on the potential impact that R. conicus and T. horridus may have on the established arthropod fauna due to the resulting increase in competition for the resources of musk thistle and the eventual decrease in musk thistle populations.

During this two-year study, approximately 103 arthropod species or groups were found on musk thistle in Tennessee. Fifty-seven families, representing thirteen orders of insects, as well as eight families of arachnids, were collected from musk thistle. The most extensive arthropod diversity was found during the flowering stage of musk thistle. The most frequently encountered orders of insects were Coleoptera, Hemiptera, Hymenoptera, Lepidoptera, and Homoptera. The two most frequently encountered families of spiders were Salticidae and Thomisidae.

Only a few of the established arthropods in Tennessee were observed to cause significant damage to musk thistle. When present in large numbers, the nymphs and adults of two species of froghoppers (Homoptera: Cercopidae), Lepyronia quadrangularis (Say) and the meadow spittlebug, Philaenus spumarius (L.), apparently stunted the growth of the plant. Froghopper nymphs were most numerous during April and early May, while the greatest number of adults were observed from early May until early June. During the bud stage, the four-lined plant bug (Hemiptera: Miridae), Poecilocapsus lineatus (F.), caused foliar damage, but was not frequently found on the plant. Poecilocapsus lineatus was observed on musk thistle between the middle of May and late June.

The larva of the pyralid moth, Dicymolomia julianalis (Walker), was observed to feed on developing seeds within the seed head of musk thistle. Infestation levels of D.

julianalis on musk thistle seed heads during the summer of 1990 at sites in middle Tennessee averaged 10 to 15%, while those in eastern Tennessee averaged 20 to 25%. Most of the adults of this pyralid moth emerged between late July and late September.

Arthropods were found on musk thistle throughout its growing season. Stem and leaf feeders (e.g., grasshoppers and froghoppers) were found in large numbers before plant flowering, which attracted the greatest variety of arthropods. A number of arthropods, such as assassin bugs, minute pirate bugs, ambush bugs, and spiders, were predaceous upon many of the insects found within the flower. Although many established arthropods utilize the resources of musk thistle, few of these arthropods cause serious damage to the reproductive capabilities of the plant.

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CHAPTER 1

INTRODUCTION

Musk thistle, Carduus thoermeri (Weinmann) (Compositae: Cynareae: Carduinae), formerly C. nutans (L.), is native to Europe and was introduced into North America in the late 1800s along the eastern seaboard of Canada and the United States and in Alabama (Batra et al. 1981). Musk thistle spread quickly from the mid-Atlantic States, where it was considered to be a weed by the early 1900s, to the Midwest, and became an economically important pest by 1950 (Batra et al. 1981). Carduus thoermeri has been recorded from 687 counties in 40 states (Dunn 1976). Although infestations are greatest in the central part of the United States and in the Appalachian region, musk thistle has been reported to be economically important in 26 states in 360 of 3,068 counties in the mainland United States (Dunn 1976).

Musk thistle is a biennial with a rosette that develops after seed germination with subsequent growth throughout the growing season (Roof et al 1982). As the rosette leaves are killed by cold weather, a tap root develops and overwinters. Early the following spring, new leaves emerge from crown buds. A shoot then develops that grows upward rapidly and branches. Buds then appear, blooming later in the spring.

Musk thistle is characterized by numerous sharp spines along the leaf margins, branches, and stems. Plant height may vary from 1 to slightly greater than 2 meters (Roof et al. 1982). The reddish-pink flowers are large (4-8 cm) and are often located at the tip of a long stem or branch that bends or nods, which gives rise to the common name "nodding thistle" (Steyermark 1981). Plants begin to bloom in late April to early June, dependent upon the latitude and elevation, and may continue to bloom throughout the summer. However, most of the blooming occurs before the middle of August.

Seeds can be carried and dispersed by the wind many kilometers from their origin. Because several hundred seeds are produced by each seed head, the potential for the spread of musk thistle into noninfested areas is great. Seeds from musk thistle are commonly established in any area where the soil has been disturbed, such as along roadsides, railroad right-of-ways, fence borders, wastelands, and in pastures. Rangelands and pastures are rendered less productive due to competition for moisture, nutrients, light, and space from musk thistle (Roof et al. 1982).

Thistle-infested areas hinder the general maintenance of roadways due to manpower, equipment, and chemical expenses incurred in their removal from ditchbanks and elsewhere. During the last few years, the Tennessee

Department of Transportation has spent approximately $200,000 a year on chemical herbicides alone for the control of musk thistle along roadways. This amount does not include expenditures for machinery and labor. In addition, contact with the spine-tipped leaves may injure grazing animals and lead to secondary infection (Lambdin and Grant 1989).

Thistles have been considered to be a serious weed problem since Biblical times (Genesis 3:18). The use of a hoe, shovel, or scythe is limited to small areas or modest infestations that are accessible (Trumble and Kok 1982). However, mowing can be used to control larger areas of thistle although terrain may be a limiting factor. Uneven plant maturity that requires two or more mowings per season may limit the benefits of mowing to suppress thistle infestations. Other means of cultural control (e.g., reduced grazing, control of erosion, and periodic reseeding of grass) are important in maintaining low numbers of thistle seedlings (Trumble and Kok 1982).

During the 1960s and early 1970s, considerable research was focused on chemical control of musk thistle. In eastern Nebraska, picloram (4-amino-3,5,6-trichloropicolinic acid), sprayed during early and late season, was the most effective herbicide evaluated. Satisfactory control also was achieved with dicamba (2-methoxy-3,6-dichlorobenzoic acid) and 2,4-D

(2,4-dichlorophenoxyacetic acid) during early and late season (Feldman et al. 1968). 2,4-D, the most commonly used and recommended chemical herbicide for control of thistle, has been shown to quickly interfere with many of the vital biological functions of the plant. Silvex [2-(2,4,5-trichlorophenoxy) propionic acid] and MPCA (2-methyl-4-chlorophenoxyacetic acid) also have been successfully used against thistles. Although chemical herbicides achieve a measure of control against thistles, rough terrain and the potential of groundwater contamination limit their use. The high costs (e.g., time, energy, money, and environmental concerns) of this method of control, as well as the threat of the reintroduction of thistles from untreated areas, provided the impetus for researchers to evaluate alternative control techniques (Trumble and Kok 1982).

In 1968, the head weevil, Rhinocyllus conicus (Froelich) (Coleoptera: Curculionidae), was introduced into the United States by the United States Department of Agriculture for biological control of thistles, particularly musk thistle. Rhinocyllus conicus is capable of completing its life cycle on four genera of thistles: Carduus, Cirsium, Silybum, and Onoporum. This weevil is native to the Mediterranean region, eastern Europe, and western Asia and has the capacity to survive cold winters (Hodgson and

Rees 1976). *Rhinocyllus conicus* reduces the number of seeds produced by infested thistle plants (Roberts and Kok 1979).

Adults emerge from overwintering sites during April or May, mate, and begin to oviposit on the bracts of the thistle buds. Each female may lay approximately 200 eggs on the developing buds, and eggs hatch after about six days (Roberts and Kok 1979). Larvae then burrow into the receptacle, form cells, and feed on the developing seeds for 25 to 30 days prior to pupation. The pupal stage lasts from 8 to 14 days (Hodgson and Rees 1976). First generation adults emerge in July or August, remain on the plant for 1 to 3 weeks, and then overwinter as adults. These adults emerge the following spring and begin the cycle again (Roberts and Kok 1979).

The initial introduction of *R. conicus* into the United States originated from France and Italy (Kok and Surles 1975, Batra et al. 1981). In Gallatin County, Montana, 1,890 adult *R. conicus* were released during 1969, 200 during 1971, 400 in 1972, and 450 in 1973. By the summer of 1974, *R. conicus* had dispersed over a 1,280 square kilometer area, effectively reducing the seed-producing capacity of musk thistle in this area (Hodgson and Rees 1976).

In Pulaski County, Virginia, 100 adult *R. conicus* were released in the spring of 1969. By 1975, density of musk thistle in this area had been reduced by 95%, and eggs and adults were found 32 kilometers from the original release site (Kok and Surles 1975). In Virginia, the following larval-pupal hymenopteran parasitoids of R. conicus were found: Bracon mellitor (Say) (Braconidae), Nealiolus curculionis (Fitch) (Braconidae), formerly known as Aliolus curculionis, Zatropis sp. (Pteromalidae), and Neocatolaccus sp. (Pteromalidae). Although levels of parasitism on some dates were occasionally high, overall parasitism levels during the season were low (Dowd and Kok 1982). The parasitism levels of head weevil larvae that had developed in musk thistle peduncles were higher than the parasitism of weevils that had developed in flower heads of musk thistle and plumeless thistle, Carduus acanthoides L. (Dowd and Kok 1982).

In Webster County, Missouri, 490 adult R. conicus were released on May 7, 1975. By 1977, R. conicus had been recovered up to 5 kilometers from the original release site. Larvae of R. conicus collected from musk thistle in Missouri were found to be parasitized by two braconid species, B. mellitor and N. curculionis. However, these parasitoid species were considered to have little impact on populations of R. conicus in Missouri (Puttler et al. 1978).

Releases in Virginia and Missouri produced a large number of head weevils after several years. From the release of 100 adults in 1969 in Virginia, more than 20,000 head weevils were collected each year from 1973 to 1975 and used for further studies and new releases (Kok and Surles 1975). By 1981, head weevils that had originated from the releases in Missouri in 1975 were located as many as 18 kilometers from the original release site and had greatly multiplied. In 1981, sufficient numbers of head weevils were present in this area (within 3.2 kilometers of the original release site) to redistribute 500 head weevils at each of 26 locations in 23 counties (Roof et al. 1982).

Another biological control agent of musk thistle, the rosette weevil, Trichosirocalus horridus (Panzer) (Coleoptera: Curculionidae), formerly Ceuthorhynchidius horridus (Panzer), was introduced from Italy and approved for release in the United States in 1974 (Batra et al. 1981). Trichosirocalus horridus feeds on the rosette, resulting in necrosis of the crown tissue, and is compatible with R. conicus because they both feed on different parts of the plant. During the spring and fall of 1974 and 1975 and the spring of 1976, T. horridus was first released in North America (Kok and Trumble 1979). Larvae and adults of T. horridus were released at 10 Carduus thistle-infested sites in six counties (Warren, Montgomery, Giles, Pulaski, Russell, and Washington) in Virginia (Kok and Trumble 1979). Three of these sites were infested with musk thistle, six with plumeless thistle, and one with both musk and plumeless thistle. Because of these releases, T. horridus was established at the three musk thistle sites, one of the plumeless thistle sites, and the one mixed thistle site.

Trichosirocalus horridus is believed to prefer large (18.5-75 cm) musk thistle rosettes over small (0-11.5 cm) ones for oviposition. When a low weevil to thistle ratio (<30/100 plants) exists, musk thistle is preferred to plumeless thistle for oviposition (Sieburth and Kok 1982). Life cycle studies of T. horridus on Carduus thistles were conducted in Virginia between 1975 and 1978 (Trumble and Kok 1979a). These researchers concluded that the rosette weevil has one generation each year, and oviposition occurs between the middle of December and the early part of April. Larvae are found on the rosettes from late December to late May and pupation occurs in the soil (Trumble and Kok 1979a). The pupal stage lasts about 12 to 20 days (Roberts and Kok 1979). Adults are active from mid-May through June. For the next three months, adults are believed to be in aestival diapause. Diapause ends in late September with the resumption of feeding which continues through mid-December (Trumble and Kok 1979a).

After these two species of weevils, R. conicus and T. horridus, were established as biological control agents of musk thistle, Trumble and Kok (1979b) evaluated the compatibility of these biological control agents with chemical herbicides in a management program against musk thistle. In experiments with R. conicus and 2,4-D at a concentration level of 1.68 kg/ha, the recommended rate, larval mortality was not significantly ($p > 0.05$) affected unless plants were sprayed less than 48 hours after oviposition. Plants sprayed less than 2 weeks after oviposition would not produce viable seeds due to the effect of the herbicide (Trumble and Kok 1979b).

Experiments were conducted to determine the response of T. horridus to selected rates of 2,4-D at various durations after application (Trumble and Kok 1980). Treatment of the recommended rate of 2,4-D (1.68 kg/ha) did not significantly ($p > 0.05$) affect the survival rate of T. horridus when compared with untreated controls. LC_{50} values were determined for males (70.2 kg/ha) and females (61.4 kg/ha). Thus, 2,4-D can be applied at sufficient rates to cause mortality of the host plant without adversely affecting the population increase of T. horridus (Trumble and Kok 1980). Eighty-five percent mortality of musk thistle was achieved in a study using T. horridus and 2,4-D at the rate of 0.252 kg/ha, which is 15% of the recommended rate (1.68 kg/ha). Either method alone would have produced only 7% and 55% mortality, respectively (Stoyer and Kok 1987). The factors of poor or good leaf condition and herbicide presence or absence were compared in terms of egg viability and larval mortality. Stoyer and Kok (1989) concluded that ovipositional behavior was more of a factor of leaf condition than that of herbicide effect at a dosage of 0.252 kg/ha of 2,4-D. Significantly ($p \leq 0.05$) more eggs were laid in healthy leaves than in dead or drying leaves. No significant ($p > 0.05$) difference was observed in oviposition between thistles sprayed with the lower rate of 2,4-D and those that were not sprayed (Stoyer and Kok 1989).

In 1989, R. conicus and T. horridus were introduced into Tennessee to assess their potential for the biological control of musk thistle (Lambdin and Grant 1989). In conjunction with this study, a survey of arthropods was conducted to better understand the diversity and specialization of the arthropod fauna that is associated with musk thistle in Tennessee. This research will evaluate the potential impact that R. conicus and T. horridus may have on the arthropod fauna due to the resulting increase in competition for the resources of musk thistle and the eventual decrease in musk thistle populations. In addition, the potential impact of the present arthropod fauna on R. conicus and T. horridus could be evaluated.

The ecological relationships among arthropods and musk thistle are not well known, particularly in the southern United States. In South Dakota (Morihara and Balsbaugh 1976), a survey of insect fauna of musk thistle was conducted in 1973 and 1974. An estimated 98 species, 61 of these were identified to species, were collected from 8 identified orders, 36 families, and 62 genera. The most commonly found species included: Melanoplus bivittatus (Say) (Orthoptera: Acrididae), M. differentialis (Thomas), M. femurrubrum (DeGeer), Oecanthus nigricornis (Saussure) (Orthoptera: Gryllidae), Adelphocoris lineolatus (Goeze) (Hemiptera: Miridae), Lygus lineolaris (Palisot de Beauvois) (Miridae), Plagiognathus politus (Uhler) (Miridae), Poecilocapsus lineatus (F.) (Miridae), Cosmopepla bimaculata (Thomas) (Hemiptera: Pentatomidae), Euschistus euschistoides (Vollenhouen) (Pentatomidae), E. tristigmus (Say), Ceresa constans (Walker) (Homoptera: Membracidae), Stictocephala inermis (F.) (Membracidae), Aceratagallia uhleri (Van Duzee) (Homoptera: Cicadellidae), Agalliopsis novella (Say) (Cicadellidae), Endria inimica (Say) (Cicadellidae), Macrosteles divisa (Uhler) (Cicadellidae), Neosteles neglecta (Delong and Davidson) (Cicadellidae), Paraphlepsius irroratus (Say) (Cicadellidae), Chaetocnema confinis (Crotch) (Coleoptera: Chrysomelidae), Systena frontalis (F.) (Chrysomelidae), Vanessa cardui (L.) (Lepidoptera: Nymphalidae), Papaipema nebris (Guenee) (Lepidoptera: Noctuidae), Platyptilia carduidactyla (Riley) (Lepidoptera: Pterophoridae), Homoeosoma electellum (Hulst) (Lepidoptera: Pyralidae), Euaresta bella (Loew) (Diptera: Tephritidae), Paracantha culta (Wiedeman) (Tephritidae), Apis mellifera (L.) (Hymenoptera: Apidae), Megabombus pennsylvanicus (DeGeer) (Apidae) and Pyrobombus griseocollis (DeGeer) (Apidae). Various plant associations among these and other insect species with musk thistle at the sites in South Dakota were recorded (Morihara and Balsbaugh 1976). The area of the plant (e.g., root, stem, leaf, pollen, flower head and bud) where the insects were found was indicated. If the insect species or group was ectophagous or endophagous, this relationship with the plant also was indicated (Morihara and Balsbaugh 1976).

The sunflower moth, Homoeosoma electellum (Hulst) (Lepidoptera: Pyralidae), common where sunflowers are grown commercially, was found to infest the seed heads of musk thistle in Louisiana (Goyer 1978). Immature thistle seed heads were collected from Bossier, Caddo, DeSoto, Natchitoches, and Red River Parishes and dissected to determine the level of infestation by H. electellum. Thirty-six percent of the seed heads collected from June 24 to July 16, 1976, was infested by H. electellum. Infestation of musk thistle by H. electellum provides this pyralid with an additional food source and reduces to some extent the seed production of musk thistle in Louisiana.

Because of the lack of information available on the ecological relationships among arthropods and musk thistle in Tennessee, a two-year study was initiated to better understand these relationships. The objectives of this research were to:

1. determine the species of insects and arachnids present on musk thistle,
2. determine the seasonality of selected insects and arachnids on musk thistle, and
3. observe the impact of selected arthropods on musk thistle.

CHAPTER 2

ABOVE-GROUND ARTHROPOD SPECIES ASSOCIATED WITH MUSK THISTLE IN TENNESSEE

Introduction

Because musk thistle is not native to North America, it does not encounter the natural enemies that coexist with this species in its native country. This lack of natural enemies allows the range and density of musk thistle to be much greater in the United States than may be expected.

Musk thistle is native to Europe and was introduced into North America in the late 1800s along the eastern seaboard of Canada and the United States and in Alabama (Batra et al. 1981; see Chapter 1). This introduced plant species provides numerous established arthropod species with food or protection during its growing season. The ecological relationships among established arthropods and introduced musk thistle are not well known, particularly in the southern United States. Approximately 98 species of insects were found to be associated with musk thistle in South Dakota (Morihara and Balsbaugh 1976). Additional information regarding the insect stage(s) (e.g., immature, adult) collected from the plant and the plant association(s) (e.g., ectophagous, endophagous, roots, stems, leaves, pollen, flower heads, and buds) that the insects exhibited also were reported. In a study in Louisiana, the sunflower moth, Homoeosoma electellum (Hulst), was found to commonly inhabit immature thistle seed heads (Goyer 1978). The extent of the utilization and consumption of the resources of musk thistle by insects and other arthropods has not been evaluated in most areas of the United States. In addition, little information is available on the seasonal incidence of arthropods associated with musk thistle.

Because of the limited information available on arthropods associated with musk thistle in Tennessee, a two-year study was initiated to: (1) determine the arthropod fauna associated with this introduced weed species in eastern and middle Tennessee and (2) monitor the seasonal incidence and diversity of selected arthropod species. This information would be useful to assess the potential impact that these established arthropods and the recently introduced plant-feeding weevils, Rhinocyllus conicus (Froelich) and Trichosirocalus horridus (Panzer), may have on each other.

Materials and Methods

Several sampling and survey methods were utilized during this two-year study to ascertain the arthropods associated with musk thistle and their relationship to the plant. Above-ground arthropods were observed on, and collected from, musk thistle at selected locations throughout middle and eastern Tennessee. Observations and random sampling of arthropod species on musk thistle were made from May to August 1989 and from April to October 1990.

Data were recorded at three nonrelease sites (i.e., areas where the two plant-feeding weevils had not been released) and at eleven release sites (i.e., areas where the two plant-feeding weevils had been released) (Table 1). Although more detailed attention was directed at plants at the three nonrelease sites, arthropods were observed and collected at all of the selected release and nonrelease sites. Several additional nonrelease sites were visited occasionally in 1990 and monitored for arthropod presence and activity (Table 2). Specimens also were collected from these locations.

Species Composition

To determine the arthropod species associated with musk thistle, arthropods were collected from musk thistle plants during each stage (i.e., rosette, bud, flower, and seed dispersal) of plant growth. In 1989, arthropods were collected biweekly at the release and nonrelease sites (Table 1) from May 22 to August 25 with emphasis given to the nonrelease sites. In 1990, arthropods were collected biweekly from April 27 to June 5 at the release and nonrelease sites (Table 1). From June 5 to July 18 of 1990,

Table 1. Sites, weevil release and nonrelease, where arthropods were monitored and collected in 1989 and 1990 on musk thistle in middle and eastern Tennessee.

Weevil release sites [a]		Weevil nonrelease sites [a]	
Interstate Location	County	Interstate Location	County
I-65 mm 53	Williamson (M)	I-40 mm 228	Wilson (M)
I-24 mm 71	Rutherford (M)	I-40 mm 397	Knox (E)
I-40 mm 221	Davidson (M)	I-81 mm 19	Greene (E)
I-40 mm 245	Wilson (M)		
I-40 mm 259	Smith (M)		
I-40 mm 269	Putnam (M)		
I-75 mm 56	McMinn (E)		
I-75 mm 122	Anderson (E)		
I-40 mm 434	Cocke (E)		
I-81 mm 9	Hamblen (E)		
I-81 mm 25	Greene (E)		

[a] M = middle Tennessee; E = eastern Tennessee

Table 2. Additional nonrelease sites where arthropods were occasionally collected from musk thistle during 1990 in middle and eastern Tennessee.

Highway Location	County
I-65 mm 52	Maury (M) [a]
I-40 mm 232	Wilson (M)
McMinn County Rd. 316	McMinn (E)
I-81 mm 21-22	Greene (E)

[a] M = middle Tennessee; E = eastern Tennessee

arthropods were collected four to five times each week at release and nonrelease sites (Table 1) as well as at other selected sites where musk thistle was present in large numbers (Table 2). This time period corresponded with the greatest arthropod diversity that appeared on musk thistle. From July 18 to August 27, 1990, arthropods were collected biweekly at the release, nonrelease, and occasionally-visited sites in eastern Tennessee only (Tables 1 and 2). From August 27 to October 12, 1990, biweekly arthropod collections were made at the following two sites: I-40 mm 397 (Knox Co.) and I-81 mm 9 (Hamblen Co.).

Methods of collecting included hand collecting, enclosure of areas of the plant (usually the flower or areas where arthropods were observed or suspected) by kill jars, and the clipping of flowers and seed heads which then were placed in ziploc freezer bags and taken to the laboratory for further analysis. Collected arthropods were placed in vials containing alcohol (ca. 70%) or returned to the laboratory and pinned for later identification. In the laboratory, collected specimens were sorted and identified to order, family, genus, and species, when possible. Voucher specimens were placed in the University of Tennessee Insect Museum located on the Agricultural Campus, University of Tennessee, Knoxville.

Species Seasonality and Location on Plant

To determine the seasonality and diversity of the arthropod fauna associated with musk thistle, 30 plants were chosen at random every 2 weeks at each selected nonrelease site (Table 1). At each site, a 3 meter x 30 meter plot was delineated and then subdivided into 10 3 meter x 3 meter subplots. During each sampling visit, three plants in each subplot were randomly selected, and each plant was examined for selected arthropod species. The numbers of these arthropods and their location on the plant (e.g., stem, leaf, bud, flower, and seed head; top, middle, and bottom) were recorded on each sampling date. The number of branches or buds or flowers/plant, seed heads/plant, plant height, general weather conditions, and time of day also were recorded. An example of the data form is provided in Figure 1.

Plant-feeding insects that were believed to cause observable damage to musk thistle, particularly its ability to produce and release seeds, were especially noted. More detailed studies then were conducted to better assess their impact on the plant (see Chapter 3).

ARTHROPODS ON THISTLE

SITE: PLANT HT: TIME OF DAY:
BLOCK: NO. BRANCHES: GENERAL WEATHER:
PLANT NO:
DATE:

Specimen	Stem				Leaf				Bud				Flower			
	Top	Mid	Bot	Tot	Top	Mid	Bot	Tot	Top	Mid	Bot	Tot	Top	Mid	Bot	Tot

Figure 1. Data form used to monitor and record arthropod fauna associated with musk thistle.

Results and Discussion

Species Composition

During this two-year study, approximately 103 arthropod species or groups were found on musk thistle in Tennessee (Table 3). Fifty-seven families, representing thirteen orders of insects, were collected from musk thistle, as well as eight families from two orders of arachnids. One member of the class Chilopoda also was found on musk thistle.

The most extensive arthropod diversity was found during the flowering stage of musk thistle. Thrips, *Frankliniella* sp. (Thysanoptera: Thripidae), were often observed in large numbers in the flower. The most frequently encountered orders of insects on musk thistle were Coleoptera, Hemiptera, Hymenoptera, Lepidoptera, and Homoptera (Table 3).

One collembolan specimen was collected in a flower, late in the growing season. An Odonate, *Libellula luctuosa* (Burmeister) (Libellulidae), commonly named the Widow, was collected on a flower, presumably while searching for insects to feed upon.

Orthopterans were commonly represented by the differential grasshopper, *Melanoplus differentialis* (Thomas) (Acrididae), which was found on musk thistle throughout the growing season. Another Orthopteran, a tree cricket, *Oecanthus nigricornis* (Saussure) (Gryllidae), was found on the flower. Mantids were occasionally observed on musk

Table 3. Arthropods found on musk thistle in Tennessee, 1989 and 1990.

Order	Family	Genus	Species	Author
Collembola	Entomobryidae	—	—	—
Odonata	Libellulidae	Libellula	luctuosa	(Burmeister)
Orthoptera	Acrididae	Melanoplus	differentialis	(Thomas)
	Acrididae	Melanoplus	femurrubrum	(DeGeer)
	Gryllidae	Oecanthus	nigricornis	(Saussure)
	Tettigoniidae	—	—	—
Mantodea	Mantidae	—	—	—
Psocoptera	Ectopsocidae	Ectopsocopsis	cryptomeriae	(Enderlein)
Hemiptera	Alydidae	Alydus	eurinus	(Say)
	Anthocoridae	Orius	insidiosus	(Say)
	Coreidae	Acanthocephala	terminalis	(Dallis)
	Coreidae	Euthochtha	galeator	(F.)
	Coreidae	Leptoglossus	phyllopus	(L.)
	Lygaeidae	Geocoris	punctipes	(Say)
	Lygaeidae	Lygaeus	kalmii	(Stal)
	Miridae	Lopidea	—	—
	Miridae	Lygus	lineolaris	(Beauvois)
	Miridae	Poecilocapsus	lineatus	(F.)
	Pentatomidae	Cosmopepla	bimaculata	(Thomas)
	Pentatomidae	Euschistus	servus	(Say)
	Pentatomidae	Stiretrus	anchorago	(F.)
	Pentatomidae	Thyanta	—	—
	Phymatidae	Phymata	—	—
	Reduviidae	Apiomerus	crassipes	(F.)
	Reduviidae	Sinea	—	—
	Thyreocoridae	—	—	—
Homoptera	Acanaloniidae	Acanalonia	bivittata	(Say)
	Acanaloniidae	Acanalonia	conica	(Say)
	Aphididae	—	—	—
	Cercopidae	Lepyronia	quadrangularis	(Say)
	Cercopidae	Philaenus	spumarius	(L.)
	Cicadellidae	Oncometopia	orbona	(F.)
	Cicadellidae	Paraulaeizes	irrorata	(F.)
	Flatidae	Anormenis	chaloris	(Melichar)
	Membracidae	Stictocephala	lutea	(Walker)
Thysanoptera	Thripidae	Frankliniella	—	—
Neuroptera	Chrysopidae	—	—	—
Coleoptera	Cantharidae	Chauliognathus	pennsylvanicus	(DeGeer)
	Cerambycidae	Typocerus	velutinus	(Olivier)
	Cerambycidae	Typocerus	zebra	(Olivier)
	Cerambycidae	—	—	—
	Chrysomelidae	Diabrotica	undecimpunctata	(Barber)
	Chrysomelidae	Labidoderma	clivicolis	(Kirby)
	Chrysomelidae	Leptinotarsa	juncta	(Germar)
	Chrysomelidae	Zygogramma	suturalis	(F.)
	Chrysomelidae	—	—	—
	Cleridae	Enoclerus	rosmarus	(Say)
	Coccinellidae	Brachiacantha	ursina	(F.)
	Coccinellidae	Coccinella	septempunctata	(L.)
	Coccinellidae	Coleomegilla	maculata	(Mulsant)
	Coccinellidae	—	—	—
	Curculionidae	Apion	—	—

Table 3. (continued)

Order	Family	Genus	Species	Author
Coleoptera	Languriidae	Acropteroxys	gracilis	(Newman)
	Languriidae	Languria	mozardi	(Latreille)
	Meloidae	—	—	—
	Mordellidae	Mordella	—	—
	Nitidulidae	Conotelus	obscurus	(Erichson)
	Scarabaeidae	Euphoria	—	—
	Scarabaeidae	Popillia	japonica	(Newman)
	Scarabaeidae	Trichotinus	—	—
Diptera	Bombyliidae	—	—	—
	Calliphoridae	Pollenia	—	—
	Calliphoridae	Pollenia	—	—
	Calliphoridae	Pollenia	—	—
	Ottidae	Acrosticta	—	—
	Syrphidae	Baccha	elongata	(F.)
	Syrphidae	Microdon	—	—
	Syrphidae	Toxomerus	—	—
	Tipulidae	—	—	—
Lepidoptera	Danaidae	Danaus	plexippus	(L.)
	Hesperiidae	Atalopedes	campestris	(Boisduval)
	Hesperiidae	Epargyreus	clarus	(Cramer)
	Nymphalidae	Agraulis	vanillae	(L.)
	Papilionidae	Pterourus	troilus	(L.)
	Pieridae	Colias	eurytheme	(Boisduval)
	Pyralidae	Dicymolomia	julianalis	(Walker)
	Tortricidae	Platynota	—	—
	Yponomeutidae	Atteva	punctella	(Cramer)
	Zygaenidae	Harrisina	americana	(Guerin)
Hymenoptera	Apidae	Apis	mellifera	(L.)
	Apidae	Bombus	—	—
	Braconidae	Cotesia	—	—
	Chalcididae	Metadonia	amoena	(Say)
	Chalcididae	—	—	—
	Formicidae	—	—	—
	Halictidae	—	—	—
	Halictidae	—	—	—
	Halictidae	—	—	—
	Halictidae	—	—	—
	Ichneumonidae	—	—	—
	Ichneumonidae	—	—	—
	Vespidae	Polistes	—	—
	Xylocopidae	Xylocopa	—	—
Araneae	Araneidae	Araneus	—	—
	Araneidae	Argiope	aurantia	(Lucas)
	Araneidae	—	—	—
	Clubionidae	—	—	—
	Linyphiidae	—	—	—
	Oxyopidae	Peucetia	viridans	(Hentz)
	Salticidae	—	—	—
	Theridiidae	—	—	—
	Thomisidae	Misumenops	celer	(Hentz)
	Thomisidae	Misumenops	—	—
Opiliones	—	—	—	—
(Class *Chilopoda*)	—	—	—	—

thistle. The Psocopteran, _Ectopsocopsis_ _cryptomeriae_ (Enderlein) (Ectopsocidae), was found in the seed heads after most of the seeds had been released, possibly feeding on fragments of dead insects.

Hemipterans were found in great abundance on musk thistle. The minute pirate bug, _Orius_ _insidiosus_ (Say) (Anthocoridae), was commonly found in the flower. Three mirids were found to be occasionally associated with musk thistle. These were _Lopidea_ sp., the tarnished plant bug, _Lygus_ _lineolaris_ (Beauvois), and the four-lined plant bug, _Poecilocapsus_ _lineatus_ (F.). The most frequently encountered Hemipteran was the brown stink bug, _Euschistus_ _servus_ (F.), usually observed to feed near the bud or flower.

Three Homopterans were common on musk thistle. The membracid, _Stictocephala_ _lutea_ (Walker), was usually observed near the bud or flower of the plant. The nymphs and adults of two froghopper species (Cercopidae) when present in large numbers appeared to stunt the growth of musk thistle. These are the meadow spittlebug, _Philaenus_ _spumarius_ (L.), and _Lepyronia_ _quadrangularis_ (Say).

Eleven families of beetles (Coleoptera) were collected from musk thistle, usually in association with the flower. Three species observed in large numbers were the soldier beetle, _Chauliognathus_ _pennsylvanicus_ (DeGeer)

(Cantharidae), the spotted cucumber beetle, Diabrotica undecimpunctata (Barber) (Chrysomelidae), and Conotelus obscurus (Erichson) (Nitidulidae).

Three Lepidopterans were frequently encountered feeding on nectar from the flower of musk thistle. These were the silver-spotted skipper, Epargyreus clarus (Cramer) (Hesperiidae), the sachem, Atalopedes campestris (Boisduval) (Hesperiidae), and the orange sulfur, Colias eurytheme (Boisduval) (Pieridae).

Hymenopterans attracted to the flower included the honey bee, Apis mellifera (L.) (Apidae), bumblebees, Bombus sp. (Apidae), carpenter bees, Xylocopa sp. (Xylocopidae), and a number of halictid species. Syrphids, also attracted to the flower, were the most frequently encountered Dipterans.

Spiders were usually found in the flower or in the seed head after the seeds had been dispersed. The two most frequently encountered families of spiders on musk thistle were Salticidae and Thomisidae (Table 3). Spiders of Misumenops spp. (Thomisidae) appeared to be among the most common of the genera of arachnids which were found.

Vertical Location on Plant

The vertical location on musk thistle varied among selected arthropod species or groups, and the percentages of these arthropod species or groups that were found on the top-third, middle one-third, or bottom one-third of the plant during the survey period are listed in Table 4. The majority of organisms was observed in the top one-third of the plant, and few organisms were located in the bottom one-third of the plant. This spatial difference was apparently due to the fact that the flowers are usually located near the top of the plant. Many of the organisms (e.g., Coleopterans, Hemipterans, and Hymenopterans) found in the top of the plant were associated with the flower. This was the case, for example, with C. pennsylvanicus, D. undecimpunctata, and O. insidiosus. Other organisms (e.g., grasshoppers and froghoppers, especially P. spumarius) were located near the middle one-third of the plant because of their feeding on the stem/leaves.

Location on Plant Part

The percentages of arthropod species or groups found on selected parts of the plant are presented in Table 5. The majority of organisms was found associated with the flower as it was the primary site of food, protection, or searching for prey. Examples include mordellid beetles, D. undecimpunctata, and O. insidiosus. Other organisms were more commonly found on the stem or leaves of the plant as these plant parts were the source of nutrition. Examples include grasshoppers and P. spumarius. Few organisms were found associated with the seed head.

Table 4. Vertical location of selected arthropod species or groups on musk thistle in Tennessee, 1989 and 1990 combined.

Arthropod Species or Group	n	Vertical Location on Plant		
		Top	Middle	Bottom
Mordellidae	13	100.0 [a]	0.0	0.0
Diabrotica undecimpunctata howardi (Barber)	10	90.0	0.0	10.0
Chauliognathus pennsylvanicus (DeGeer)	27	74.1	22.2	3.7
Grasshoppers	41	34.1	48.8	17.1
Orius insidiosus (Say)	36	77.8	22.2	0.0
Pentatomidae	19	89.5	10.5	0.0
Lygus lineolaris (Palisot de Beauvois)	14	92.9	7.1	0.0
Froghoppers (Adult) [b]	237	52.3	40.5	7.2
Froghoppers (Nymph) [b]	206	30.1	51.9	18.0
Aphids	20	85.0	15.0	0.0
Ants	213	60.1	23.5	16.4
Thrips	1260	98.7	1.3	0.0
Spiders	49	77.6	20.4	2.0

[a] Percent of total individuals.

[b] Primarily Philaenus spumarius (L.).

Table 5. Plant part where selected arthropod species or groups were found on musk thistle in Tennessee, 1989 and 1990 combined.

Arthropod Species or Group	n	Part of Plant				
		Stem	Leaf	Bud	Flower	Seed Head
Mordellidae	13	15.4 [a]	0.0	0.0	84.6	0.0
Diabrotica undecimpunctata howardi (Barber)	10	20.0	0.0	0.0	80.0	0.0
Chauliognathus pennsylvanicus (DeGeer)	27	7.4	22.2	3.7	66.6	0.0
Grasshoppers	41	39.0	29.3	4.9	9.8	17.1
Orius insidiosus (Say)	36	0.0	0.0	0.0	100.0	0.0
Pentatomidae	19	21.1	0.0	10.5	21.1	47.4
Lygus lineolaris (Palisot de Beauvois)	14	14.3	7.1	28.6	50.0	0.0
Froghoppers (Adult) [b]	237	44.7	42.6	9.3	2.9	0.4
Froghoppers (Nymph) [b]	206	69.9	26.2	3.4	0.5	0.0
Aphids	20	60.0	0.0	0.0	30.0	10.0
Ants	213	35.2	16.9	12.2	30.0	5.6
Thrips	1260	0.0	0.0	1.6	98.4	0.0
Spiders	49	24.5	8.2	0.0	49.0	18.4

[a] Percent of total individuals.

[b] Primarily *Philaenus spumarius* (L.).

Seasonality of Selected Arthropod Species or Groups

The seasonality of selected arthropod species or groups observed on musk thistle at the nonrelease sites is illustrated in Figure 2. The froghopper nymphs and adults were present in substantial numbers early in the growing season, feeding on the stem or leaves of the plant. Most of the other arthropods were observed on musk thistle as flowering began. After the seeds were dispersed, few arthropods (e.g., spiders and ants) were found on the plants.

Although most arthropod species appeared to be only occasional visitors to musk thistle, many arthropods frequently utilized the nutritional resources of the plant or preyed on other arthropods present on the plant. These predaceous arthropods included spiders and minute pirate bugs.

During the early stages (rosette to bud) of the growing season of musk thistle, the most commonly encountered groups of arthropods on the plant were froghoppers (Cercopidae). The nymphs of these insects are located inside spittle masses which are spittle-like and are found on the stem or leaves of the plant. In large numbers, these froghoppers may cause stunting of plant growth. Two species of Cercopidae, L. quadrangularis and P. spumarius, were found on musk thistle in Tennessee. Philaenus spumarius was by

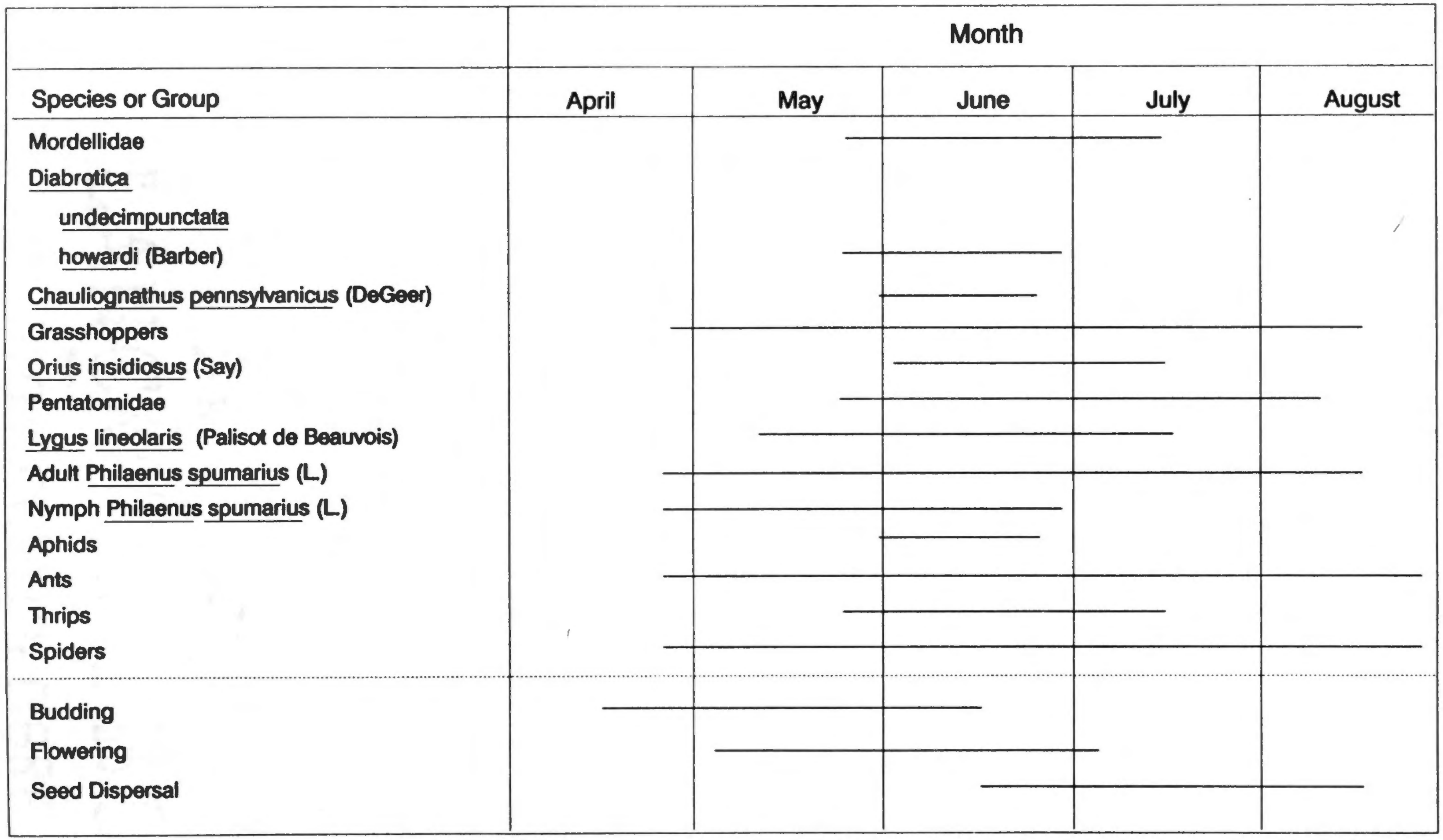

Figure 2. Seasonality of selected arthropod species or groups observed on musk thistle in middle and eastern Tennessee at the nonrelease sites during the random survey, 1989 and 1990.

far the most frequently encountered of these two species, and comprised approximately 90% of the two species of froghoppers. Nymphs of P. spumarius were observed from late March through late June, while adults were usually found from mid-April to mid-July. In 1990, on the average, more than 2 froghopper nymphs per plant were found at the two nonrelease sites in eastern Tennessee during late April. Although the extent of damage by the froghoppers to the thistle plants was not quantified, thistle may provide a reservoir population for froghoppers with the potential to move to other areas where more preferable plants can be used as a food source.

As musk thistle began to bud, a greater diversity of arthropod fauna was found to be associated with the plant. Early in the bud stage, scarlet plant bugs, Lopidea sp. (Hemiptera: Miridae), were occasionally found to feed throughout the stem and leaves; however, they did not appear to cause significant damage to the plant. The brown stink bug and the tarnished plant bug were commonly found from late May to the middle of July. The differential grasshopper also was found during this period and throughout the remainder of the growing season, particularly after the plant had attained a height of over 60 cm. Other insect species that visited the plant during the bud stage included two cicadellid species, Oncometopia orbona (F.) and

Paraulaeizes irrorata (F.), and a membracid, Stictocephala lutea (Walker). The four-lined plant bug was occasionally found on musk thistle, and caused considerable foliar damage when present, usually from late May to late June.

The greatest diversity of arthropod fauna, however, was found during the flowering stage of musk thistle. Plants began to flower in mid-May and were common through early July, although a few plants were observed to flower as late as October 12, 1990, at I-81 mm 9 in Hamblen Co.

A number of hymenopterans, including Bombus sp. (Apidae), Xylocopa sp. (Xylocopidae), A. mellifera (Apidae), and several members of the family Halictidae were attracted to the musk thistle flower. A wide variety of coleopterans, including mordellids, scarabs, chrysomelids, curculionids, cantharids, languriids, nitidulids, meloids, and cerambycids, also were found on or in the flower. Coccinellids were commonly encountered throughout the plant during the flowering stage. Some of the most frequently encountered coleopterans were: Euphoria sp. (Scarabaeidae), Trichotinus sp. (Scarabaeidae), Popillia japonica (Newman) (Scarabaeidae), Labidoderma clivicolis (Kirby) (Chrysomelidae), Apion sp. (Curculionidae), Photinus pyralis (L.) (Lampyridae), Diabrotica undecimpunctata howardi (Barber) (Chrysomelidae), Chauliognathus pennsylvanicus

(DeGeer) (Cantharidae), and Conotelus obscurus (Erichson) (Nitidulidae).

Hemipterans commonly found on musk thistle in or near the flower included coreids, lygaeids, phymatids, reduviids, pentatomids, mirids, and anthocorids. Some of the most frequently encountered hemipterans were: E. servus, L. lineolaris, Phymata sp. (Phymatidae), Leptoglossus phyllopus (L.) (Coreidae), Sinea sp. (Reduviidae), and O. insidiosus.

Other than grasshoppers, the most common orthopteran found on musk thistle during the flowering stage was a tree cricket, O. nigricornis. Syrphids were the most common dipterans observed on the flower. The most commonly observed lepidopterans found on the flowers were the sachem, a hesperid, the orange sulfur, and the silver-spotted skipper. Thrips, Frankliniella sp., also were common and abundant in the flower.

After flowering, the seeds are blown by the wind into new areas. Only a few arthropods were associated with this growth stage of the plant. The adult of the pyralid moth, Dicymolomia julianalis, emerged from the seed head after flowering was completed. The larvae of the moth feed on the developing seeds within the seed head. The psocid, Ectopsocopsis cryptomeriae (Enderlein), was found on the seed head after the seeds had been released.

Spiders were most commonly encountered on musk thistle inside the flower or inside the seed head after flowering had ended. The following spider families were found on the plant: Thomisidae, Linyphiidae, Theridiidae, Araneidae, Salticidae, Clubionidae, and Oxyopidae. Salticidae and Thomisidae comprised more than 60% of collected families of spiders on musk thistle. Spider genera or species found on the plant included *Misumenops* sp. (Thomisidae), *Misumenops celer* (Hentz) (Thomisidae), *Araneus* sp. (Araneidae), *Argiope aurantia* (Lucas) (Araneidae), and *Peucetia viridans* (Hentz) (Oxyopidae).

Arthropods were found on musk thistle throughout its growing season. Stem and leaf feeders (e.g., grasshoppers and froghoppers) were found in large numbers before the flowering stage of the plant. Their density on the plant decreased as the growing season progressed. The greatest variety of arthropods were found during the flowering stage. Many insects were found feeding within the flower, including a number of Coleopterans, Lepidopterans, and Hymenopterans. A number of arthropods, such as assassin bugs, minute pirate bugs, ambush bugs, and spiders were predaceous upon many of the insects found in the flower. Although many established arthropods utilize the resources of musk thistle, few of these arthropods cause serious damage to the reproductive capabilities of the plant. This has allowed the range of musk thistle to expand throughout much of middle and eastern Tennessee.

CHAPTER 3

INCIDENCE OF SELECTED ESTABLISHED PLANT-FEEDING INSECTS ON MUSK THISTLE IN TENNESSEE

Introduction

Musk thistle is native to Europe and was introduced into North America in the late 1800s along the eastern seaboard of Canada and the United States and in Alabama (Batra et al. 1981). The natural enemies of musk thistle that coexisted with and helped to suppress this plant pest in its native habitat are not present in Tennessee to help suppress the population of this weed (Lambdin and Grant 1989). Little information on the impact of indigenous or established arthropods on musk thistle is available.

Only a few of the established arthropods in Tennessee have been observed to cause significant damage to musk thistle. Although a large number of arthropods utilize the various resources of the plant, the net effect of many of these plant-feeding insects has not prevented musk thistle from extending its range throughout middle and eastern Tennessee (Lambdin and Grant 1989). The objective of this study was to determine the extent of damage to musk thistle by established arthropods in Tennessee.

Materials and Methods

In addition to the biweekly (from May 30 to August 25 of 1989 and April 27 to August 27 of 1990) arthropod survey of 30 randomly selected musk thistle plants at three nonrelease sites as outlined in Chapter 2, biweekly observations were made at each release site (Table 1) from May 22 to August 25, 1989. Biweekly observations also were conducted at release sites from April 27 to June 5, 1990. During 1990, release sites (Table 1) and other occasionally-visited sites (Table 2) in middle or eastern Tennessee were observed four or five times each week from June 5 to July 18, and biweekly observations also were conducted at release sites in eastern Tennessee from July 18 to August 27. In addition, biweekly observations were conducted from August 27 to October 12, 1990, at two sites: I-40 mm 397 (Knox Co.) and I-81 mm 9 (Hamblen Co.). Those insects, such as the meadow spittlebug, Philaenus spumarius (L.) (Homoptera: Cercopidae), the four-lined plant bug, Poecilocapsus lineatus (F.) (Hemiptera: Miridae), and Dicymolomia julianalis (Walker) (Lepidoptera: Pyralidae), that caused noticeable damage to musk thistle were noted, and selected types of data (e.g., insect identity, location on plant, relative density on the plant, and seasonality) were recorded.

In 1989, approximately 200 seed heads of musk thistle that appeared to be infested were collected at release and nonrelease sites in middle and eastern Tennessee biweekly from July 12 to August 25 and placed in ziploc freezer bags (Table 6). These samples were held in the laboratory at room temperature and observed for insect emergence, particularly that of D. julianalis. To determine the infestation level of D. julianalis on musk thistle, seed heads were randomly collected at 12 sites throughout middle and eastern Tennessee from July 30 to August 27, 1990. Information regarding the date, site location, and the number of seed heads collected from these 12 sites is provided in Tables 7, 8, and 9. These seed heads were placed in ziploc freezer bags, returned to the laboratory, and observed for adult moth emergence. The numbers and dates of emergences were recorded.

Results and Discussion

During the early growing season, only a few arthropod species damaged musk thistle in Tennessee. For example, Lopidea sp. (Miridae) fed on the plant during this period, particularly in middle Tennessee, but caused little noticeable damage to the plant. When present in large numbers, the nymphs and adults of two species of froghoppers (Homoptera: Cercopidae), Lepyronia quadrangularis (Say) and P. spumarius, apparently stunted the growth of the plant.

Table 6. Sites where seed heads of musk thistle were infested by the pyralid moth, Dicymolomia julianalis (Walker), 1989.

Location	No. of Moth Emergences
I-40 mm 221 (Davidson Co.) (M) [a]	4
I-40 mm 228 (Wilson Co.) (M)	11
I-40 mm 245 (Wilson Co.) (M)	3
I-40 mm 397 (Knox Co.) (E)	10
I-40 mm 434 (Cocke Co.) (E)	1
I-81 mm 9 (Hamblen Co.) (E)	10
I-81 mm 19 (Greene Co.) (E)	4
I-81 mm 25 (Greene Co.) (E)	7
I-75 mm 122 (Anderson Co.) (E)	1

[a] M = middle Tennessee; E = eastern Tennessee

Table 7. Infestation of Dicymolomia julianalis (Walker) on musk thistle in Tennessee, July 30 and August 3, 1990.

Location[a]	No. of Seed Heads Collected	No. of Adult Emergences	% of Infested Seed Heads	Date of First Emergence	Date of Last Emergence	Avg. Date of Emergence[b]
			July 30, 1990			
I-40 mm 221 (M)	107	6	5.6	8/8/90	9/10/90	8/17/90 (12.27)[c]
I-40 mm 245 (M)	51	11	21.6	8/15/90	9/27/90	8/30/90 (10.97)
I-40 mm 259 (M)	57	8	14.0	8/14/90	9/14/90	8/30/90 (11.43)
I-40 mm 269 (M)	99	1	1.0	8/17/90	—	8/17/90 —
I-24 mm 71 (M)	57	11	19.3	7/31/90	9/6/90	8/24/90 (11.53)
I-65 mm 53 (M)	149	2	1.3	8/9/90	9/6/90	8/23/90 (19.80)
			August 3, 1990			
I-40 mm 397 (E)	7	2	28.6	9/2/90	9/7/90	9/5/90 (3.54)
I-40 mm 434 (E)	71	9	12.7	8/10/90	9/7/90	8/25/90 (12.41)
I-81 mm 9 (E)	119	23	19.2	8/10/90	9/11/90	8/22/90 (9.09)
I-81 mm 19 (E)	154	34	22.1	8/8/90	9/15/90	8/26/90 (10.63)
I-81 mm 25 (E)	155	38	24.5	8/9/90	9/27/90	8/25/90 (11.98)

[a] M = middle Tennessee; E = eastern Tennessee

[b] To the nearest day

[c] ± S.D. in days

Table 8. Infestation of Dicymolomia julianalis (Walker) on musk thistle in Tennessee, August 7, August 9, and August 15, 1990.

Location[a]	No. of Seed Heads Collected	No. of Adult Emergences	% of Infested Seed Heads	Date of First Emergence	Date of Last Emergence	Avg. Date of Emergence[b]
			August 7, 1990			
I-40 mm 434 (E)	59	9	15.3	8/21/90	9/6/90	8/25/90 (5.61)[c]
I-81 mm 9 (E)	154	7	4.6	8/13/90	9/7/90	8/24/90 (9.64)
I-81 mm 19 (E)	183	15	8.2	8/10/90	9/15/90	8/22/90 (10.18)
I-81 mm 25 (E)	194	60	30.9	8/10/90	9/21/90	8/24/90 (9.90)
			August 9, 1990			
I-75 mm 56 (E)	112	11	9.8	8/22/90	9/11/90	8/28/90 (6.23)
McMinn Co. (E) Rd. 316	118	25	21.2	8/19/90	9/10/90	8/28/90 (5.87)
			August 15, 1990			
I-81 mm 9 (E)	33	8	24.2	8/19/90	9/9/90	8/25/90 (12.88)
I-81 mm 19 (E)	71	21	29.6	8/19/90	9/14/90	8/31/90 (9.23)
I-81 mm 25 (E)	110	22	20.0	8/20/90	9/14/90	8/31/90 (7.96)

[a] E = eastern Tennessee

[b] To the nearest day

[c] ± S.D. in days

Table 9. Infestation of Dicymolomia julianalis (Walker) on musk thistle in Tennessee, August 22 and August 27, 1990.

Location[a]	No. of Seed Heads Collected	No. of Adult Emergences	% of Infested Seed Heads	Date of First Emergence	Date of Last Emergence	Avg. Date of Emergence[b]
			August 22, 1990			
I-81 mm 9 (E)	53	1	1.9	8/29/90	—	8/29/90
I-81 mm 19 (E)	60	9	15.0	8/26/90	9/23/90	9/6/90 (10.24)[c]
I-81 mm 25 (E)	123	12	9.8	8/25/90	9/23/90	9/5/90 (8.73)
			August 27, 1990			
I-40 mm 397 (E)	17	0	0.0	—	—	— —
I-81 mm 9 (E)	71	8	11.3	8/29/90	9/19/90	9/7/90 (8.06)
I-81 mm 19 (E)	84	7	8.3	8/31/90	9/14/90	9/7/90 (5.91)
I-81 mm 25 (E)	102	5	4.9	8/29/90	9/19/90	9/10/90 (9.60)

[a] E = eastern Tennessee

[b] To the nearest day

[c] ± S.D. in days

In late April 1990, densities of froghopper nymphs averaged more than two per plant at two locations (I-81 mm 19 and I-40 mm 397) in eastern Tennessee.

During the bud stage, the four-lined plant bug caused foliar damage to the plant. However, this insect was not frequently found on the plant, limiting the number of plants damaged, usually to less than five per site. Most of the plants damaged by this insect were located in Davidson, McMinn, and Knox Counties. The four-lined plant bug was observed on musk thistle from mid-May until late June.

The larva of the pyralid moth, D. julianalis, was observed to feed on developing seeds within the seed head of musk thistle. Adult moths were reared from field-collected seed heads at 15 sites in middle and eastern Tennessee in 1989 and 1990 (Tables 6, 7, and 8). Larvae of D. julianalis have been reported to feed on a diversity of food types. For example, the larva of D. julianalis has been reported to be predaceous on the eggs of the bagworm moth, Thyridopteryx ephemeraeformis (Haworth) (Lepidoptera: Psychidae) (Gahan 1909, McCreary 1930, Balduf 1937, and Barrows 1974). Dicymolomia julianalis also has been reported to be an endoparasitoid, attacking larvae and pupae of T. ephemeraeformis (Kaufmann 1985). Larvae of D. julianalis have been recorded from milk-vetch, Astragalus canadensis (L.), thistle, Cirsium lecontei (Torrey), cat-tails Typhus sp., cactus stems, Opuntia sp., and senescent cotton bolls (Gossypium sp.) (Munroe 1972).

Fifty-one adult D. julianalis moths emerged from approximately 200 seed heads that were collected at nine sites in middle and eastern Tennessee during the summer of 1989 (Table 6). No moths emerged from seed heads collected at four other sites in 1989: I-24 mm 71, I-75 mm 56, I-40 mm 259, and I-40 mm 269. These seed heads had been selected because they appeared to be infested by D. julianalis. Only one adult moth was found to emerge from each seed head; thus, approximately 25% of collected seed heads were infested.

The infestation level of D. julianalis on seed heads of musk thistle in middle and eastern Tennessee during the summer of 1990 was determined (Tables 7, 8, and 9). Ninety-nine percent of the adult emergences occurred in August and September, with the average date of emergence usually in late August. As the collection dates approached late August, the emergence percentage generally declined. This decline was due to the emergence of the adult moth before the seed head was collected. The infestation level was greater in eastern Tennessee than in middle Tennessee (Tables 7, 8 and 9). The infestation levels at sites in middle Tennessee averaged 10 to 15%, while those in eastern Tennessee averaged 20 to 25%. These differences may be attributed in part to the abundance of bagworms that were adjacent to many of the thistle sites in eastern Tennessee. These bagworms may provide the pyralid with an additional food source (Kaufmann 1985).

Musk thistle is not prevented from spreading into new areas as a result of established plant-feeding insects. Although feeding takes place on the stems or leaves by insects such as grasshoppers, froghoppers, and the four-lined plant bug, these plant areas are usually only very slightly damaged, if at all. The destruction of the inside of the seed head by D. julianalis reduces the total seed production of musk thistle. However, the infestation level of D. julianalis is low and may not prevent the rapid spread of seeds into new areas.

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