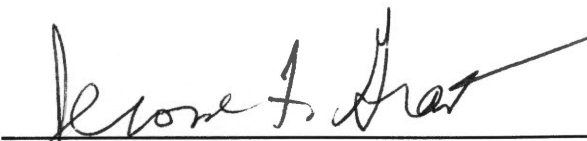
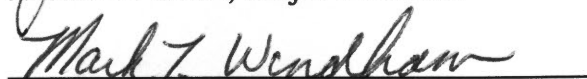


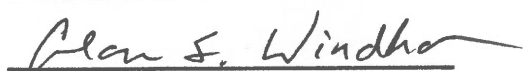
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**DIVERSITY OF ARTHROPODS ON DOGWOODS IN FOREST
AND NURSERY ENVIRONMENTS**

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

David Scott Neitch

May 1995

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ABSTRACT

In the last decade the flowering dogwood, *Cornus florida* Link., has become threatened by a fungal disease, dogwood anthracnose (caused by *Discula destructiva* Redlin). Symptoms include leaf spots, twig blights, and limb/trunk cankers, which lead to the eventual death of the tree. Mortality of the flowering dogwood is extremely high in forested areas, such as the Great Smoky Mountains National Park, where dogwood density has declined in recent years.

Little information is available about environmental conditions that may predispose a tree to conidia of *D. destructiva*, which is believed to be dispersed by wind or rain. Researchers have suggested that insect species also may play an important role in the epidemiology of dogwood anthracnose. Unfortunately, little information is available on the insect communities associated with dogwoods in forest and nursery environments. Because of concern about the possible loss of dogwoods from the forest ecosystem and the lack of information on insects on dogwoods, a two-year research project was initiated to: 1) identify insect taxa associated with anthracnose-infected (diseased) and non-infected (healthy) dogwoods in natural and nursery/ornamental settings, 2) monitor the seasonality of selected insects, 3) compare insect densities on anthracnose-infected and non-infected dogwoods, and 4) compare insect densities among dogwood cultivars.

The most abundant insect orders collected in the Great Smoky Mountains National Park were Coleoptera, Hymenoptera, and Diptera. Significant differences in densities of Coleoptera, Diptera, and Homoptera, as well as the total number of insects and

arthropods, were found among sampling dates, sites, and tree types. Greater numbers of insects were observed in 1993, when Diptera comprised approximately 50% of all taxa.

In 1993, insect densities generally peaked in June; however, peak densities were observed during July in 1994. Seasonal abundance varied among sites. In 1993, insect densities peaked in mid to late June at Cades Cove and Rich Mountain, and in July at Mt. Sterling. In 1994, insect densities were greatest in early June at Rich Mountain and in mid July at Cades Cove, and July at Mt. Sterling. Environmental conditions, such as harsh weather and cooler temperatures, may have contributed to delays in peak densities of insects at Mt. Sterling, the high elevation site. In this study, insect densities were greatest early in the season when incidence of *D. destructiva* occurs at its highest levels.

Percent composition of insect orders was similar for healthy and diseased trees. More insects, numerically, were collected from healthy than diseased trees, but no significant differences were documented between tree types within a year.

The most common insect orders collected at the Plateau Experiment Station, Crossville, TN, were Coleoptera, Homoptera, and Diptera. More insects were collected in 1994 than in 1993, and significant differences among sampling dates and cultivars were detected. In 1993, Homoptera was the most abundant insect order, while in 1994, Coleoptera was the most abundant insect order.

Insect diversity and abundance varied among the three cultivars of dogwood, each with a different foliage coloration (green-Cherokee Princess, purple-Purple Glory, or

yellow-First Lady). Overall insect densities were greatest on First Lady (cultivar Y) than on the Cherokee Princess (cultivar G) or Purple Glory (cultivar P).

In 1993, densities of Coleoptera, Diptera, and Hymenoptera, as well as the total number of insects and arthropods, were significantly greater on cultivar Y than on the other cultivars. Densities of Homoptera were not significantly different among cultivars, although more (ca. 2 to 3x) were collected from cultivar Y than G or P. In 1994, the number of Homoptera were significantly greater on cultivar Y. Insect densities also were greater (ca. 3 to 6x) on this cultivar than on G or P. No other significant differences were detected among cultivars in 1994, although densities of Coleoptera were numerically greater (ca. 4 to 6x) on cultivar Y than on any other cultivar.

Seasonal abundance of insect orders was similar for each cultivar. In 1993, insect densities on each cultivar peaked in late May and again in late July on cultivar Y; on the other hand, densities in 1994 peaked during April and again in August on cultivar Y.

Previous greenhouse, laboratory, and field studies have demonstrated that insects can transport and disseminate viable conidia of *D. destructiva* to healthy dogwood foliage and that the foliage can develop lesions symptomatic of dogwood anthracnose. Because insect densities are greatest when incidence of conidia of *D. destructiva* are present, insects may play an important role in the epidemiology of dogwood anthracnose. This research will provide a better understanding of the insect taxa associated with dogwood and may be useful in the development and implementation of management programs, especially in nursery environments.

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CHAPTER I

LITERATURE REVIEW

The flowering dogwood, *Cornus florida* Link., is a small tree that is native to the eastern one-half of the United States. It is valued as an ornamental because of its white or pink blooms in early spring and its red foliage and berries in the fall (Dirr 1990). These spring floral displays, much anticipated every year, are economically important tourist attractions for many urban and forested areas, such as the Great Smoky Mountains National Park.

Dogwoods also are recognized for their role in the ecosystem (Redlin 1991). The flowering dogwood is an important understory component in forested areas of the eastern United States (Chellemi et al. 1992) and is one of the first woody species to recolonize disturbed forests (Boring et al. 1981). Dogwoods provide cover and edible fruit for 12 species of mammals and 42 species of birds (Smith 1991, Mitchell et al. 1988). The lipid-rich berries are consumed in quantity by wildlife in the fall and early winter (Chellemi and Britton 1992).

Aside from their ecological importance and beautiful appearance as an understory component, dogwoods also are a valuable asset to homeowner's property (Anon. 1991). Due to its popularity, dogwood has become a favorite plant in the landscaping of homes and businesses. Dogwood is one of the most significant nursery-grown plants in Tennessee (Windham et al. 1991), where it contributes substantially to the economy.

Tennessee nurserymen sell more dogwoods than nurserymen from any other state. In 1989, wholesale dogwood sales in Tennessee were estimated at 30 million dollars (K. Tilt, personal communication to M. T. Windham).

Dogwood also has economic and social value as an ornamental tree whose spring blossoms are celebrated in festivals across the southeastern United States (Chellemi et al. 1992). The Knoxville Dogwood Arts Festival is estimated to generate between 10 million and 13 million dollars annually to the economy of Knoxville, Tennessee (B. Neil, personal communication).

Since the late 1970's, a lower twig dieback on dogwood has been recorded in the northeastern United States (Daughtrey and Hibben 1983, Hibben and Daughtrey 1988, Mielke and Daughtrey 1989). Also, a similar disease of the pacific flowering dogwood, *Cornus nutallii* Audubon, was reported in the Pacific northwest (Byther and Davidson 1979). The fungus *Discula* sp. was associated with the disease on *C. nutallii* in Washington State, Oregon, Idaho, and British Columbia (Salogga and Ammirati 1983). Daughtrey et al. (1988) concluded that the same anthracnose disease occurs in both geographical locations. The fungus that caused this disease was later identified as *Discula destructiva* Redlin (Redlin 1991).

Early reports of dogwood anthracnose near ports of entry on both coasts suggested that the pathogen was imported. The entry and pattern of pathogen dispersal of the Dutch elm disease fungus into the United States in the 1930's was similar (Daughtrey et al. 1988). Daughtrey et al. (1988) proposed an alternative hypothesis that dogwood anthracnose was present in the northeastern United States prior to the recent outbreaks,

but at low levels, and infection was triggered by some sequence of abiotic factors. Recently, Trigiano and coworkers (1993) stated that the fungus was not native to the United States.

This fungal disease is characterized by leaf spots, twig blights, and limb/trunk cankers (Hibben and Daughtrey 1988). Other symptoms include necrotic blotches, leaf blights, shoot dieback and death. The most obvious symptom of dogwood anthracnose is a leaf blight, characterized as purple-rimmed lesions with tan necrotic centers on the leaf (Daughtrey et al. 1988). Fruiting bodies of the fungus form in these necrotic areas (Redlin 1991). Conidia exude from the fruiting bodies as slime droplets on dead leaf tissue.(Daughtrey et al. 1986). The tips of inferted shoots become grey-tan, and a purple zone forms between the dead and healthy bark (Daughtrey et al. 1988).

Discula destructiva infections of the main stem were believed to cause cankers on the main stem of the tree (Daughtrey et al. 1988). Venkatasubbaiah and Chilton (1991) reported that *D. destructiva* produced toxins that could be involved in canker formation. If cankers, which occur at the base of blighted twigs and epicormic branches, girdle the tree, death may occur (Daughtrey et al. 1988).

Since its discovery, dogwood anthracnose has caused extensive mortality in both woodland and ornamental dogwoods (Mielke and Daughtrey 1989). This disease is capable of destroying many trees in naturally-forested areas (Mielke and Langdon 1986, Schneeberger and Jackson 1989, and Anderson et al. 1993). Mielke and Langdon (1986) reported 33% mortality of flowering dogwoods in Catoctin Mountain Park, Maryland, in 1984. Researchers reported 79% mortality in the same area in 1988 (Schneeberger

and Jackson 1989). In the southeastern United States, an estimated 2,280,000 hectares of forest were affected by *D. destructiva* by December 1990 (Anderson 1991).

Many commercial nurserymen and homeowners are concerned about the threat of losing such a beneficial and beautiful asset. Populations of dogwoods may decline severely or the species may become extinct (Chellemi and Britton 1992). In the latter case, the dogwood may disappear from our landscape, due to this fungal disease, much the same way as the American elm, *Ulmus americana* L., and chestnut, *Castanea dentata* (Marsh.) Borkh.

Dogwood anthracnose affects flowering dogwood in natural and ornamental settings and is the most damaging disease in much of the tree's natural range (Anderson et al. 1993). Most of the infected trees have been found in "hot spots" in mountainous regions at elevations higher than 305 m above sea level (Windham et al. 1991). Disease incidence was affected by altitude, where dogwood trees encountered about 915 m elevation had 15% greater disease incidence than trees lower than 915 m (Bruck and Grand 1993).

Dogwood anthracnose has been found to extend down the Appalachian Mountain Range into northern Alabama and Georgia (Anderson 1991, Hagan and Mullen 1993). It was first identified in Tennessee in 1988 and has been detected in more than 30 counties (Windham et al. 1991). By 1990, a working group of federal and state employees had documented the disease in 102 counties in 7 states in the southeastern United States (Anderson 1990), where it was found primarily in the mountains, foothills, and upper Piedmont physiogeographic provinces (Anderson 1991). In the Great Smoky

Mountains National Park, disease levels varied significantly across the landscape of three separate areas (Anderson 1991). Studies have indicated that there may be no host genetic barriers to the continued expansion of the geographical range of this disease (Santamour 1989).

Certain environmental factors, such as extremely damp weather, may predispose a tree to conidia of *D. destructiva* (Brown et al. 1991). Previous studies have shown that cool, moist environmental conditions favor the *Discula* spp. that cause anthracnose of ash, oak, and sycamore (Neely and Himeliek 1963). At present, the decline of dogwoods in the northeastern United States is believed to be caused by one or more stress factors, such as cold winter temperatures, excessive spring rains, summer drought and/or trunk injuries, with subsequent infection by canker-causing fungi (Byther and Davidson 1979, Daughtrey and Hibben 1983, Daughtrey and Hibben 1984, Walton 1984, and Daughtrey et al. 1988). Daughtrey et al. (1988) anticipate the continued spread of dogwood anthracnose, with disease severity varying annually depending on weather conditions, especially during the spring.

Little information about the dissemination of this pathogen is available. Researchers have speculated that conidia of *D. destructiva* are often dispersed by wind or rain (Daughtrey et al. 1988). In most cases, especially in ornamental settings, some type of mechanical injury often allows for the introduction of the pathogen (Anon. 1991).

Researchers also have suggested that certain insect species may play a role in the epidemiology of dogwood anthracnose. Insects, which comprise more than one half of all living organisms and exist in almost any habitat, are responsible for the transmission

of more than 200 plant diseases (White 1983, Borror et al. 1989). Dutch elm disease, oak wilt disease, and chestnut blight are prime examples of how fungi can be dispersed by insects (Webber and Gibbs 1989).

Several characteristics are essential for an insect to become an effective "vector" of plant diseases and fungi. Webber and Gibbs (1989) stated that the association among the insect, plant, and pathogen, and the positioning of conidia during transport are key factors which must be considered. Other important factors are host preference, insect habitat, and environmental conditions.

Dogwoods, in urban and forested areas, attracted an abundant and diverse group of insects, which included coleopterans, hymenopterans, and dipterans (Grant 1993). The transportation or dissemination of fungal pathogens is not linked to any specific order of insects. Coleopterans, specifically members of the Scolytidae and Nitidulidae, have proven to be successful in transporting the pathogens of Dutch elm disease and oak wilt disease. Hymenopterans, halictid and andrenid bees, and dipterans (e. g., syrphid flies) are the most common pollinators of dogwood (Eyde 1988). Rogers and Grant (1990) observed that the dogwood borer, *Synanthedon scitula* Harris, a clearwing moth, was associated with the decline of stressed dogwoods in an urban setting.

Studies have indicated that a variety of insects are associated with dogwoods. Researchers also have observed that insects are capable of transporting conidia of *D. destructiva*. Colby (1993) demonstrated that the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville, could transport and disseminate conidia both internally and externally under laboratory conditions. Also, Holt (1995) observed that 7% of insects,

collected from dogwoods in the Great Smoky Mountains National Park, transported viable conidia, and levels of conidia-infested insects were greatest (14%) when disease incidence was at its highest levels.

The possible involvement of insects in the dissemination and transmission of viable *D. destructiva* conidia, along with increased dogwood mortality, prompted this research project. The objectives of this research were to: 1) identify insect taxa associated with anthracnose-infected (diseased) and non-infected (healthy) dogwoods in a natural setting, 2) monitor the seasonality of selected insects, 3) compare insect densities on anthracnose-infected and non-infected dogwoods, and 4) compare insect densities among dogwood cultivars in a nursery/ornamental setting.

CHAPTER II

THE INFLUENCE OF DOGWOOD ANTHRACNOSE ON ARTHROPOD TAXA IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

i. Introduction

In the last decade, the flowering dogwood, *Cornus florida* Link., has become threatened by a fungal disease, dogwood anthracnose, caused by *Discula destructiva* Redlin. Symptoms include leaf spots, twig blights, and limb/trunk cankers, which lead to the eventual death of the tree (Brown et al. 1991). Mortality of the flowering dogwood is extremely high in forested areas, such as the Great Smoky Mountains National Park, where dogwood density has declined in recent years (M.T. Windham, personal communication).

Little information about transmission of this pathogen is available. Environmental factors, such as damp weather, may predispose a tree to conidia of *D. destructiva* which are often dispersed by wind or rain (Hibben and Daughtrey 1988). In most cases, some type of mechanical injury allows for the introduction of the pathogen (Anon. 1991). Researchers have suggested that insect species also may play an important role in the epidemiology of dogwood anthracnose.

Because of the possible loss of dogwoods from the forest ecosystem and the potential impact on the arthropod community, a two-year research project was initiated

to determine insect taxa associated with flowering dogwood in a forest habitat. The specific objectives of this research were to: 1) identify insect taxa associated with anthracnose-infected (diseased) and non-infected (healthy) dogwoods at three sites within the Great Smoky Mountains National Park, 2) monitor the seasonality of selected insects, and 3) compare insect densities on anthracnose-infected and non-infected dogwoods.

ii. Materials and Methods

Arthropod communities were sampled on individual dogwood trees at three sites (Cades Cove, Mt. Sterling, and Rich Mountain) within the boundaries of the Great Smoky Mountains National Park (Fig. 1). Sites for insect collection were selected based on differences in elevation and the presence of anthracnose-infected and non-infected dogwoods. At each site, trees were evaluated for disease incidence and severity using a modified Horsfal-Barratt rating scale (Horsfal and Barratt 1945). Ratings were converted to percent leaf area using Elanco conversion tables (Redman et al. 1969). Based on disease ratings, trees were categorized as healthy or diseased. At each site, six trees (three rated as healthy, three rated as diseased) were selected and tagged. Levels of disease incidence and elevation varied among sites (Table 1). Disease incidence at Mt. Sterling, the high elevation site, was greatest when compared to the other two sites. Disease-free dogwoods were not available at this site, where trees classified as healthy averaged ca. 47% infected foliage/tree (Table 1). Dogwoods with this level of infection

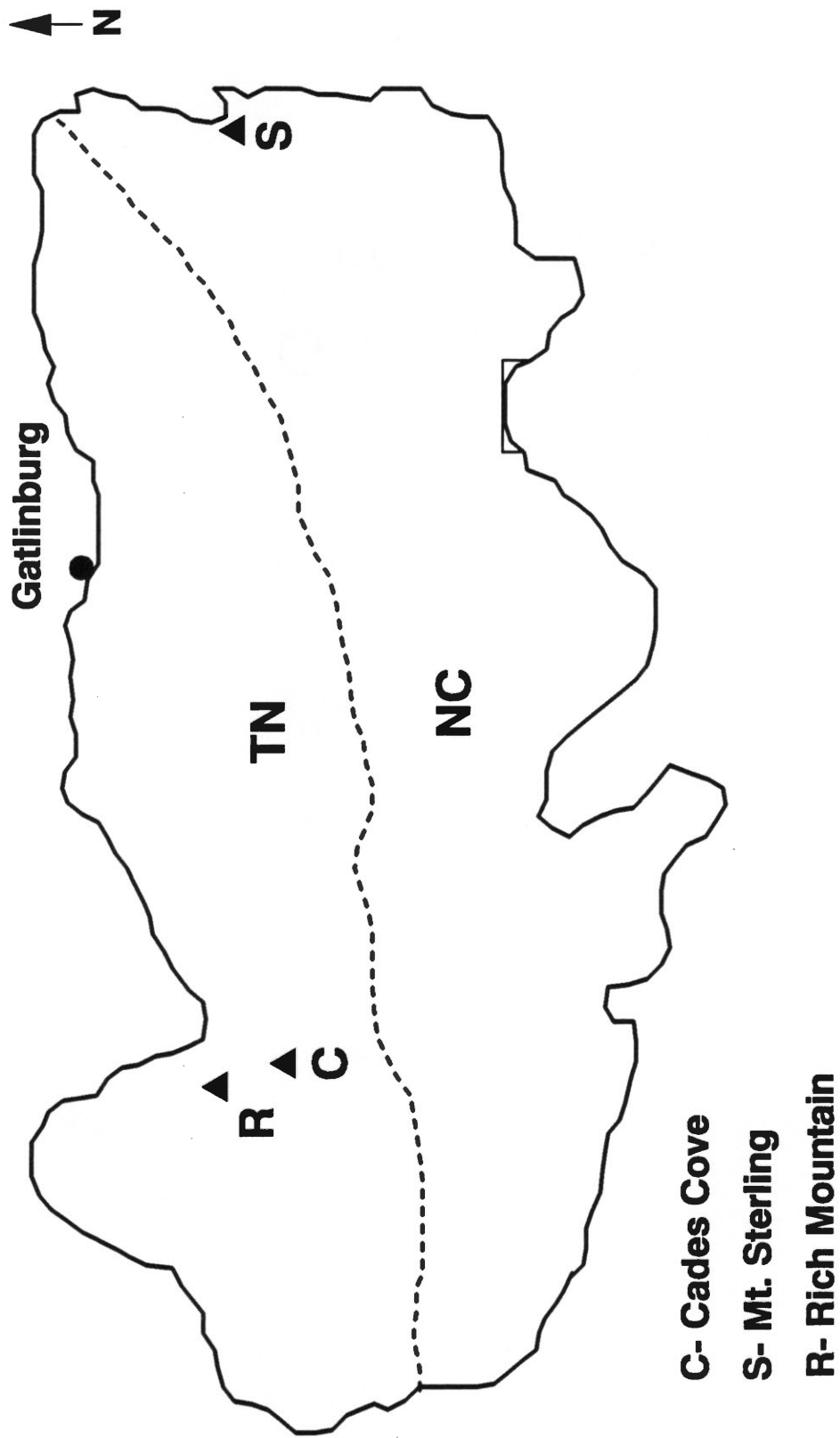


Fig. 1. Approximate locations of sites within the Great Smoky Mountains National Park.

Table 1. Characteristics of each sampling site within the Great Smoky Mountains National Park.

SITE	ELEVATION (m)	DISEASE COMPARISON (Range)
Cades Cove	603	3.9% - 36.0% ^a
Rich Mountain	835	5.5% - 31.3%
Mt. Sterling	1,219	46.7% - 88.3%

^a Number represents average percent infected foliage/tree in trees rated as healthy or diseased at each site.

would have been categorized as diseased at the other two sites where dogwoods with little or no disease were available.

During 1993 and 1994, insects were collected bimonthly from April/May to October from individual dogwoods at each site (Table 2). On each sampling date, plastic tarps (3.6 m x 4.6 m) were placed underneath tree canopies. Insects were sampled from the foliage by insecticidal spraying, usually between 10:00am and 2:00pm (EST). A selected insecticide, Pyrenone® (a pyrethrin [botanical]), was applied until the leaves were saturated, in a ratio of 10 ml/3.8 liter of water, to the canopy of the dogwood using a 11.36 liter, Solo®backpack sprayer. Also, extension hoses and ladders were utilized to ensure complete coverage of the canopy by the insecticide.

After waiting for a safe reentry period of 2-4 hours, the fallen insects were removed from the tarps into individual plastic containers using a modified, battery operated Dustbuster®. Containers were labeled with the date, site, and tree number and placed into similarly labeled Ziploc® freezer bags (1.10 liter). Samples were then placed in an Igloo® ice chest, transported to the laboratory, and placed in a freezer (0°C) until further processing and identification could be completed.

Prior to processing of samples, the containers were removed from the freezer, and samples were allowed to thaw at approximately 20°C for 1-2 hours. The contents of each sample were then placed onto paper towels, and the insects were separated from debris and leaf litter using forceps and a Luxo®, 22 volt, magnifier. Insects were first gross separated by order and placed into appropriately labeled petri dishes. Gross insect counts, date, site, tree number, and insect orders were recorded. These numbers were

Table 2. Sampling dates for each site within the Great Smoky Mountains National Park during 1993 and 1994.

YEAR	SITE	SAMPLING DATE
1993	Cades Cove	24 May, 8 June, 22 June, 7 July, 20 July, 4 August, 18 August, 30 August, 13 September, 11 October
	Mt. Sterling	26 May, 9 June, 23 June, 12 July, 21 July, 9 August, 17 August, 3 September, 23 September, 13 October
	Rich Mountain	24 May, 8 June, 22 June, 7 July, 20 July, 4 August, 18 August, 30 August, 13 September, 11 October
1994	Cades Cove	12 April, 26 April, 16 May, 13 June, 5 July 2 August, 22 August, 9 September, 11 October
	Mt. Sterling	14 April, 2 May, 17 May, 9 June, 1 July, 2 August 19 August, 13 September, 12 October
	Rich Mountain	12 April, 26 April, 16 May, 13 June, 5 July, 2 August, 22 August, 9 September, 11 October

then entered into a data file. Data were subjected to an analysis of variance procedure (PROC GLM) to evaluate influences of date, site, and tree type on insect taxa collected from dogwoods (SAS Institute 1989). When significant ($p=0.1$) differences were observed, Duncan's multiple range test was used to determine significant differences among the means.

Insects were later identified to family and placed into a voucher collection. Insect family, species name, if known, and the total number of each taxa present in a sample also were recorded. From these data, seasonal incidences of selected taxa were determined. Voucher specimens of each taxa will be incorporated into two collections, located at the Great Smoky Mountains National Park Museum and The University of Tennessee, Department of Entomology and Plant Pathology Insect Museum.

iii. Results and Discussion

General Overview

During 1993 and 1994, approximately 11,000 insects were collected in the Great Smoky Mountains National Park. The three most common orders collected were Coleoptera, Diptera, and Hymenoptera (Fig. 2). These three orders are among the largest orders and contain about 67% of the insect species found in the world and 45% of the insect families found in North America, north of Mexico (Borror et al. 1989). These three orders comprised approximately 70% of the insects collected from dogwoods in the Great Smoky Mountains National Park in 1993 and 1994 (Fig. 2). About 2.5 times as many insects were collected in 1993 than in 1994. Several factors may account

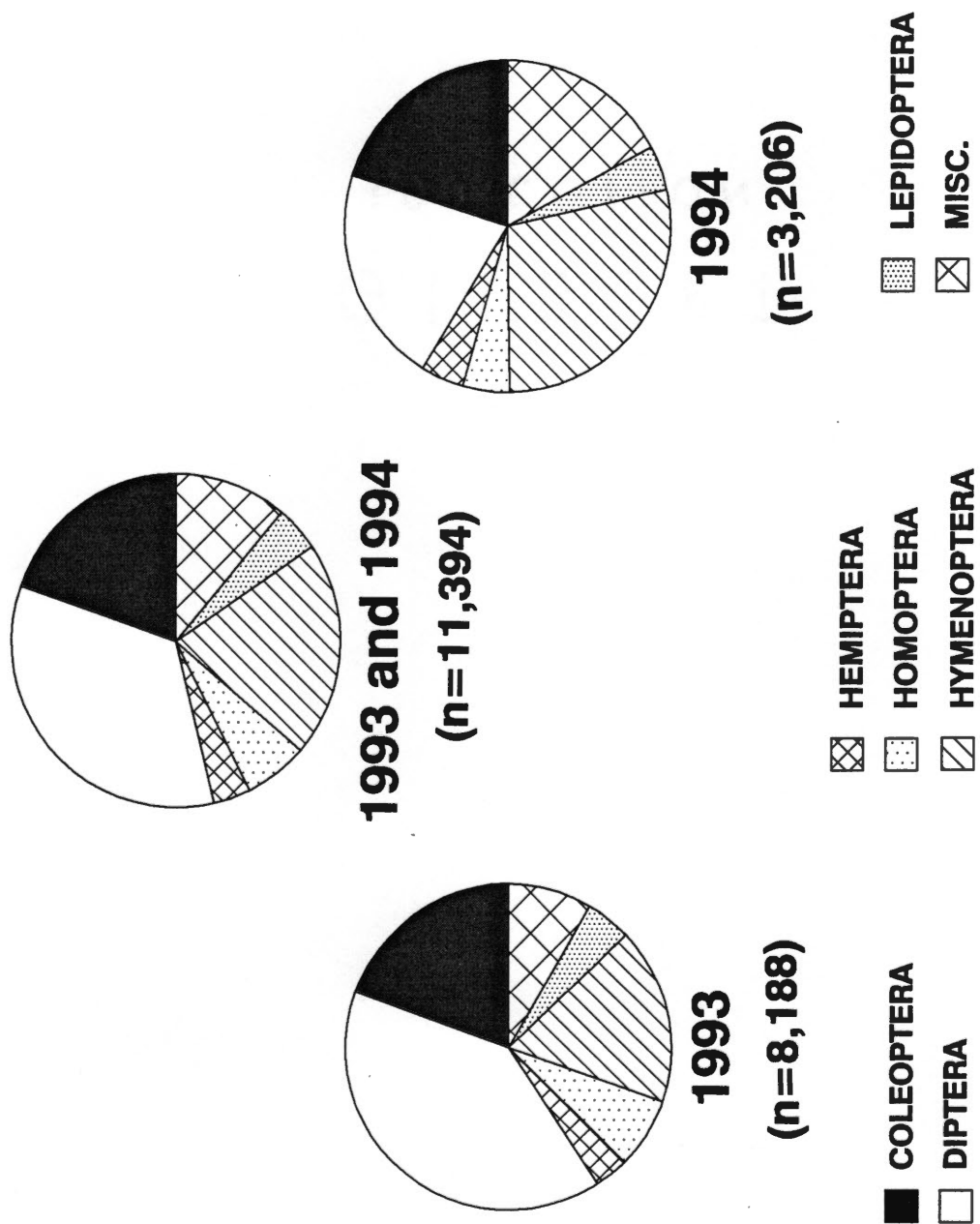


Fig. 2. Percent composition of insects collected from sites within the Great Smoky Mountains National Park during 1993 and 1994.

for these differences in numbers. In 1994, there was one less sampling date and sampling began earlier in the season. Also, weather conditions on specific sampling dates may have affected the number of insects collected throughout the season. During this study, significant differences in densities of Coleoptera, Diptera, Homoptera, and Hymenoptera, as well as among the total number of insects and the total number of arthropods, were found among sampling date, site or tree type.

Differences between Years and Dates

In 1993, dipterans comprised approximately 40% of all insects collected (Fig. 2). Hymenopterans and coleopterans were similar, each accounting for about 20% of all insects. The remaining orders comprised about 20% of all insects.

In 1994, the insect compositions differed from those in 1993. The percentage of dipterans decreased by 50%, while those of hymenopterans and miscellaneous orders more than doubled and coleopterans remained approximately the same (Fig. 2). Excessive spring rains and flooding early in the year may have affected changes in insect composition. Heavy rains and flooding at sites, such as Cades Cove and Rich Mountain, may be responsible for the destruction of breeding sites of certain insects. Also, summer droughts, which followed the spring flooding, could have destroyed preferred breeding sites of some insects, especially members of the order Diptera. On the other hand, these same conditions may have facilitated the increase in numbers of other orders, such as the miscellaneous orders. Miscellaneous orders contain insects that are not among the most abundant orders represented in this study (e.g., mecopterans, neuropterans, orthopterans, and psocopterans).

In 1993, densities of all taxa groups were significantly different among dates (Table 3). This finding was not unexpected because of the variability in seasonality of insects. On the third sampling date, densities of dipterans and all insects combined were significantly greater than on any other sampling date (Table 4). Peak densities of Coleoptera were found on date 4 and hymenopterans on dates 2 and 3 (Fig. 3). From these data, peak numbers of Coleoptera, Diptera, Hymenoptera, and the total number of insects were observed when levels of disease incidence of dogwood anthracnose have been reported to occur at their greatest levels (M. T. Windham, personal communication).

Data in 1994 were similar to those in 1993. Densities of Coleoptera, Diptera, Homoptera, and Hymenoptera, as well as the total number of insects and the total number of arthropods, were significantly different among sampling dates (Tables 5 and 6). Peak numbers of all insects combined were observed on date 5 (Fig. 3), approximately 3 to 4 weeks later than peak emergence in 1993. Many factors, such as harsh environmental conditions, may have been responsible for this delay in peak numbers found during 1994.

Differences among Sites

During 1993 and 1994, percent compositions of insects were similar among the three sites (Fig. 4). Coleopterans and dipterans made up a higher percentage (55%) of the insects collected at Mt. Sterling as compared to Cades Cove (35%) and Rich Mountain (35%). Many dipterans and some coleopterans thrive in cool moist areas,

Table 3. ANOVA table illustrating significance among effects in model during 1993 (Great Smoky Mountains National Park).

EFFECTS	DF	COLEOPTERA	HOMOPTERA	HYMENOPTERA	DIPTERA	TOTAL NO. INSECTS	TOTAL NO. ARTHROPODS
MODEL	27	**	*	*	*	*	*
DATE NO.	9	*	*	*	*	*	*
SITE	2	*	NS ^b	*	NS	NS	NS
TREE TYPE	1	NS	NS	*(NS) ^c	NS	*(NS)	*(NS)
REP	2	NS	NS	NS	NS	NS	NS
TREE TYPE * SITE	2	NS	NS	*	NS	*	*
TREE TYPE * REP	2	NS	NS	*	NS	NS	NS
TREE TYPE * DATE NO.	9	NS	NS	NS	NS	NS	*

*Significantly different ($p \leq 0.1$), PROC GLM.

^bNot significantly different ($p > 0.1$), PROC GLM.

^cSignificance levels indicated in parentheses are based on analysis of main effects with significant interaction terms.

Table 4. The influence of sampling date on the mean number of insects collected from dogwoods during 1993 (Great Smoky Mountains National Park).

ARTHROPOD TAXA	Sampling Date ^a									
	1	2	3	4	5	6	7	8	9	10
Coleoptera	15.71ab ^b (12.95) ^c	13.50abc (8.83)	11.33bcd (8.28)	20.78a (39.61)	8.47bcde (7.96)	9.67bcde (8.50)	4.89cde (4.35)	3.17de (3.03)	0.94e (1.03)	1.11e (1.88)
Homoptera	9.77a (10.65)	6.06b (4.68)	4.11bc (4.03)	1.28c (1.18)	2.00c (1.58)	1.78c (1.99)	0.89c (1.45)	3.12bc (6.78)	2.71c (6.80)	1.50c (1.58)
Hymenoptera	10.41ab (8.19)	12.72a (9.45)	12.11ab (6.85)	5.67cde (5.39)	8.77bc (6.53)	11.44ab (7.60)	8.33bc (6.93)	6.53cd (5.84)	2.29e (2.14)	3.44de (3.17)
Diptera	23.47b (17.62)	22.17bc (20.38)	72.72a (74.15)	18.67bcd (23.03)	33.71b (40.40)	3.44d (4.26)	4.61cd (3.97)	1.88d (1.65)	0.94d (0.90)	3.06d (2.36)
Total Number Insects	74.00b (48.17)	69.11b (40.98)	108.06a (82.48)	53.33bc (65.91)	61.76b (48.51)	33.67cd (21.96)	24.50d (6.10)	18.71d (12.71)	8.65d (8.89)	12.17d (7.96)
Total Number Arthropods	77.59b (49.09)	74.22b (43.11)	111.94a (83.18)	56.11bc (65.90)	65.12b (49.10)	37.78cd (22.28)	28.94d (19.96)	21.59d (14.11)	10.35d (9.40)	15.44d (10.25)

^aRefers to date(s) that insects were collected from dogwoods during 1993 (Great Smoky Mountains National Park); See Table 2.

^bMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

^cRefers to standard deviation of mean.

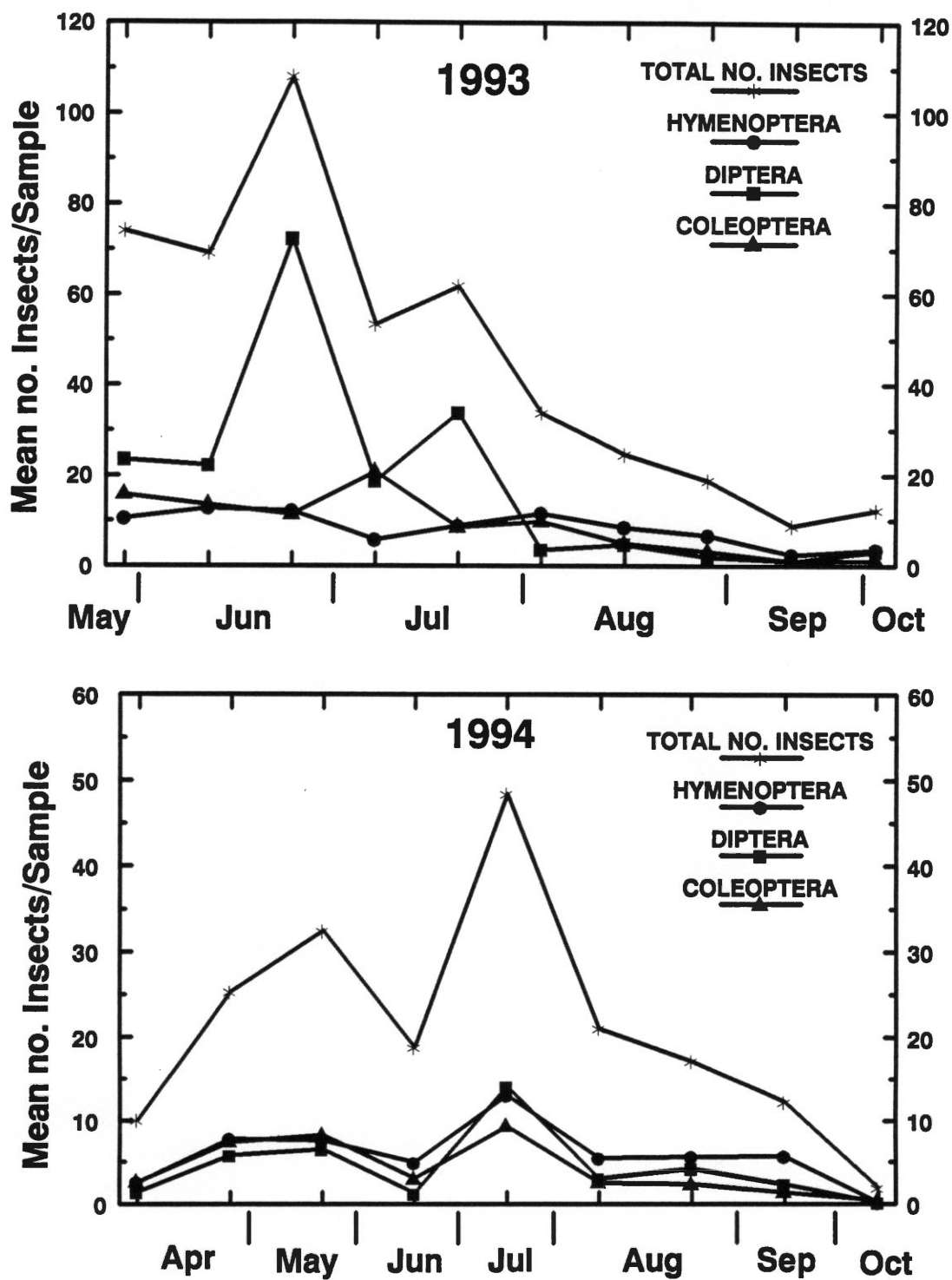


Fig. 3. Mean number of insects per sampling date for selected orders and the total number of insects collected during 1993 and 1994 (Great Smoky Mountains National Park).

Table 5. ANOVA table illustrating significance among effects in model during 1994 (Great Smoky Mountains National Park).

EFFECTS	DF	COLEOPTERA	HOMOPTERA	HYMENOPTERA	DIPTERA	TOTAL NO. INSECTS	TOTAL NO. ARTHROPODS
MODEL	25	**	*	*	*	*	*
DATE NO.	8	*	*	*	*	*	*
SITE	2	*	NS ^b	*	*	*	*
TREE TYPE	1	NS	NS	NS	NS	NS	NS
REP	2	NS	*	NS	NS	NS	NS
TREE TYPE * SITE	2	NS	NS	NS	NS	NS	NS
TREE TYPE * REP	2	NS	NS	NS	NS	NS	*
TREE TYPE * DATE NO.	8	NS	NS	NS	NS	NS	NS

*Significantly different ($p \leq 0.1$), PROC GLM.

^bNot significantly different ($p > 0.1$), PROC GLM.

Table 6. The influence of sampling date on the mean number of insects collected from dogwoods during 1994 (Great Smoky Mountains National Park).

ARTHROPOD TAXA	Sampling Date ^a								
	1	2	3	4	5	6	7	8	9
Coleoptera	2.65b ^b (3.45) ^c	7.44a (6.46)	8.28a (7.87)	3.00b (2.76)	9.35a (10.07)	2.56b (2.64)	2.39b (2.89)	1.39b (1.46)	0.44b (0.78)
Homoptera	0.88bc (1.32)	0.89bc (1.81)	1.89ab (2.17)	2.58a (3.80)	1.24bc (1.75)	0.39c (0.70)	0.50c (0.86)	0.56c (1.25)	0.22c (0.43)
Hymenoptera	2.59cd (2.32)	7.83b (7.52)	7.56b (8.27)	4.92bc (4.76)	13.06a (11.89)	5.50bc (3.88)	5.67bc (5.15)	5.72bc (6.44)	0.17d (0.71)
Diptera	1.41de (1.37)	5.83bc (3.94)	6.56b (6.17)	1.25de (1.91)	14.12a (12.17)	3.06cde (3.12)	4.28bcd (3.23)	2.33de (3.03)	0.17e (0.52)
Total Number Insects	10.06de (8.11)	25.33bc (15.22)	32.44b (24.08)	18.83cd (22.97)	48.47a (45.82)	21.11bcd (13.60)	17.22cd (11.68)	12.22cde (11.30)	1.94e (2.51)
Total Number Arthropods	11.06de (8.42)	27.38bc (15.07)	34.00b (24.85)	20.08cd (24.07)	52.29a (49.65)	23.56bcd (14.46)	19.06cd (12.50)	13.61cde (12.58)	2.72e (3.43)

^aRefers to date(s) that insects were collected from dogwoods during 1994 (Great Smoky Mountains National Park); See Table 2.

^bMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

^cRefers to standard deviation of mean.

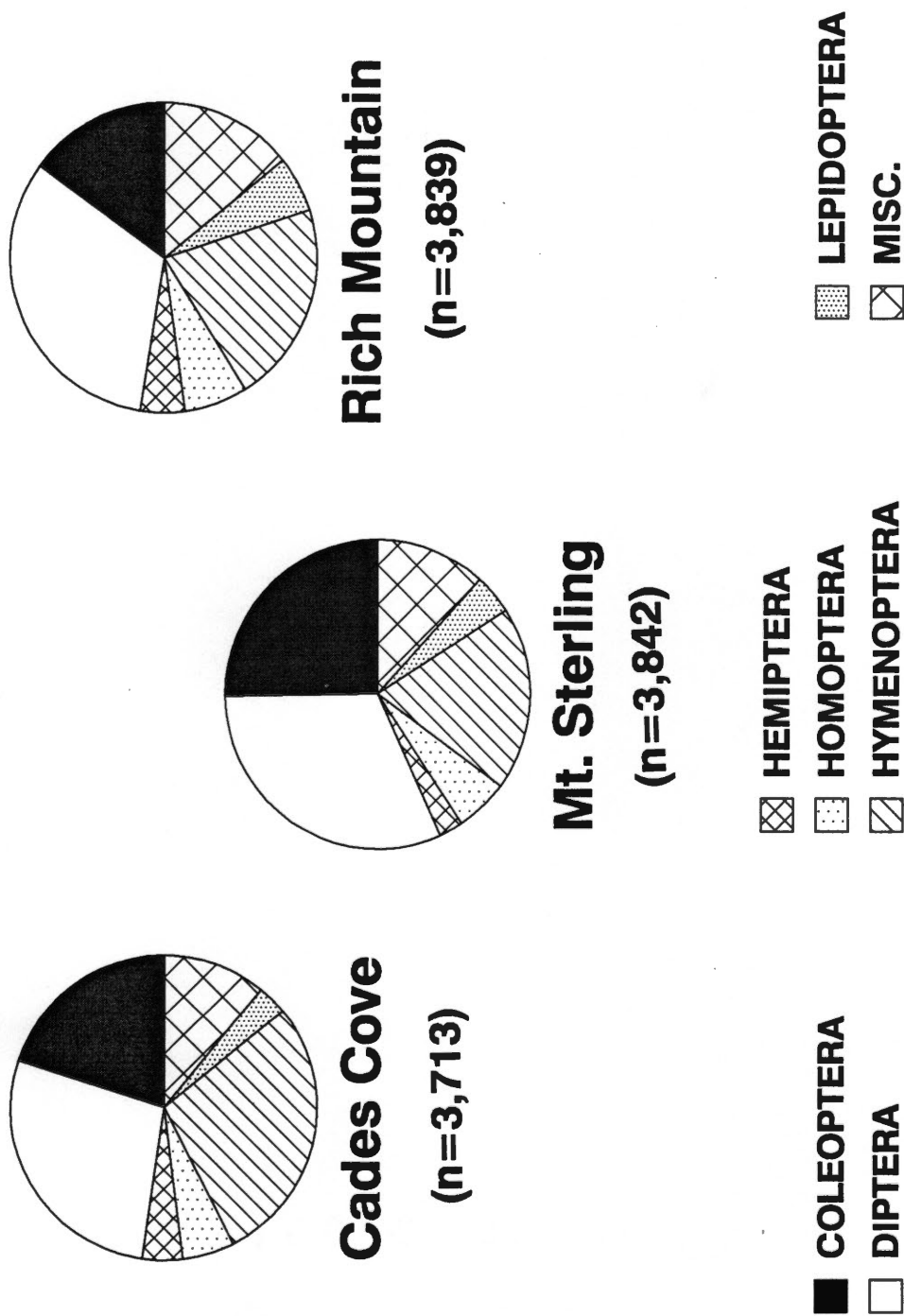


Fig. 4. Percent composition of insects collected at each site during 1993 and 1994 (Great Smoky Mountains National Park).

where fungi and decaying matter are found in abundance (White 1983, Borror et al. 1989). Mt. Sterling, the high elevation site, has the highest levels of disease incidence and temperatures are much cooler due to the high elevation. Hymenopterans comprised a greater percentage of the insects collected at Cades Cove, where members of the family formicidae (ants) were among the most abundant hymenopterans. Ants are a common and widespread group of insects and their feeding habits vary greatly. Many ants feed on plants, fungi, sap, and nectar, while some ants feed on the flesh of other animals (Borror et al. 1989).

In 1993, insect compositions differed among the three sites (Fig. 5). Significantly more coleopterans were found at Mt. Sterling than at Cades Cove or Rich Mountain (Table 7). However, densities of hymenopterans were significantly lower at Mt. Sterling than at Cades Cove. At Mt. Sterling, the cooler temperatures may have negatively affected the abundance of hymenopterans, while positively affecting coleopterans. Significantly greater numbers of dipterans were found at Rich Mountain than at Cades Cove. Site characteristics may have led to this abundance of dipterans at Rich Mountain, where moist vegetative material and standing pools of water were common during 1993. No significant differences in the total number of insects or total number of arthropods were detected among the three sites (Table 7).

Insect densities within a year were similar for both healthy and diseased trees at all sites (Fig. 6 and 7). In 1993, peak densities were found in mid to late June at Cades Cove and Rich Mountain, while densities were greatest in mid to late July at Mt. Sterling

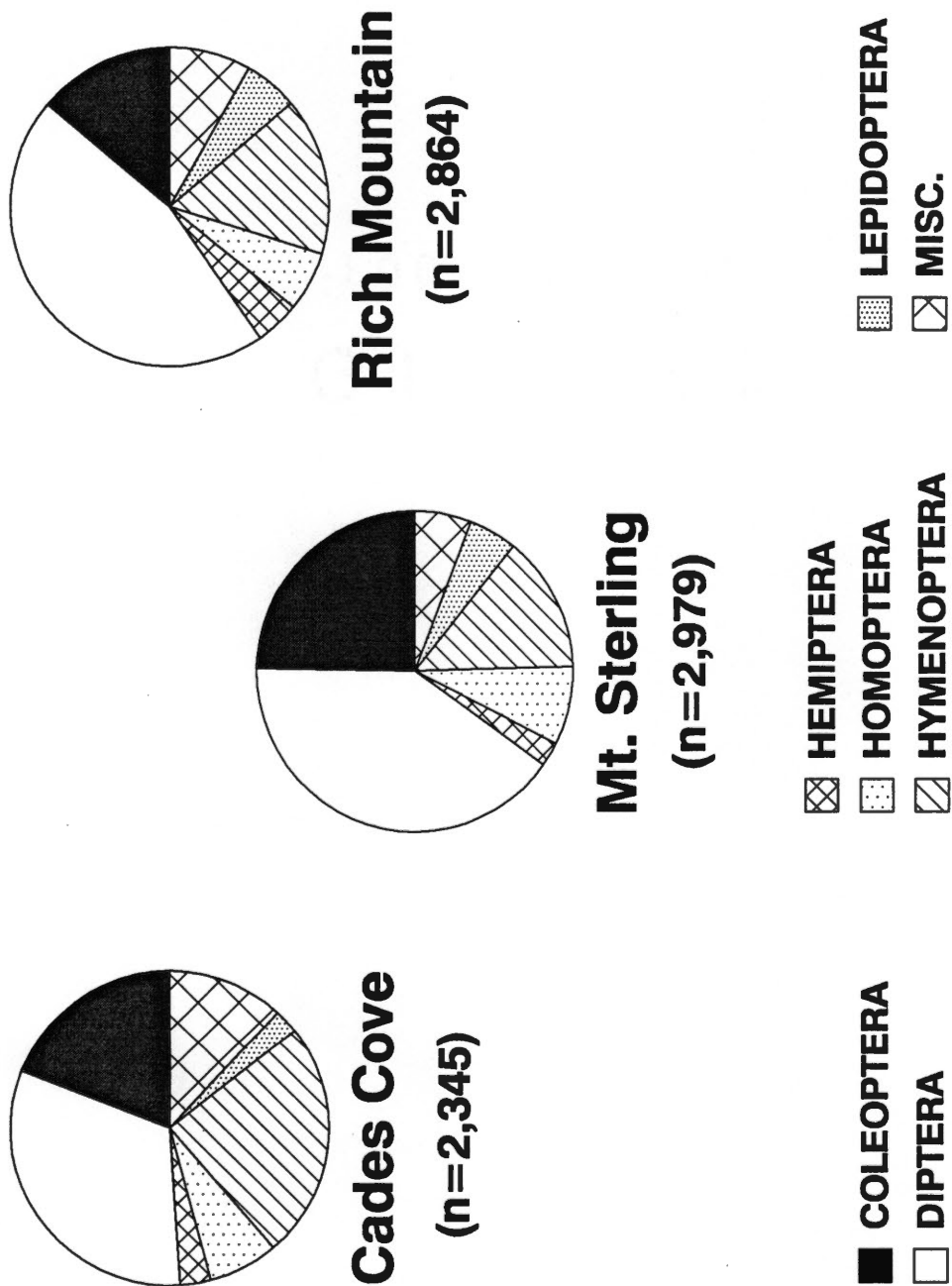


Fig. 5. Percent composition of insects collected at each site during 1993 (Great Smoky Mountains National Park).

Table 7. The influence of site on the mean ($\pm$ SD) number of insects collected from dogwoods during 1993 (Great Smoky Mountains National Park).

ARTHROPOD TAXA	SITE		
	CADES COVE	MT. STERLING	RICH MOUNTAIN
Coleoptera	7.48 $\pm$ 7.68b ^a	12.49 $\pm$ 24.22a	6.98 $\pm$ 7.17b
Homoptera	2.78 $\pm$ 5.69a	4.03 $\pm$ 6.48a	3.07 $\pm$ 4.07a
Hymenoptera	9.53 $\pm$ 7.26a	6.95 $\pm$ 6.68b	8.09 $\pm$ 7.72ab
Diptera	12.45 $\pm$ 18.94b	20.39 $\pm$ 29.28ab	23.05 $\pm$ 51.09a
Total Number Insects	39.08 $\pm$ 36.70a	50.49 $\pm$ 54.20a	50.24 $\pm$ 62.81a
Total Number Arthropods	44.42 $\pm$ 39.14a	53.59 $\pm$ 54.78a	52.32 $\pm$ 63.26a

^aMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

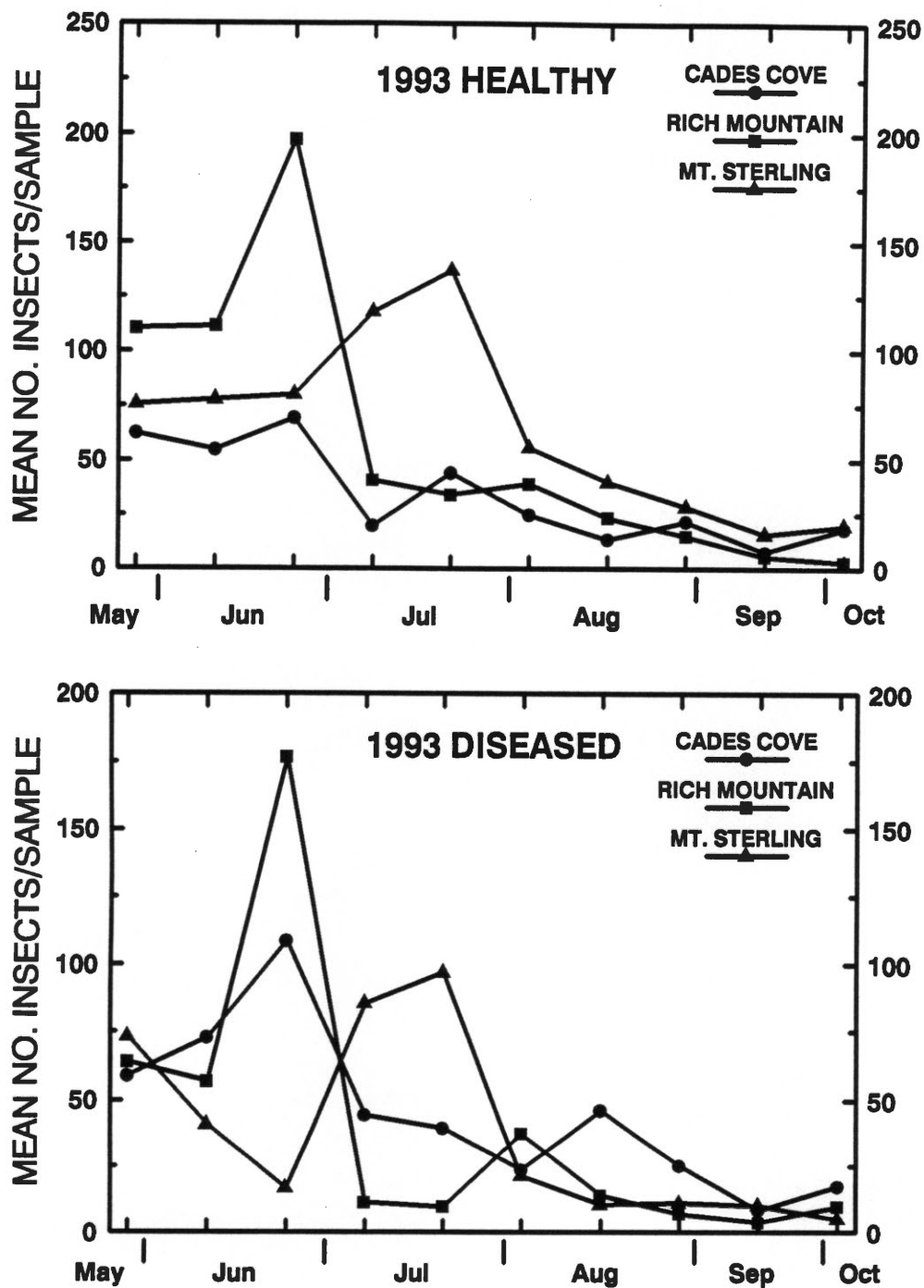


Fig. 6. Mean number of insects collected at each site from healthy and diseased dogwoods on each sampling date during 1993 (Great Smoky Mountains National Park).

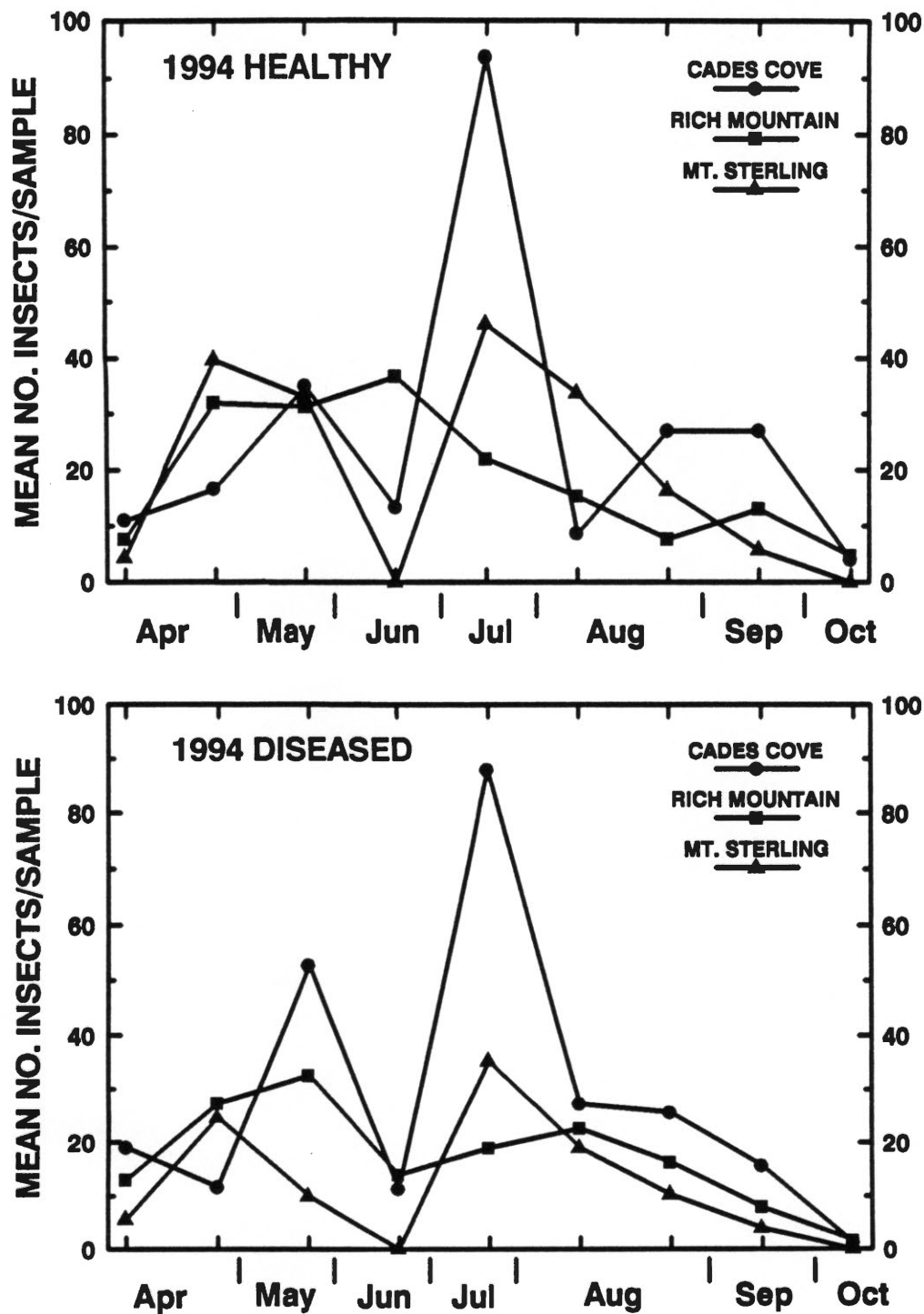


Fig. 7. Mean number of insects collected at each site from healthy and diseased dogwoods on each sampling date during 1994 (Great Smoky Mountains National Park).

(Fig. 6). Seasonal abundances of insects in 1994 were somewhat similar to those in 1993 for healthy and diseased trees among the three sites (Fig. 7). Densities of insects at Cades Cove were greatest in mid July when slightly more were collected on healthy than on diseased trees. Densities at Rich Mountain were greatest in late May to mid June, while those at Mt. Sterling peaked in April and July with more found on healthy trees.

In 1994, percent compositions of insect taxa differed from those in 1993. However, Coleoptera, Diptera, and Hymenoptera still comprised the largest percentages of insects found among the three sites (Fig. 8). Compositions of hymenopterans increased tremendously at each site in 1994 compared to 1993. Significantly more coleopterans were collected at Cades Cove and Mt. Sterling than at Rich Mountain (Table 8). Coleopterans are found in a variety of habitats and feed on plant and animal materials. Beetles may feed upon any part of the plant; preferred feeding sites are the roots, foliage, and blossoms (Borror et al. 1989). Tree characteristics varied among sites. For example, trees at Cades Cove and Mt. Sterling were larger and tended to contain more foliage. These characteristics may partially explain why greater numbers of beetles were found at these sites. Densities of hymenopterans and dipterans were greatest at Cades Cove than at Rich Mountain or Mt. Sterling. Some hymenopterans and dipterans are the most common pollinators of dogwood (Eyde 1988), and dogwoods require the aid of pollinators for maintaining healthy populations (Barrett and Helenurm 1987). Cades Cove, the low elevation site, contains a diverse and an abundant variety of vegetative plant material. This diversity of plant life, at Cades Cove, is capable of

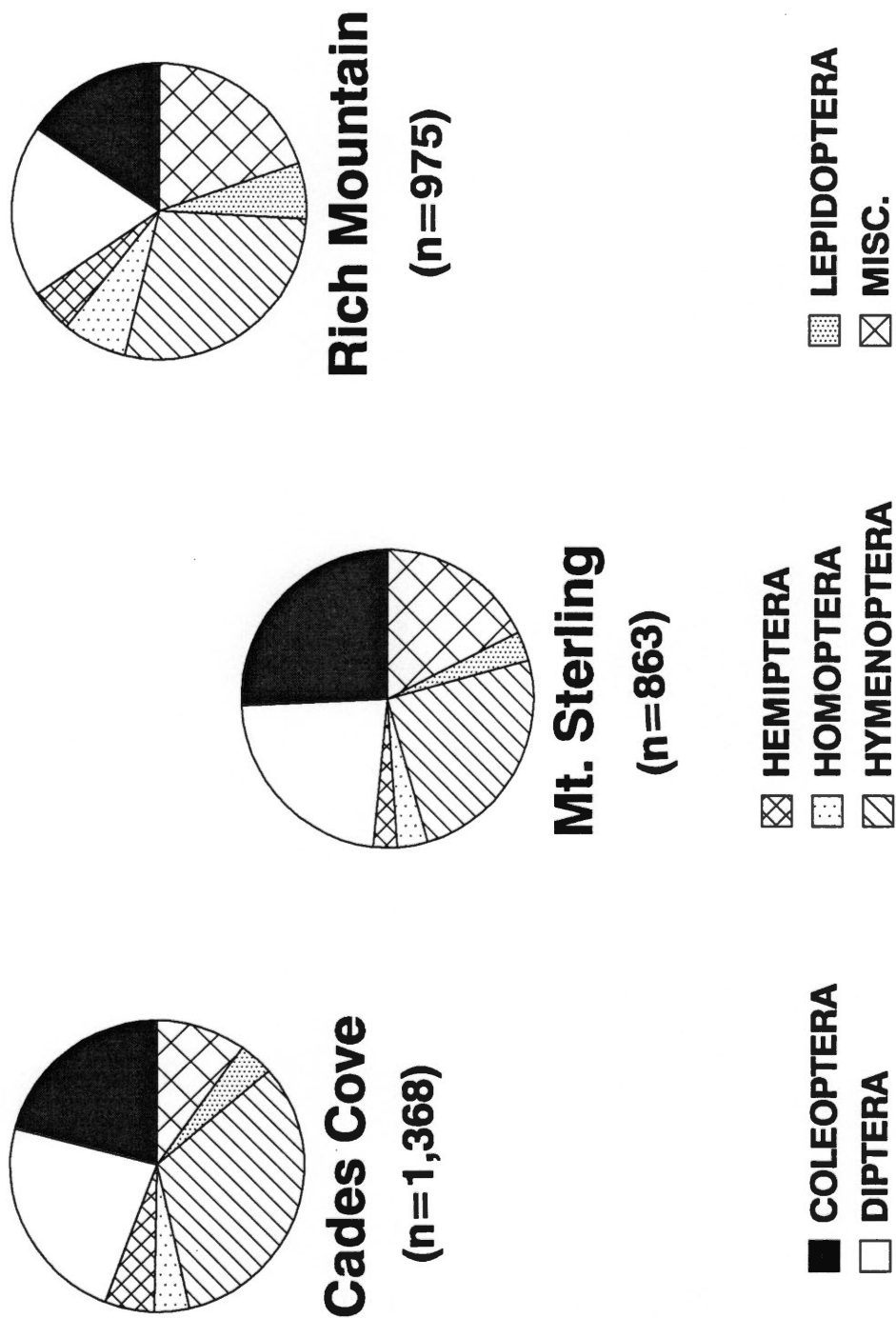


Fig. 8. Percent composition of insects collected at each site during 1994 (Great Smoky Mountains National Park).

Table 8. The influence of site on the mean ($\pm$ SD) number of insects collected from dogwoods during 1994 (Great Smoky Mountains National Park).

ARTHROPOD TAXA	SITE		
	CADES COVE	MT. STERLING	RICH MOUNTAIN
Coleoptera	5.21 $\pm$ 7.73a ^a	4.63 $\pm$ 6.05a	2.82 $\pm$ 3.18b
Homoptera	0.94 $\pm$ 2.08ab	0.60 $\pm$ 1.27b	1.28 $\pm$ 1.87a
Hymenoptera	8.14 $\pm$ 9.87a	4.46 $\pm$ 5.97b	5.04 $\pm$ 4.09b
Diptera	5.77 $\pm$ 8.54a	4.06 $\pm$ 5.91b	3.41 $\pm$ 3.79b
Total Number Insects	26.31 $\pm$ 32.98a	17.98 $\pm$ 19.30b	18.06 $\pm$ 15.30b
Total Number Arthropods	28.75 $\pm$ 35.28a	19.58 $\pm$ 20.37b	19.43 $\pm$ 15.88b

^aMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

supporting an abundant and diverse number of insects, many of which are hymenopterans and dipterans. Significantly greater numbers of insects and arthropods were collected at Cades Cove than at Rich Mountain or Mt. Sterling.

Differences among Tree Types

During 1993 and 1994, percent composition of insects was similar for healthy and diseased trees (Fig. 9). Numerically more insects were found on healthy than diseased trees, but no significant differences were documented between the two tree types for the combined years.

Percent composition of insects within a year was similar for healthy and diseased trees (Fig. 10 and 11). In general, more insects were collected from healthy trees than from diseased trees. Since diseased trees often contain less foliage, they may be less attractive than healthy trees to many insects. With an abundant number of other insects on healthy trees, one would expect to find hymenopterans, which include parasitoids of other insects. No significant differences between healthy and diseased trees were detected among orders in 1993 and 1994 (Tables 9 and 10).

Insect densities within a year, averaged across all sampling dates, were similar for healthy and diseased trees (Fig. 12). Densities of insects peaked in mid to late June in 1993 and in mid July in 1994. During both years, more insects were collected from healthy than diseased trees.

Differences among Tree Types at Each Site

In 1993, percent composition of insects and insect densities within a year were similar for healthy and diseased trees at each of the three sites. Differences in insect

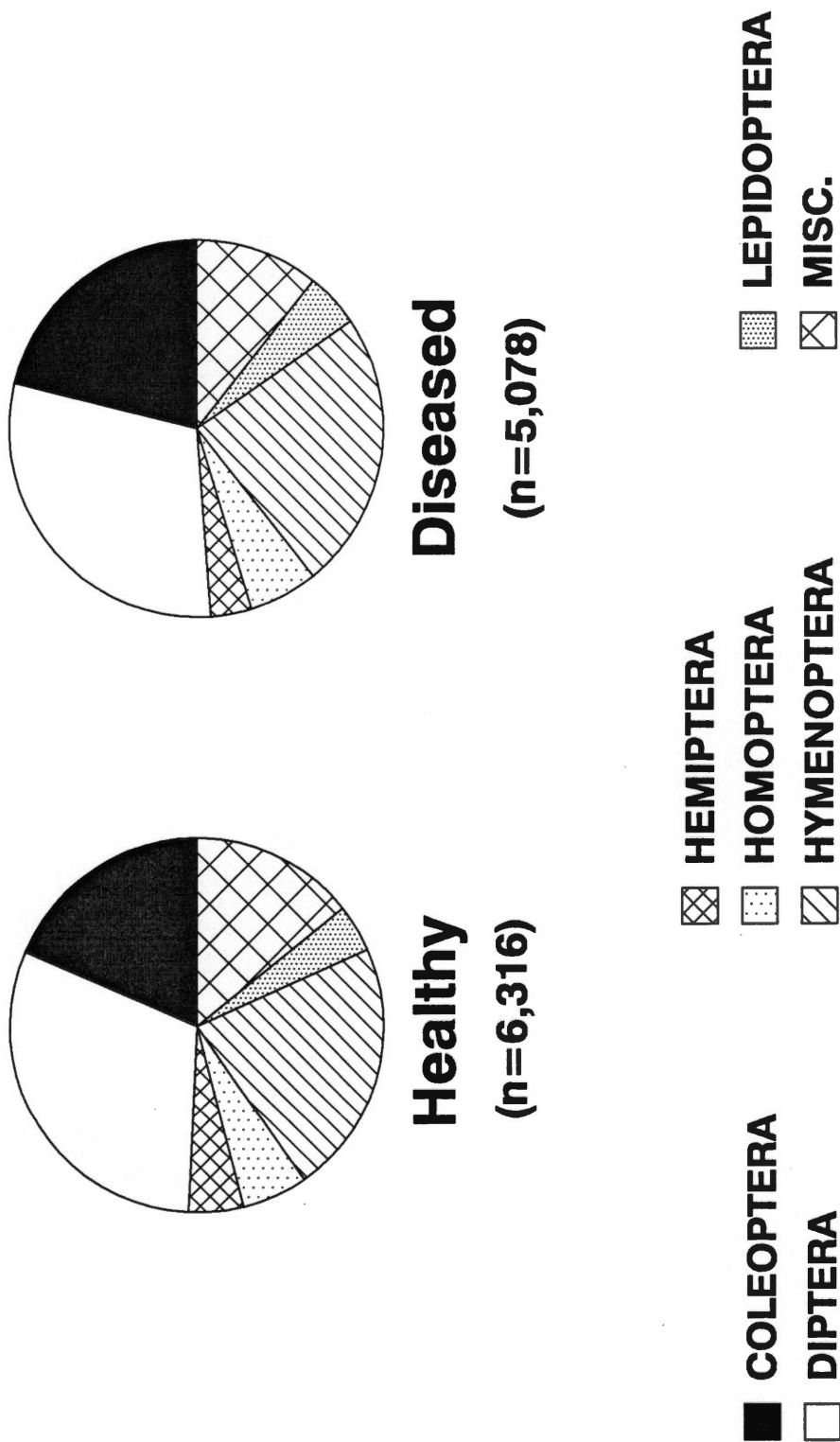


Fig. 9. Percent composition of insects collected at each site from healthy and diseased dogwoods during 1993 and 1994 (Great Smoky Mountains National Park).

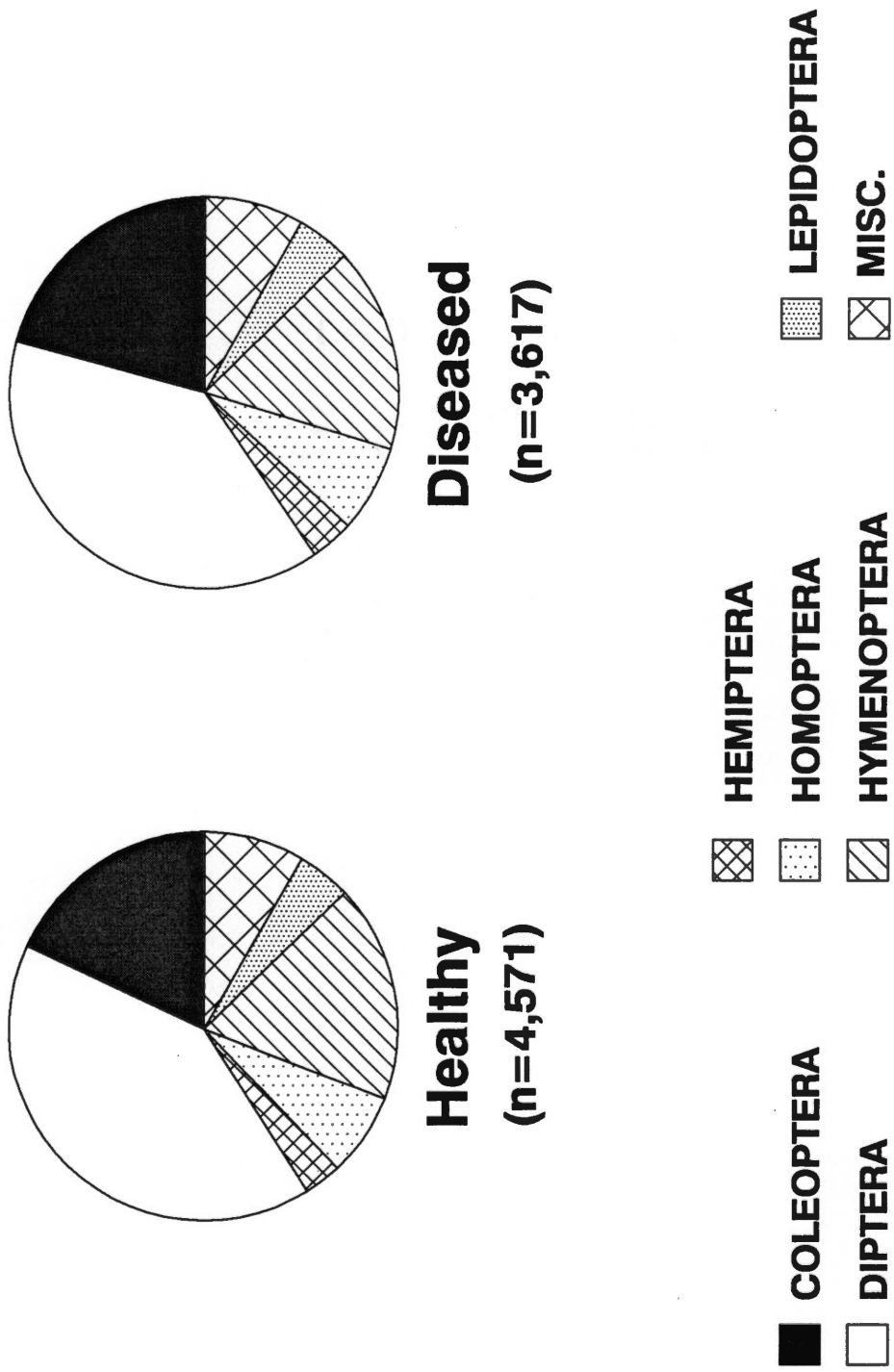


Fig. 10. Percent compositions of insects collected from healthy and diseased dogwoods during 1993 (Great Smoky Mountains National Park).

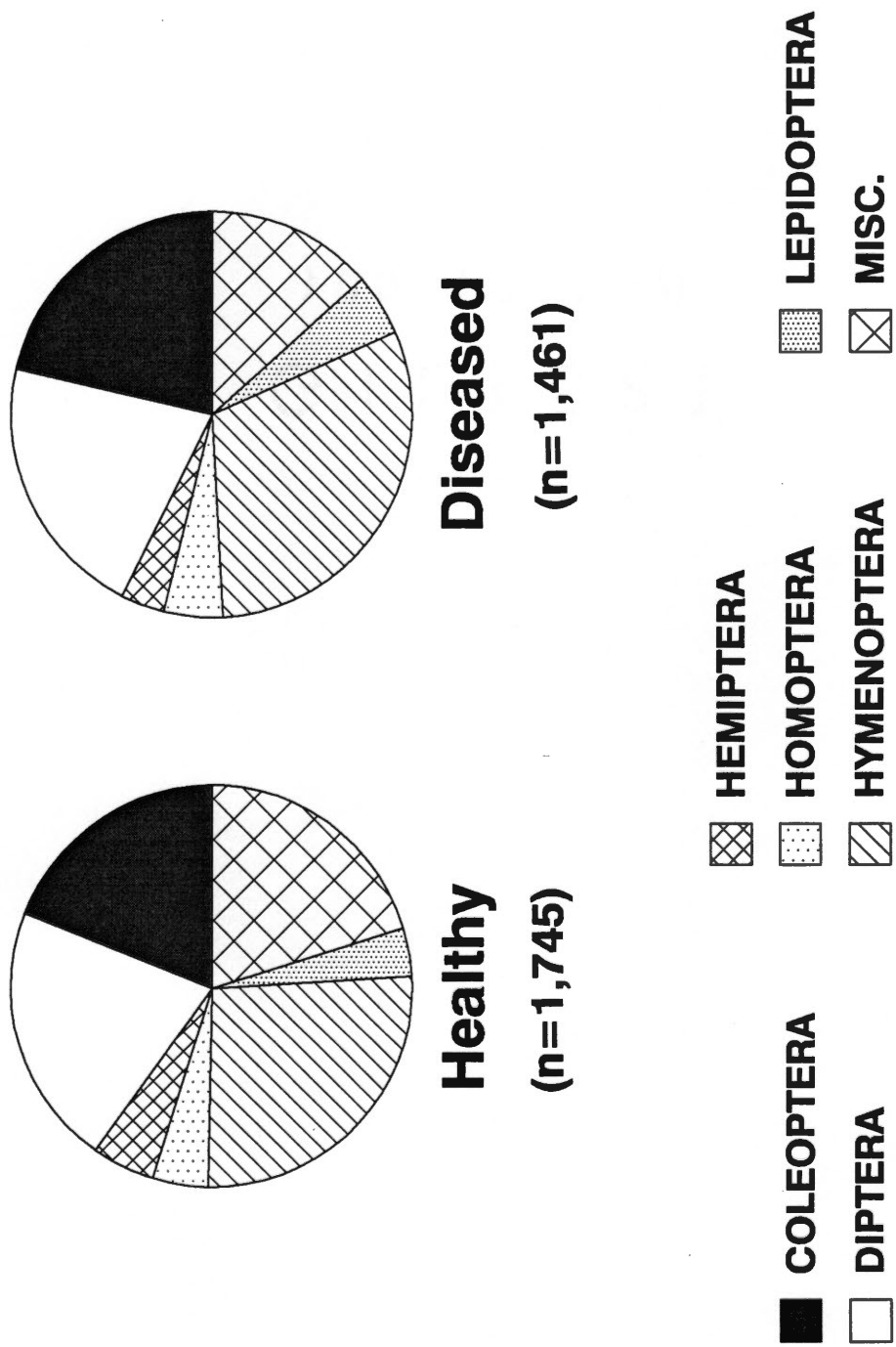


Fig. 11. Percent composition of insects collected from healthy and diseased dogwoods during 1994 (Great Smoky Mountains National Park).

Table 9. The influence of tree type on the mean ($\pm$ SD) number of insects collected from dogwoods during 1993 (Great Smoky Mountains National Park).

ARTHROPOD TAXA	TREE TYPE	
	HEALTHY	DISEASED
Coleoptera	9.55 $\pm$ 16.20 ^a	8.46 $\pm$ 14.63a
Homoptera	3.67 $\pm$ 6.26a	2.93 $\pm$ 4.68a
Hymenoptera	9.52 $\pm$ 8.19a	6.91 $\pm$ 6.00a
Diptera	21.40 $\pm$ 37.83a	15.75 $\pm$ 33.06a
Total Number Insects	52.54 $\pm$ 56.83a	40.64 $\pm$ 46.69a
Total Number Arthropods	56.67 $\pm$ 57.68a	43.58 $\pm$ 47.41a

^aMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

Table 10. The influence of tree type on the mean ($\pm$ SD) number of insects collected from dogwoods during 1994 (Great Smoky Mountains National Park).

ARTHROPOD TAXA	TREE TYPE	
	HEALTHY	DISEASED
Coleoptera	4.31 $\pm$ 6.12 ^a	4.07 $\pm$ 5.88a
Homoptera	1.01 $\pm$ 2.12a	0.90 $\pm$ 1.41a
Hymenoptera	5.96 $\pm$ 7.86a	5.84 $\pm$ 6.52a
Diptera	4.79 $\pm$ 7.44a	4.03 $\pm$ 5.20a
Total Number Insects	22.66 $\pm$ 28.00a	18.97 $\pm$ 19.07a
Total Number Arthropods	24.77 $\pm$ 29.75a	20.48 $\pm$ 20.30a

^aMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

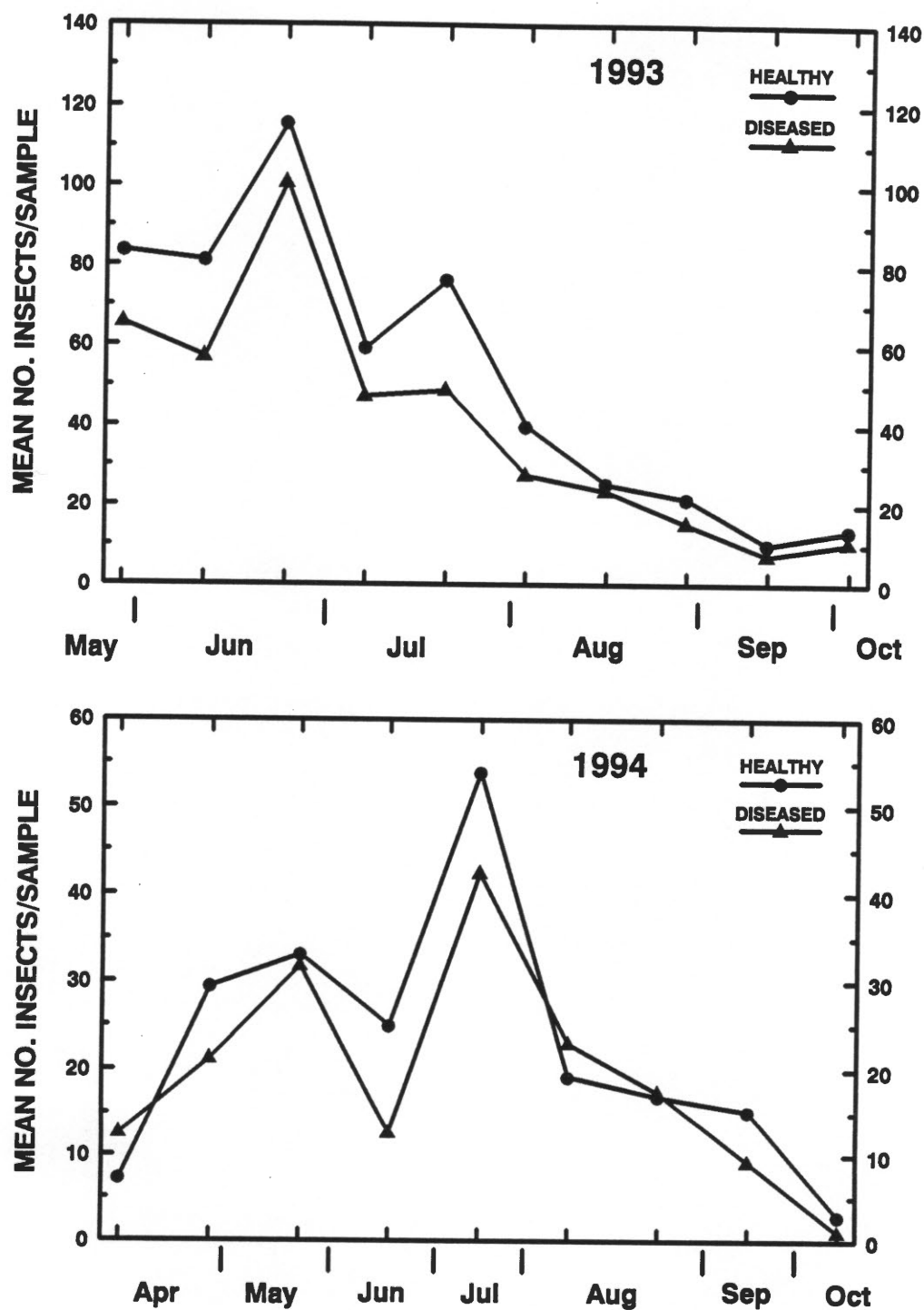


Fig. 12. Mean number of insects collected from healthy and diseased dogwoods on each sampling date during 1993 and 1994 (Great Smoky Mountains National Park).

composition between healthy and diseased trees at a site were documented in 1994. The following information discusses differences in insect taxa among tree types at each site.

Cades Cove

Although no significant differences were observed, more dipterans and fewer homopterans were found on diseased than on healthy trees at Cades Cove in 1993 (Fig. 13). In 1994, greater percentages of dipterans, hemipterans, homopterans, and lepidopterans were found on healthy trees, while the diseased trees contained more coleopterans and hymenopterans (Fig. 14). Percentages of miscellaneous orders remained approximately the same.

Since hymenopterans and dipterans are among the most active fliers of the insects collected, the chance that they would come into contact with viable conidia, while visiting diseased trees, is greatly increased. These types of associations may expand the possible role of insects as active transporters of viable conidia of *D. destructiva*.

In 1993, peak numbers of insects were found in mid to late June (Fig. 15), when incidence of *D. destructiva* occurs at its greatest levels (M. T. Windham, personal communication). Insect abundance on these dates supports earlier theories that insects may play a role in transporting viable conidia. In 1994, peak densities of insects were found in mid July. Environmental conditions, such as cooler temperatures, may account for the delayed peaks in densities.

Rich Mountain

Dipterans comprised approximately 50% of all insects collected at Rich Mountain (Fig. 16). The percentage of lepidopterans was higher on diseased trees than on healthy

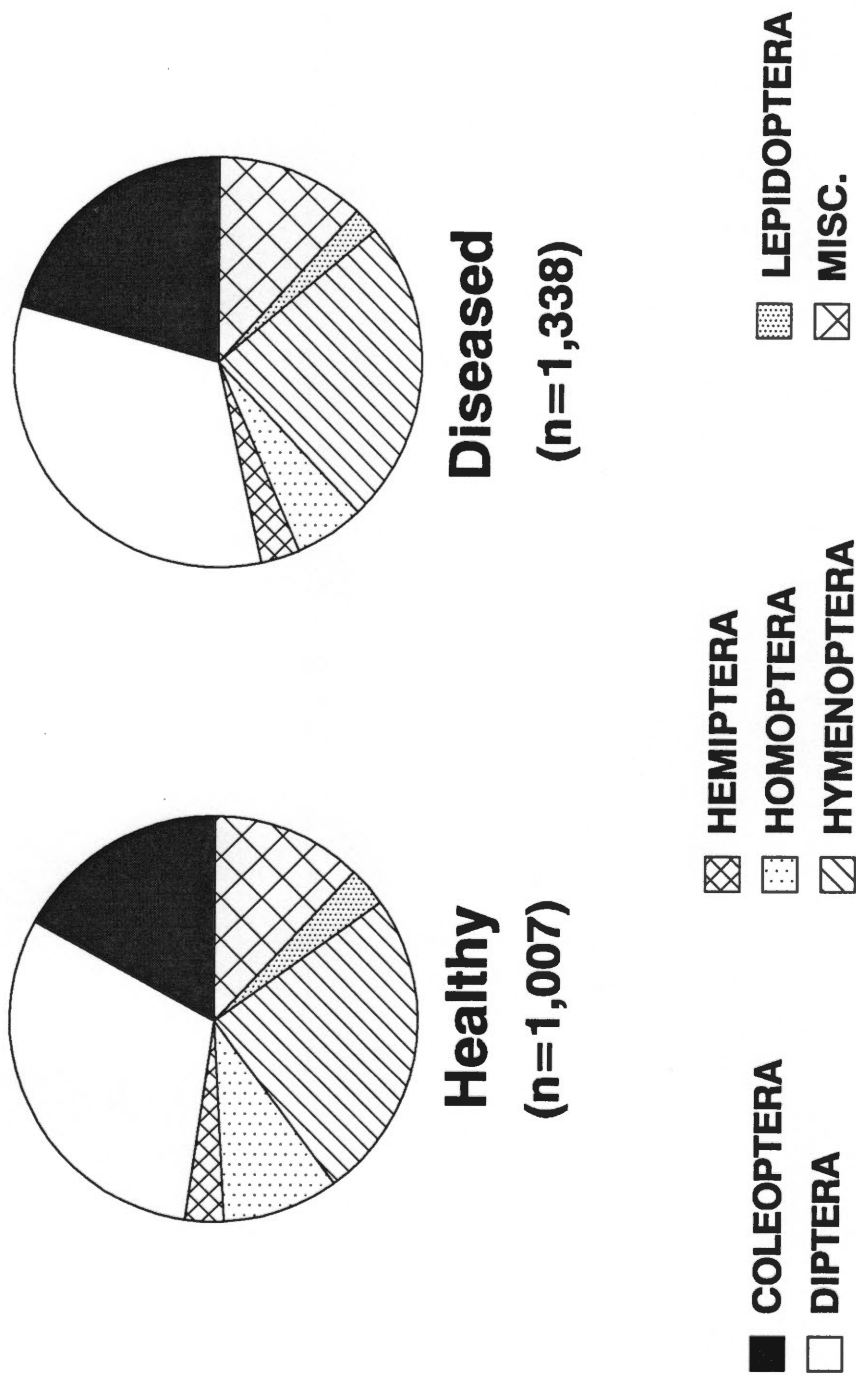


Fig. 13. Percent composition of insects collected from healthy and diseased dogwoods at Cades Cove during 1993 (Great Smoky Mountains National Park).

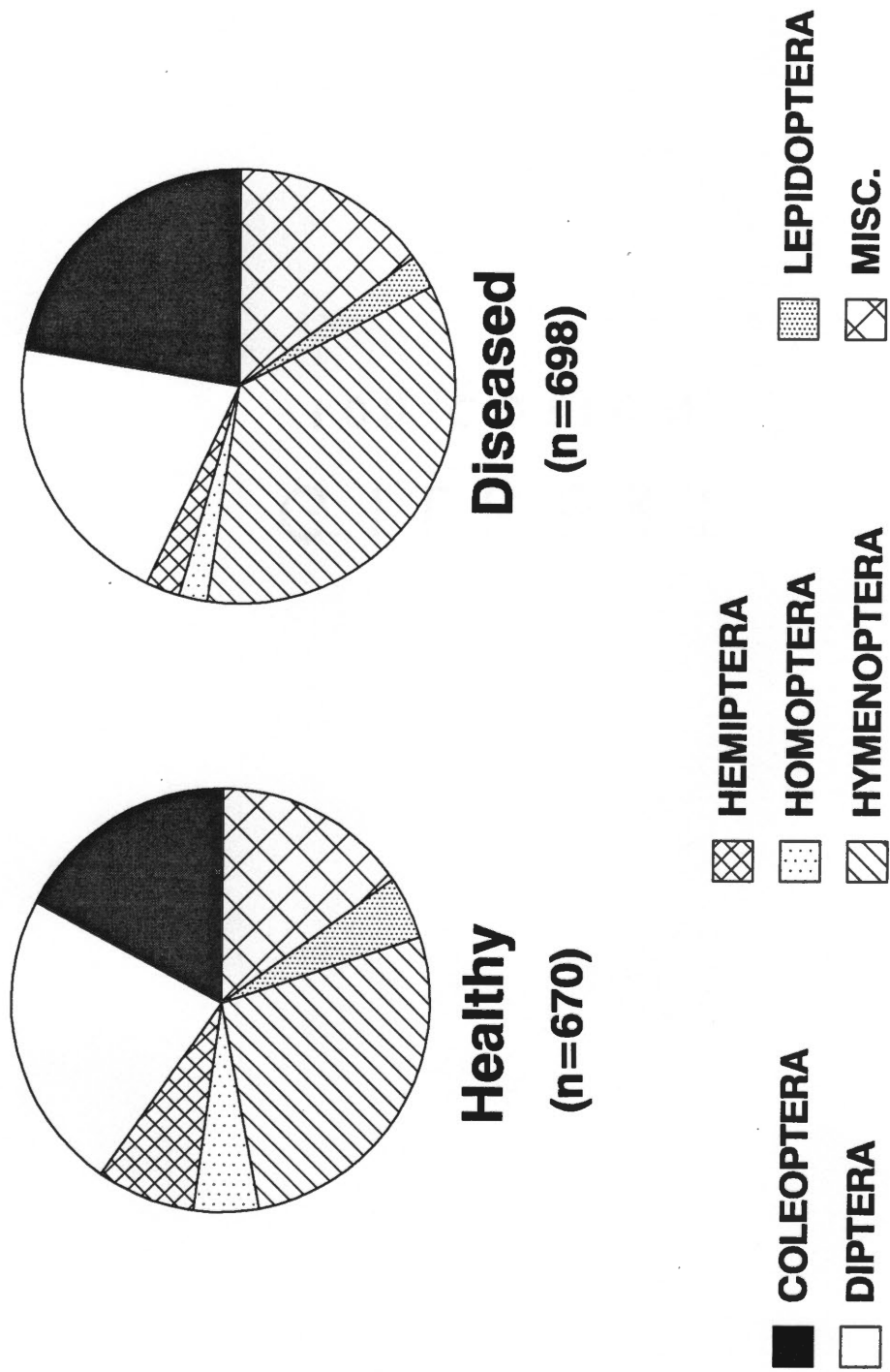


Fig. 14. Percent composition of insects collected from healthy and diseased dogwoods at Cades Cove during 1994 (Great Smoky Mountains National Park).

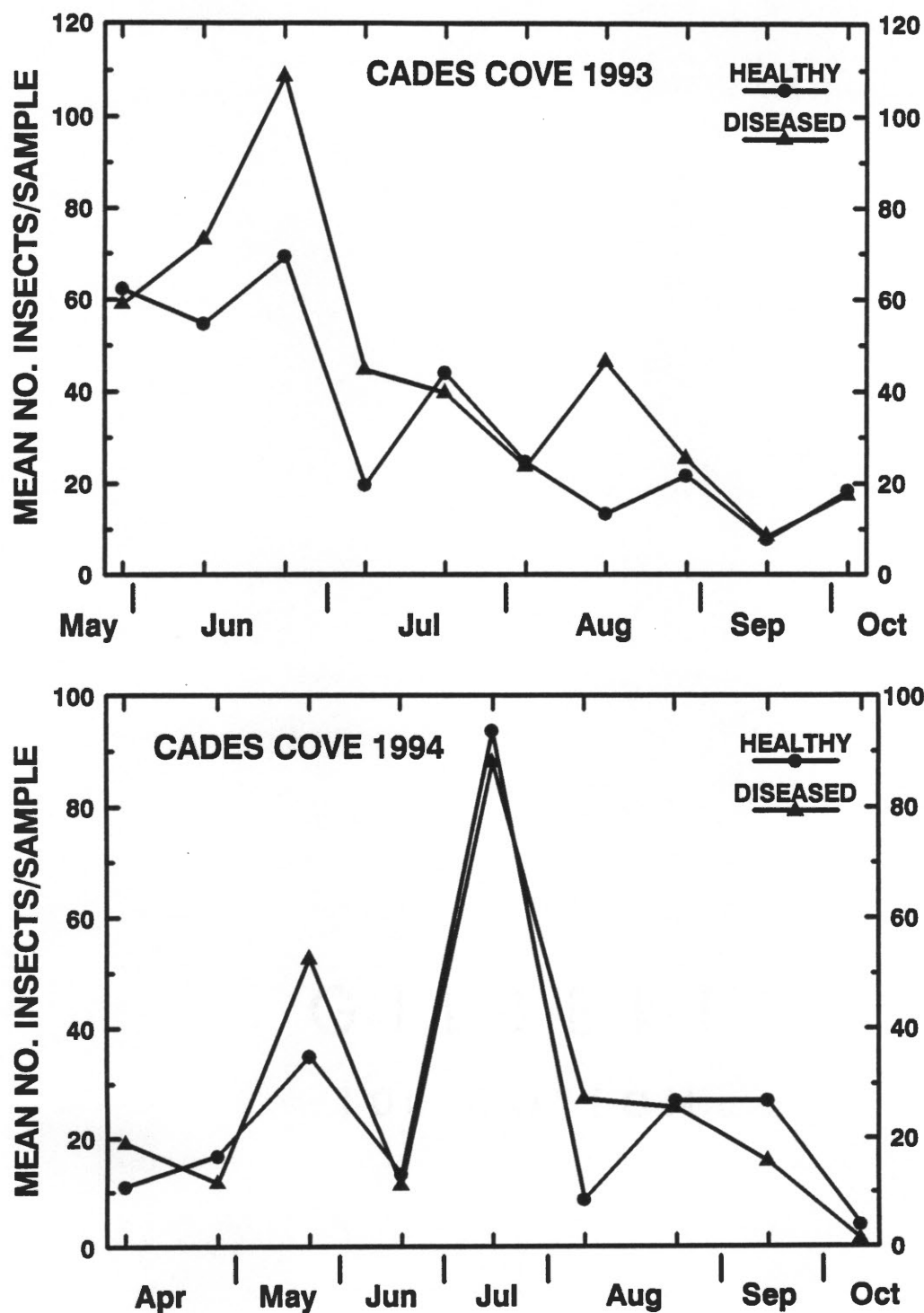


Fig. 15. Mean number of insects collected on each sampling date from healthy and diseased dogwoods at Cades Cove during 1993 and 1994 (Great Smoky Mountains National Park).

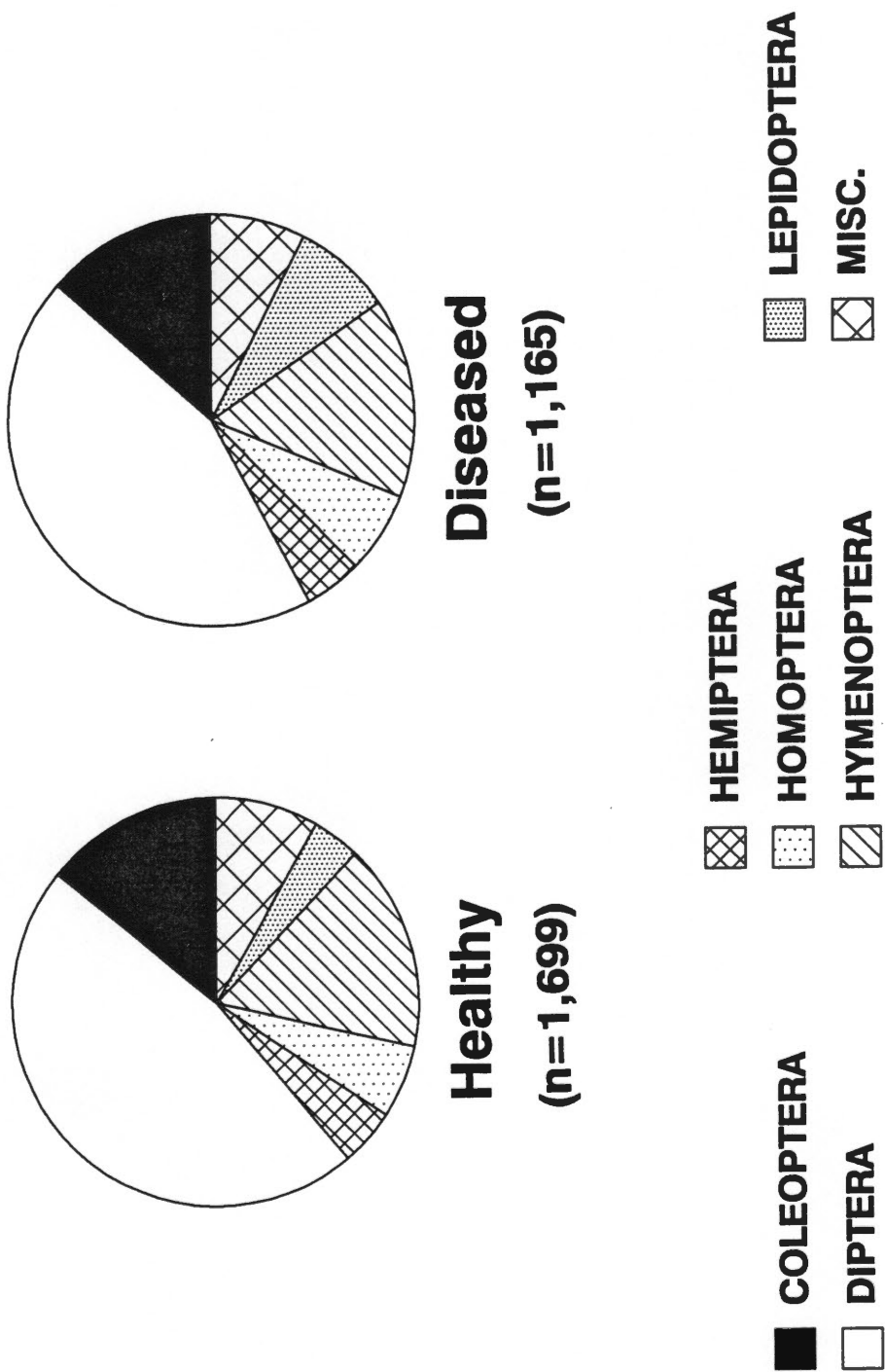


Fig. 16. Percent composition of insects collected from healthy and diseased dogwoods at Rich Mountain during 1993 (Great Smoky Mountains National Park).

trees. In 1994, percent composition changed tremendously from that found in 1993 (Fig. 16 and 17). The number of dipterans decreased by about half of those collected in 1993, while the number of hymenopterans almost doubled. Changes in site characteristics may account for these differences. Many species of dipterous larvae thrive in some sort of aquatic habitat, such as temporary puddles (Borror et al. 1989). Excessive spring flooding and summer drought could have eliminated these potential breeding sites. Hymenopterans, which thrive in warmer environments, occur less frequently and have a less active role in pollination as site temperatures decrease (Eyde 1988, LaBarge and Ribble 1972). Almost twice as many lepidopterans were found on diseased trees than on healthy trees. On the other hand, about twice as many members of miscellaneous orders were collected on healthy trees than on diseased trees.

Peak numbers were found in mid to late June during 1993 and in mid June during 1994 (Fig. 18). During both years, more insects were collected from healthy than from diseased trees.

Mt. Sterling

Greater percentages of coleopterans, dipterans, hemipterans and homopterans were found on diseased trees than on healthy trees at Mt. Sterling in 1993 (Fig. 19). On the other hand, more hymenopterans, lepidopterans, and miscellaneous orders were found on healthy trees. In 1994, percent composition of insects was similar on healthy and diseased trees (Fig. 20). Miscellaneous orders comprised a higher percentage of the insects collected on healthy trees.

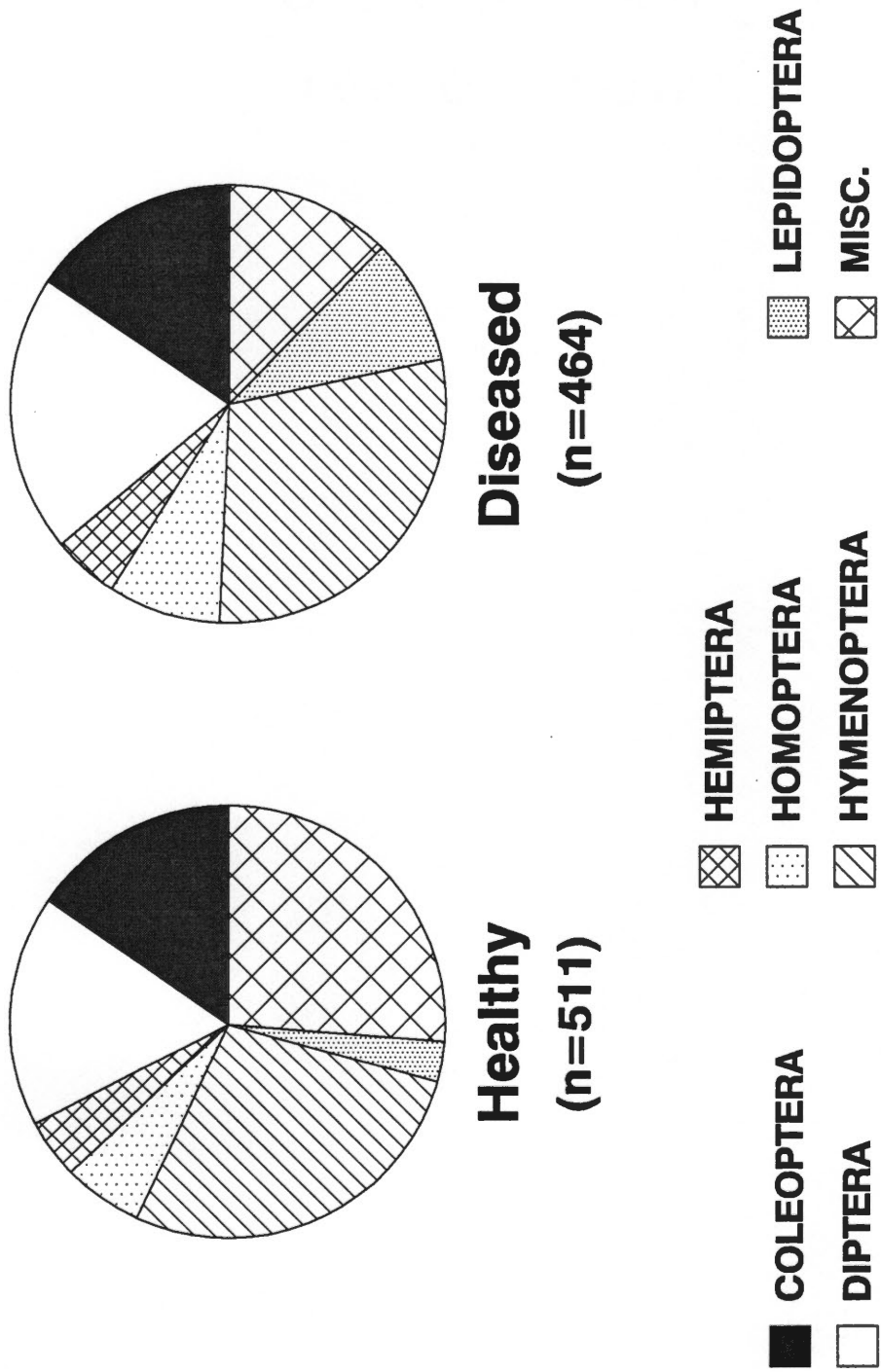


Fig. 17. Percent composition of insects collected from healthy and diseased dogwoods at Rich Mountain during 1994 (Great Smoky Mountains National Park).

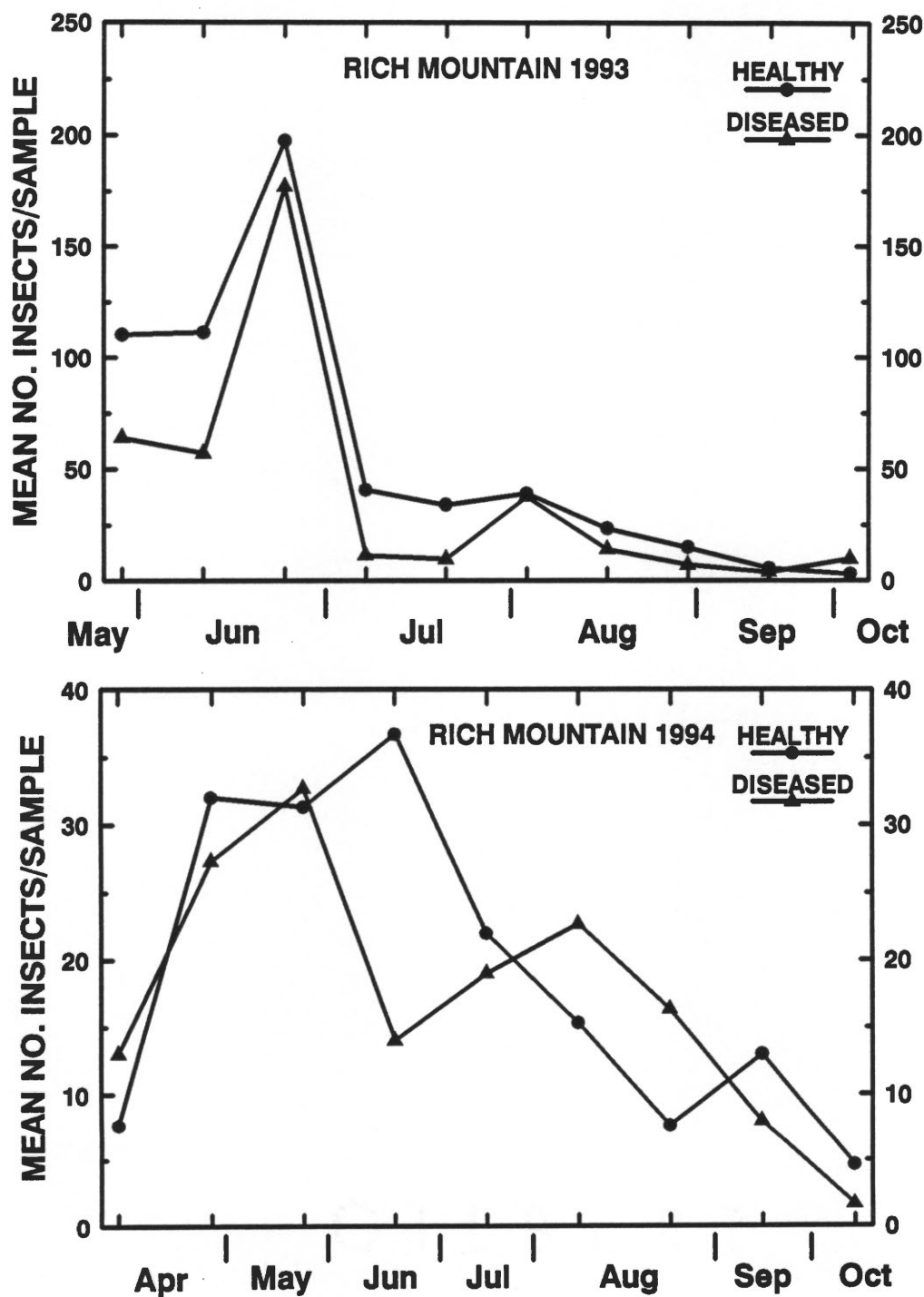


Fig. 18. Mean number of insects collected on each sampling date from healthy and diseased dogwoods at Rich Mountain during 1993 and 1994 (Great Smoky Mountains National Park).

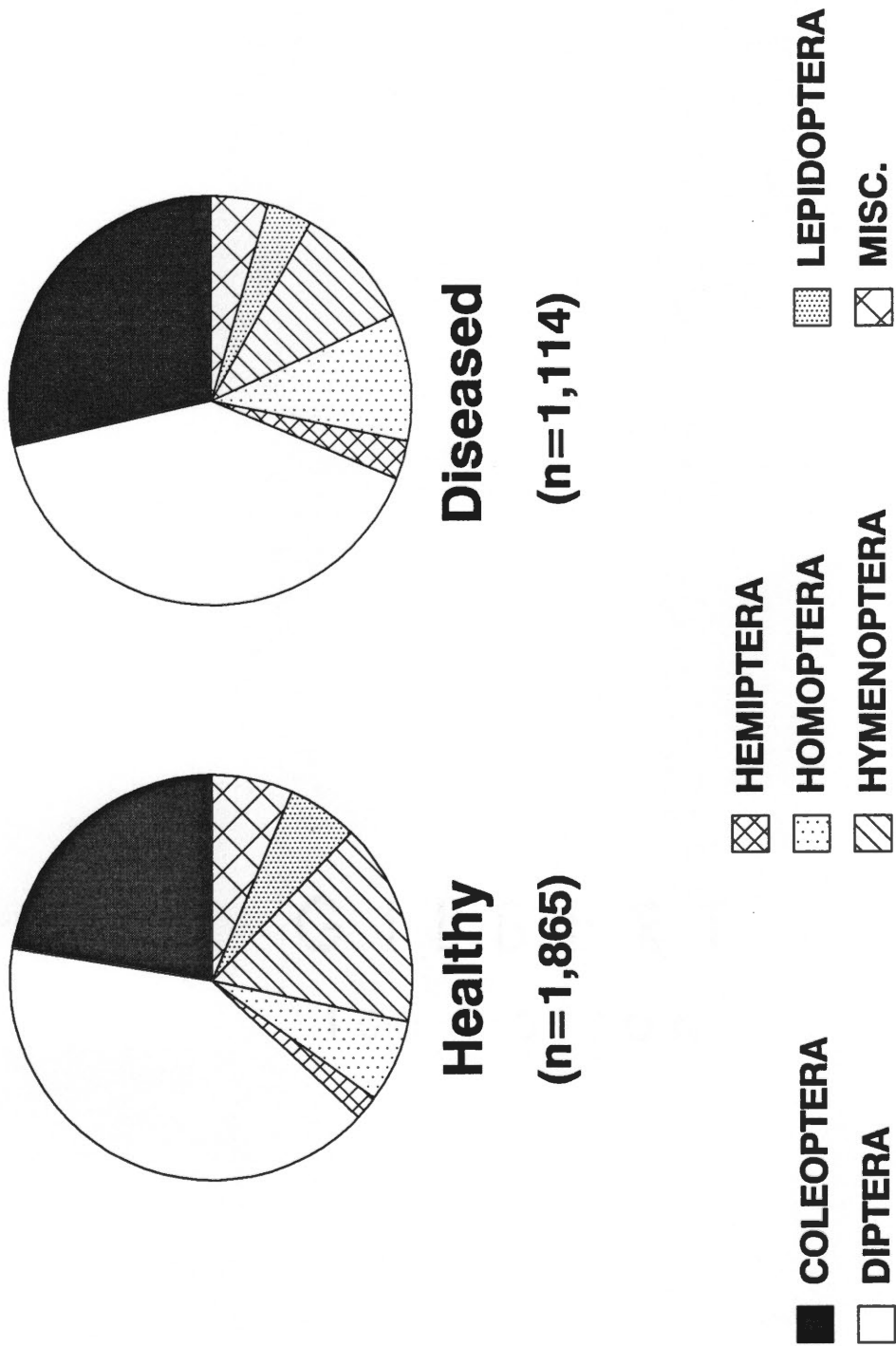


Fig. 19. Percent composition of insects collected from healthy and diseased dogwoods at Mt. Sterling during 1993 (Great Smoky Mountains National Park).

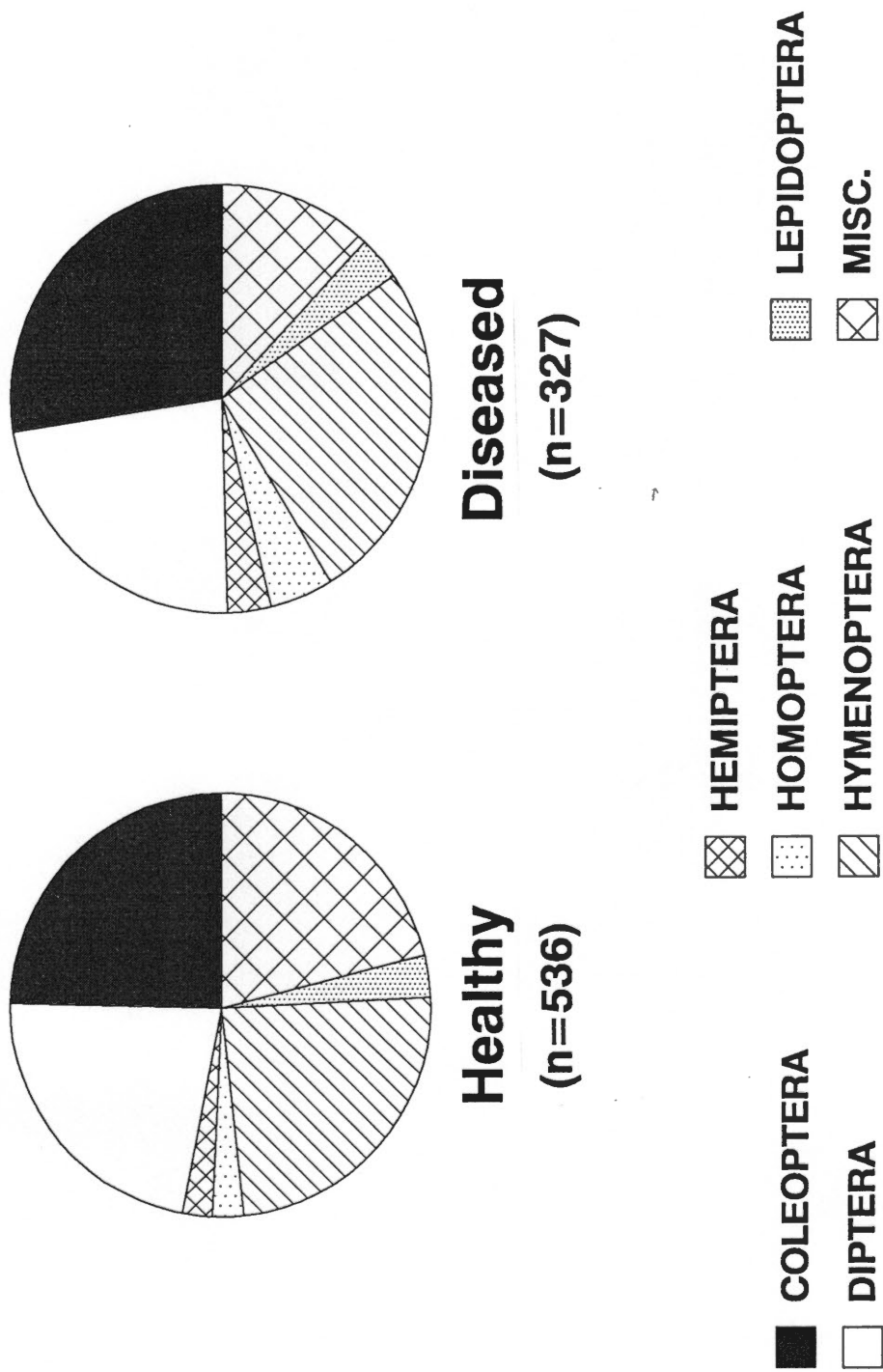


Fig. 20. Percent composition of insects collected from healthy and diseased dogwoods at Mt. Sterling during 1994 (Great Smoky Mountains National Park).

Peak numbers of insects were found in mid July during 1993 and in late April and mid July during 1994 (Fig. 21). These two peaks in 1994 are somewhat misleading. The impression is given that insect densities had two major peaks, with the greatest numbers found in mid July. Due to inclement weather on the fourth sampling date, some data were missing, which resulted in incomplete numbers. During both years, more insects were collected from healthy trees than from diseased trees.

iv. Summary

Previous studies have indicated that insects may play an active role in the dissemination of *D. destructiva*, the pathogen responsible for causing dogwood anthracnose. This study indicates that a diverse and abundant variety of insects are associated with dogwoods in a forest environment. The most abundant of these insects are members of the orders Coleoptera, Diptera, and Hymenoptera.

Although no significant differences were observed in densities of insect taxa between healthy and diseased trees, numerically more insects were collected from healthy trees. Also, peak numbers of insects were observed when reported incidence of *D. destructiva* is at its highest levels. These data suggest that insects may indeed play some role in the spread of dogwood anthracnose. Future research is needed to determine the exact role of insects in the epidemiology of dogwood anthracnose in a natural environment and which of these insects are involved in the dissemination of viable conidia.

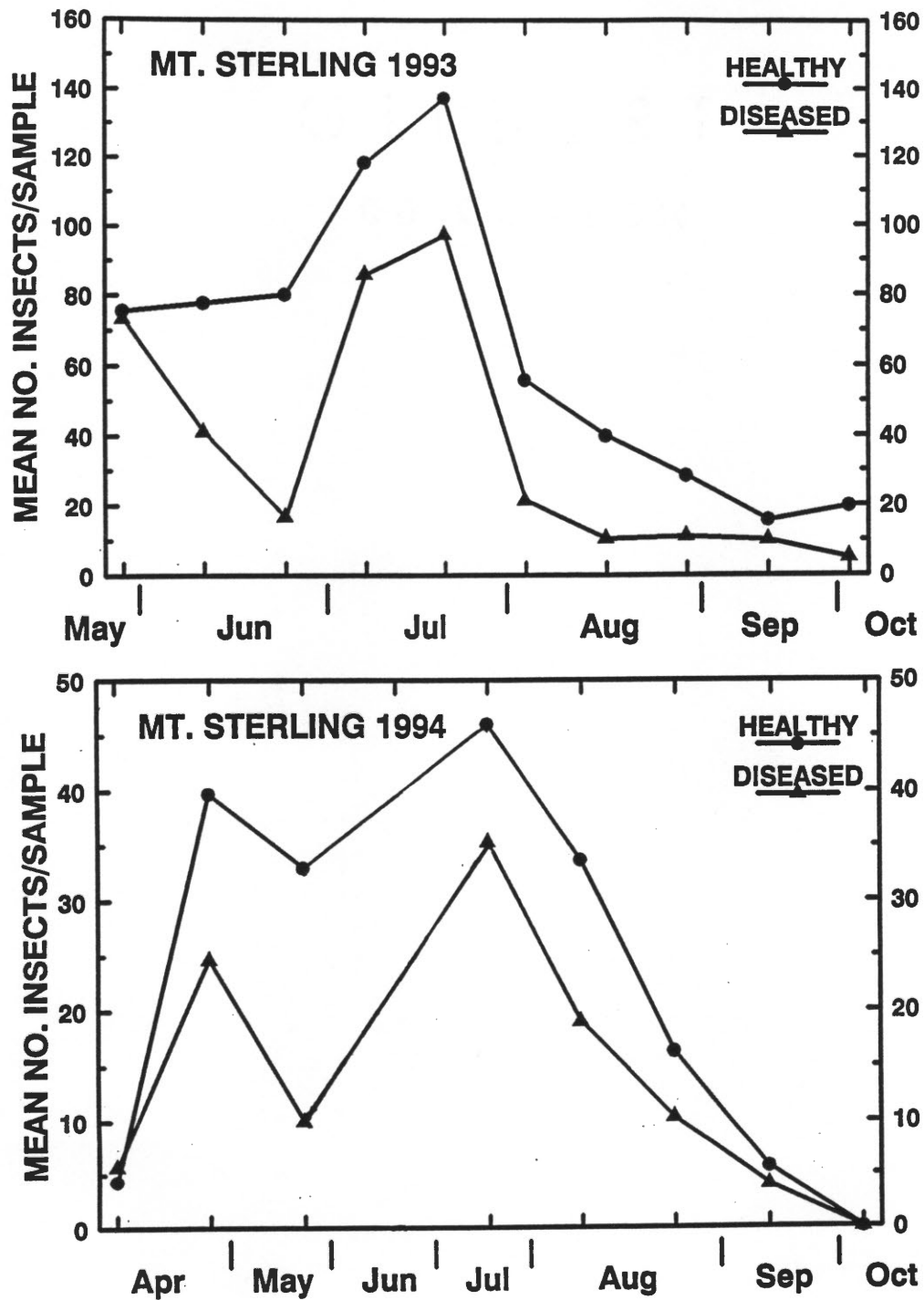


Fig. 21. Mean number of insects collected on each sampling date from healthy and diseased dogwoods at Mt. Sterling during 1993 and 1994 (Great Smoky Mountains National Park).

CHAPTER III

THE INFLUENCE OF FOLIAGE COLORATION ON ARTHROPOD DIVERSITY AMONG THREE CULTIVARS OF DOGWOOD

i. Introduction

Dogwood trees are recognized for their aesthetic value as well as for their role in the ecosystem (Redlin 1991). Dogwoods are important economically to thousands of nurserymen. In the eastern United States, dogwood sales reach approximately \$100 million annually, contributing \$35-40 million to the nursery economy in Tennessee (K. Tilt, personal communication to M. T. Windham).

In the last decade, the flowering dogwood, *Cornus florida* Link., has become threatened by dogwood anthracnose, a fungal disease caused by *Discula destructiva* Redlin. Many commercial nurserymen and homeowners are concerned about the threat of losing such a beneficial and beautiful asset. The disease is characterized by leaf spots, twig blights, and limb/trunk cankers (Hibben and Daughtrey 1988). Since its discovery, dogwood anthracnose has caused extensive mortality in both woodland and ornamental dogwoods (Mielke and Daughtrey 1989).

Little information about the transmission of the pathogen is available. Environmental factors, such as damp weather, may predispose a tree to conidia of *D. destructiva* which are often dispersed by wind or rain (Brown et al. 1991). Researchers

have suggested that insect species may play an important role in the epidemiology of dogwood anthracnose. Because of the possible loss of dogwoods and questions about the possible role of insects in dissemination of conidia of *D. destructiva* among dogwoods, a two-year research project was initiated to determine insect taxa associated with three cultivars of flowering dogwood. The specific objectives were to: 1) identify insect taxa associated with dogwood cultivars with different foliage colorations, 2) monitor seasonality of selected insects, and 3) compare insect densities among three cultivars of the flowering dogwood.

ii. Materials and Methods

Arthropod communities were sampled on three cultivars of the flowering dogwood (Cherokee Princess-green foliage, First Lady-yellow foliage, and Purple Glory-purple foliage) located in a nursery setting at the Plateau Experiment Station, Crossville, Tennessee. Six trees, two of each cultivar, were selected and tagged for future identification at this location.

During 1993 and 1994, insects were collected bimonthly from April/May to October from individual dogwoods at the Plateau Experiment Station (Table 11). On each sampling date, plastic tarps (3.6 m x 4.6 m) were placed underneath tree canopies. Insects were sampled from the foliage by insecticidal spraying, usually between 10:00am and 2:00pm (EST). A selected insecticide, Pyrenone® (a pyrethrin [botanical]), was

Table 11. Sampling dates at the Plateau Experiment Station, Crossville, Tennessee, during 1993 and 1994.

YEAR	SAMPLING DATE
1993	27 May, 10 June, 24 June, 8 July, 22 July, 5 August, 16 August, 1 September, 22 September, 12 October
1994	18 April, 6 May, 18 May, 16 June, 6 July, 25 July, 20 August, 16 September, 10 October

applied until the leaves were saturated, in a ratio of 10ml/3.8 liter of water, to the canopy of the dogwood using a Solo® backpack sprayer. Also, extension hoses and ladders were utilized to ensure complete coverage of the canopy by the insecticide.

After waiting for a safe reentry period of 2-4 hours, the fallen insects were removed from the tarps into individual plastic containers using a modified, battery operated, Dustbuster®. Containers were labeled with the date, site, cultivar, and tree number and placed into similarly labeled Ziploc® freezer bags (1.10 liter). Samples were placed in an Igloo® ice chest and transported to the laboratory where they were held in a freezer (0°C) until further processing and identification could be completed.

Prior to processing of samples, the containers were removed from the freezer, and samples were allowed to thaw at approximately 20°C for 1-2 hours. The contents of each sample were placed onto paper towels, and the insects were separated from debris and leaf litter using forceps and a Luxo®, 22 volt, magnifier. Insects were first gross separated by order and placed into appropriately labeled petri dishes. Gross insect counts, date, site, cultivar, tree number, and insect orders were recorded. These numbers were then entered into a data file. Data were subjected to an analysis of variance procedure (PROC GLM) to evaluate influences of date and foliage coloration on insects collected from the three cultivars of dogwood (SAS Institute 1989). When significant ($p=0.1$) differences were observed, Duncan's multiple range test was used to determine significant differences among the means.

Insects were later identified and placed into a voucher collection. Insect family, species name, if known, and the total number of each taxa present in a sample also were

recorded. From these data, seasonal incidences of selected taxa were determined. Voucher specimens of each species will be incorporated into The University of Tennessee, Department of Entomology and Plant Pathology Insect Museum.

iii. Results and Discussion

General Overview

During 1993 and 1994 at the Plateau Experiment Station, Crossville, TN, approximately 4,500 insects were collected from three cultivars of dogwood. Each cultivar exhibited different foliage colorations [Cherokee Princess (G)-green, Purple Glory (P)-purple, and First Lady (Y)-yellow]. The three most common orders represented, comprising 75% of all insects collected, were Coleoptera, Homoptera, and Diptera (Fig. 22). About 800 more insects were collected in 1994 than in 1993. The increase in numbers in 1994 was due to an unexplained abundance of Coleoptera early in the season.

Differences between Years and Dates

In 1993, Homoptera, Coleoptera, and Diptera were the three most commonly collected orders, comprising 65% of the insects collected (Fig. 22 and 23). Homopterans were the most abundant of all insect orders represented in 1993 (Fig. 23). This order contains an abundant and diverse group of insects. Site characteristics may explain the increased number of homopterans. The trees at the Plateau Experiment Station were located in a field, which was surrounded by a variety of field and forage crops. These

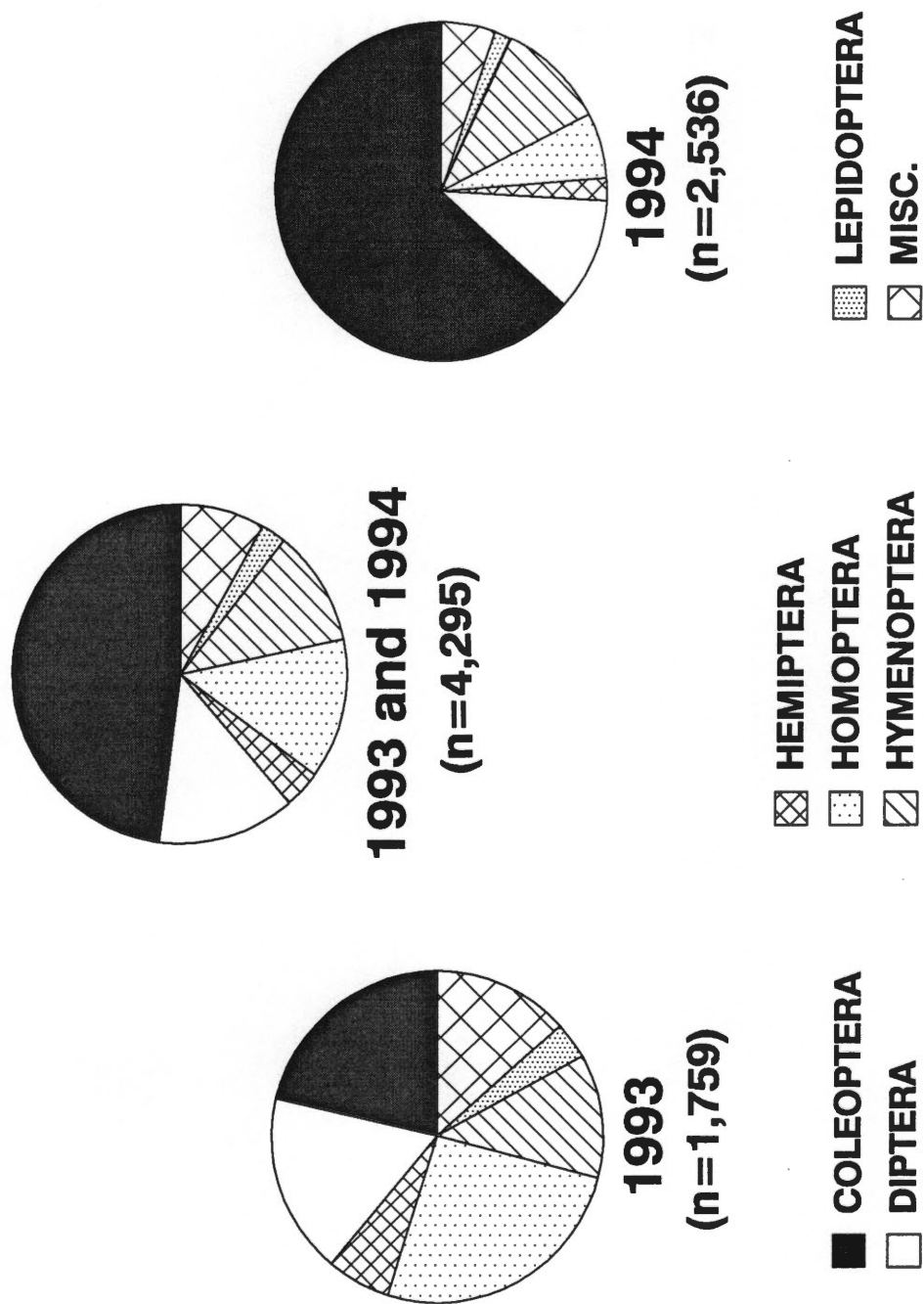


Fig. 22. Percent composition of insects collected from dogwood at the Plateau Experiment Station, Crossville, TN, during 1993 and 1994.

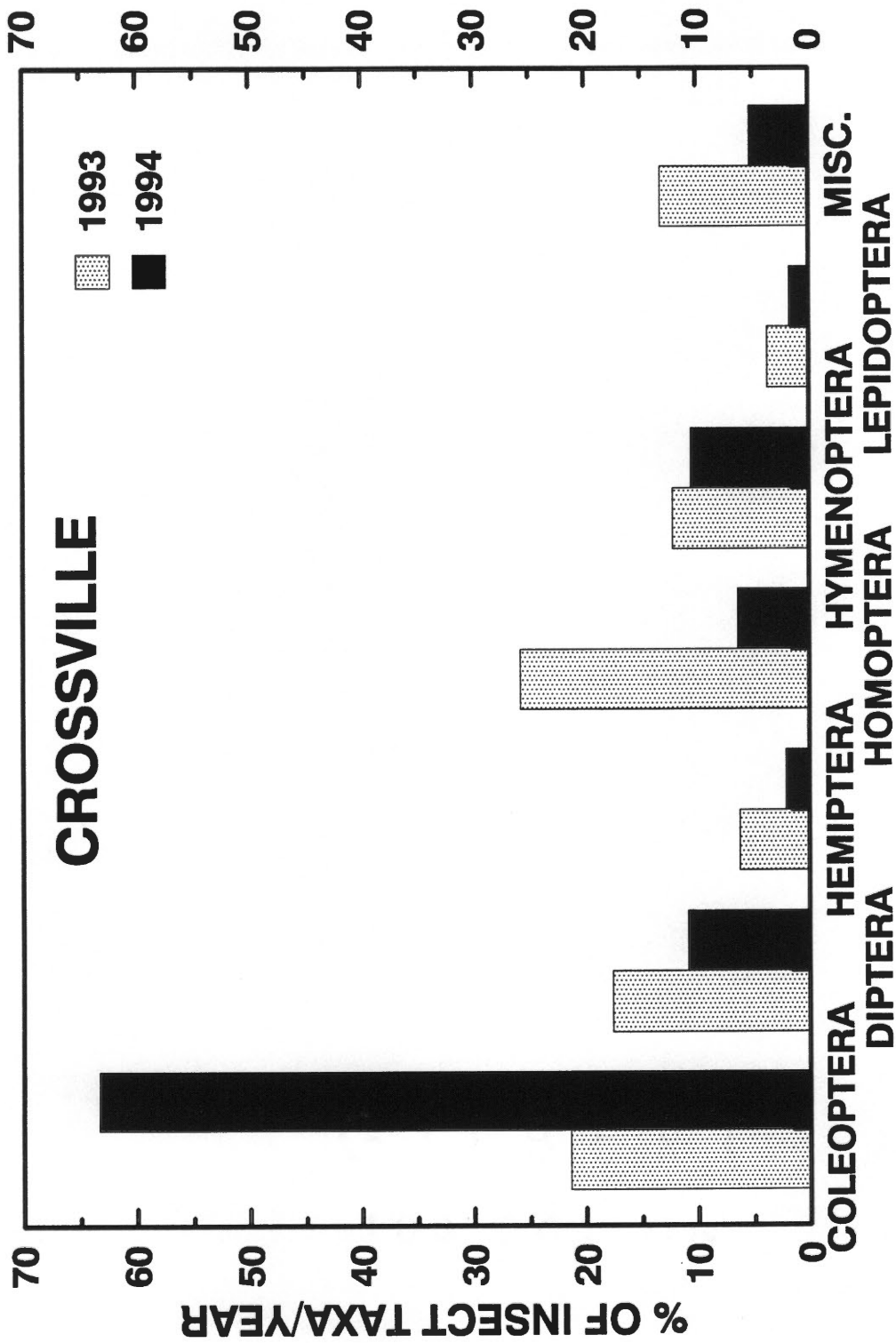


Fig. 23. Percent of insect taxa collected per year from cultivars of dogwood during 1993 and 1994 (Plateau Experiment Station).

surrounding crops may have provided the necessary habitat to support such high populations of homopterans and other insects. All of the Homoptera are plant feeders, and many species are serious pests of cultivated plants (Borror et al. 1989).

In 1994, Coleoptera, Diptera, and Hymenoptera were the three most abundant orders collected, comprising about 85% of all insects collected (Fig. 22 and 23). This composition differed from that found in 1993; homopterans were replaced by coleopterans as the most abundant order (Fig. 23). The percentage of homopterans decreased from 26% of all insects in 1993 to approximately 6% in 1994, while the percentage of coleopterans more than tripled in 1994 compared to 1993. Increased percentages of Coleoptera was due to a large number of beetles collected on the first sampling date in 1994. Percent compositions of the other insect orders did not vary as greatly between years as did the Coleoptera and Homoptera (Fig. 23).

In 1993, densities of Coleoptera, Hymenoptera, and Diptera, as well as the total number of insects and arthropods, were significantly different among treatment effects (Table 12). Significant differences in densities of Coleoptera, Diptera, and the total number of insects were detected among date and cultivar. Densities of Hymenoptera and all arthropods were significantly different among dates. Densities of homopterans, however, were not significantly different among any treatment effects. Densities of Coleoptera and the total number of insects and arthropods were significantly greater on the first sampling date than on any other sampling date (Table 13). Peak numbers of dipterans and hymenopterans also were found on this date (Fig. 24). Peak numbers of

Table. 12. ANOVA table illustrating significance among effects in model during 1993 (Plateau Experiment Station, Crossville, TN).

EFFECTS	DF	COLEOPTERA	HOMOPTERA	HYMENOPTERA	DIPTERA	TOTAL NO. INSECTS	TOTAL NO. ARTHROPODS
MODEL	37	**	NS ^b	*	*	*	*
DATE NO.	8	*	NS	*(*) ^c	*(*)	*	*
CULTIVAR	2	*	NS	*(NS)	*(*)	*(*)	*(NS)
REP.	1	*	NS	NS	NS	NS	NS
DATE * CULTIVAR	16	NS	NS	*	*	NS	NS
DATE * REP.	8	NS	NS	*	NS	NS	NS
CULTIVAR * REP.	2	NS	NS	*	NS	*	*

*Significantly different ($p \leq 0.1$), PROC GLM conducted on transformed data.

^bNot significantly different ($p > 0.1$), PROC GLM conducted on transformed data.

^cSignificance levels indicated in parentheses are based on analysis of main effects with significant interaction terms.

Table 13. The influence of sampling date on the mean number of insects collected from cultivars of dogwood during 1993 (Plateau Experiment Station, Crossville, TN).

ARTHROPOD TAXA	SAMPLING DATE ^a									
	1	2	3	4	5	6	7	8	9	10
Coleoptera	17.83 ^a (8.04) ^c	8.67 ^b (6.06)	5.00 ^{bc} (2.65)	6.83 ^{bc} (4.17)	4.50 ^{bc} (2.43)	5.83 ^{bc} (3.37)	3.83 ^c (3.13)	4.67 ^c (4.80)	4.33 ^c (4.08)	1.00 ^d (1.26)
Homoptera	17.67 ^a (11.74)	2.67 ^a (2.07)	3.00 ^a (3.67)	11.50 ^a (7.71)	19.17 ^a (32.27)	6.00 ^a (7.87)	2.83 ^a (2.23)	1.67 ^a (1.51)	3.33 ^a (4.08)	7.00 ^a (5.48)
Hymenoptera	8.33 ^a (7.92)	6.33 ^{ab} (5.28)	2.20 ^{cd} (2.95)	3.00 ^{bcd} (2.53)	2.50 ^{cd} (2.26)	4.50 ^{abc} (2.66)	1.33 ^d (1.97)	2.17 ^{cd} (3.43)	1.00 ^d (1.26)	4.00 ^{abc} (1.67)
Diptera	18.50 ^a (10.48)	10.50 ^b (7.12)	1.40 ^c (1.14)	1.83 ^c (2.14)	2.50 ^c (1.64)	0.83 ^c (0.75)	0.50 ^c (0.84)	0.83 ^c (0.98)	1.67 ^c (2.66)	12.33 ^{ab} (3.08)
Total Number Insects	69.50 ^a (39.25)	37.33 ^{bc} (22.80)	15.80 ^{de} (12.40)	30.67 ^{bcd} (12.44)	43.83 ^b (40.29)	21.50 ^{bcd} (13.23)	10.33 ^e (6.19)	13.83 ^e (10.19)	19.33 ^{cde} (11.84)	28.67 ^{bcd} (6.06)
Total Number Arthropods	77.67 ^a (44.46)	43.00 ^{bc} (25.51)	17.40 ^{de} (13.96)	34.00 ^{bc} (12.85)	49.83 ^b (42.99)	25.83 ^{cde} (16.31)	12.17 ^e (5.31)	15.50 ^e (10.78)	23.83 ^{cde} (13.56)	31.67 ^{bcd} (7.09)

^aRefers to date(s) that insects were collected from cultivars of dogwood during 1993; see Table 11.

^bMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

^cRefers to standard deviation of mean.

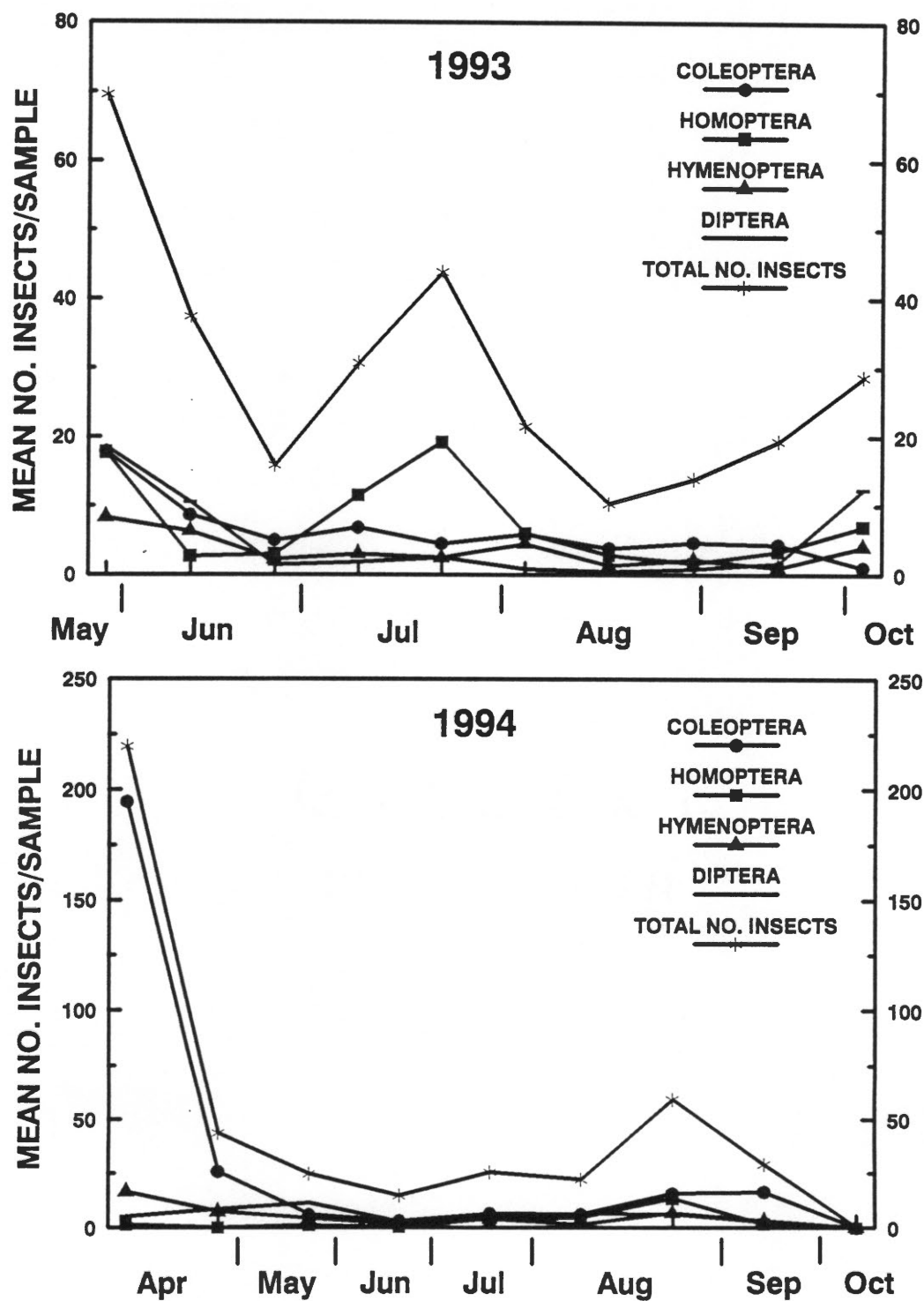


Fig. 24. Mean number of insects per sampling date collected from dogwood for selected orders and the total number of insects during 1993 and 1994 (Plateau Experiment Station).

homopterans, such as planthoppers, leafhoppers, and aphids, were found on the fifth sampling date (Table 13).

In 1994, densities of homopterans were significantly different among sampling dates (Table 14). No significant differences in densities of other insect orders were detected among dates or cultivars. Densities of homopterans were significantly greater on the seventh sampling date than on any other date (Table 15, Fig. 24). Densities of coleopterans were greatest on the first sampling date, when an abundant number of phalacrids were observed on dogwoods. Phalacridae, the shining flower beetle, are quite common on some plants, such as goldenrod and other composites (Borror et al. 1989). This high number of coleopterans is responsible for the peak densities in the total number of insects observed on this date. One possible explanation for such large numbers is that some species of phalacrids are found in grasses. This fact is important because of the characteristics of this site. The trees are bordered on all sides by grasses and numerous grasses grow between the rows of the trees. Environmental conditions, such as weather and temperature, may have affected the emergence of the beetles at this particular time in 1994 and not in 1993. Also, in 1993, the grasses around the trees were mowed regularly and in 1994, the grasses were not mowed on a regular basis.

Differences among Cultivars

During 1993 and 1994, percent composition of insects varied among the three cultivars of dogwood (Fig. 25). Coleoptera was the most abundant order represented on the three cultivars. Diptera, Homoptera, and Hymenoptera also were among the most

Table 14. ANOVA table illustrating significance among effects in model during 1994 (Plateau Experiment Station, Crossville, TN).

MODEL	EFFECTS	DF	COLEOPTERA	HOMOPTERA	HYMENOPTERA	DIPTERA	TOTAL NO.	
							INSECTS	ARTHROPODS
		37	NS ^b	**	NS	NS	NS	NS
	DATE NO.	8	NS	*	NS	NS	NS	NS
	CULTIVAR	2	NS	NS	NS	NS	NS	NS
	REP.	1.	NS	NS	NS	NS	NS	NS
	DATE * CULTIVAR	16	NS	NS	NS	NS	NS	NS
	DATE * REP.	8	NS	NS	NS	NS	NS	NS
	CULTIVAR * REP	2	NS	NS	NS	NS	NS	NS

*Significantly different ($p \leq 0.1$), PROC GLM.

^bNot significantly different ($p > 0.1$), PROC GLM.

Table 15. The influence of sampling date on the mean number of insects collected from cultivars of dogwood during 1994 (Plateau Experiment Station, Crossville, TN).

ARTHROPOD TAXA	SAMPLING DATE ^a								
	1	2	3	4	5	6	7	8	9
Coleoptera	194.50a ^b (312.18) ^c	26.00a (21.43)	6.17a (5.31)	3.25a (3.40)	6.60a (5.77)	6.17a (5.12)	15.83a (20.42)	16.50a (30.41)	0.00a (0.00)
Homoptera	1.67b (1.37)	0.17b (0.41)	1.33b (1.75)	0.50b (0.58)	4.20b (2.77)	4.83b (3.54)	13.50a (15.78)	1.83b (2.64)	0.00b (0.00)
Hymenoptera	16.67a (27.76)	7.50a (6.98)	4.50a (5.17)	2.00a (2.31)	4.00a (4.00)	1.67a (1.75)	6.83a (4.71)	3.17a (4.12)	0.17a (0.41)
Diptera	5.33a (2.94)	8.67a (7.09)	11.33a (12.03)	3.00a (2.94)	4.40a (3.29)	6.67a (3.67)	6.17a (3.49)	2.67a (1.97)	0.17a (0.41)
Total Number Insects	219.67a (308.72)	43.67a (29.63)	24.83a (23.90)	14.75a (12.69)	25.60a (15.88)	22.33a (12.93)	59.17a (52.59)	29.33a (33.91)	0.50a (0.84)
Total Number Arthropods	221.50a (308.69)	46.00a (30.45)	30.33a (28.29)	16.25a (13.82)	29.20a (17.20)	24.67a (14.67)	62.17a (54.52)	31.33a (33.95)	1.17a (1.17)

^aRefers to date(s) that insects were collected from cultivars of dogwood during 1994; see Table 12.

^bMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

^cRefers to standard deviation of mean.

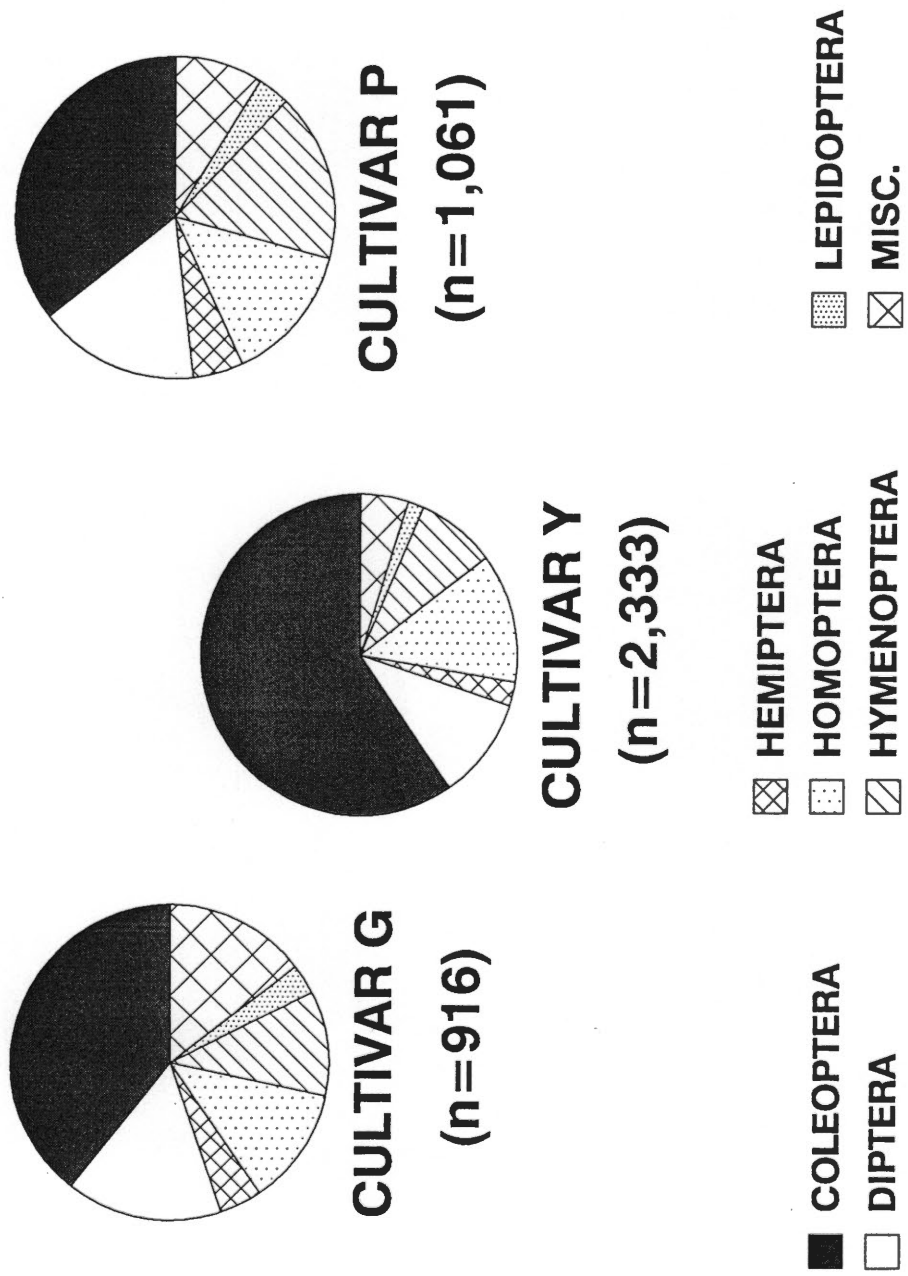


Fig. 25. Percent composition of insects collected from each cultivar of dogwood during 1993 and 1994 (Plateau Experiment Station).

abundant orders. Greater numbers of insects (about 2x) were collected from cultivar Y than cultivars G or P.

In 1993, percent compositions of insect taxa per sample varied among cultivars (Fig. 26). Percent compositions of Coleoptera, Hymenoptera, and miscellaneous orders were generally greater on cultivar G, while that of homopterans was generally greater on cultivar Y. However, densities of Coleoptera, Diptera, Hymenoptera, and the total number of insects and arthropods were significantly greater on cultivar Y than on G or P (Table 16). In most cases, ca. twice as many insects were collected. Densities of Homoptera were not significantly different among cultivars, although about 2 to 3x as many homopterans were collected from cultivar Y than from cultivars G or P.

In 1994, percent composition of coleopterans was greatest on cultivar Y, while those of Diptera, Homoptera, and miscellaneous orders were greatest on cultivar G (Fig. 26). Percent composition of Hymenoptera was greatest on cultivar P. However, densities of Homoptera were significantly greater on cultivar Y than on cultivar P (Table 17). No significant differences among cultivars were detected among other insect orders. However, densities of Coleoptera were numerically greater (ca. 4 to 6x) on cultivar Y than on any other cultivar.

Seasonal abundance of insects was similar for each cultivar of dogwood throughout the season during 1993 (Fig. 27). Densities of insects on each cultivar peaked in late May and those on cultivar Y peaked again in late July. Seasonality of insect emergence may be responsible for increases in insect densities. The peaks in

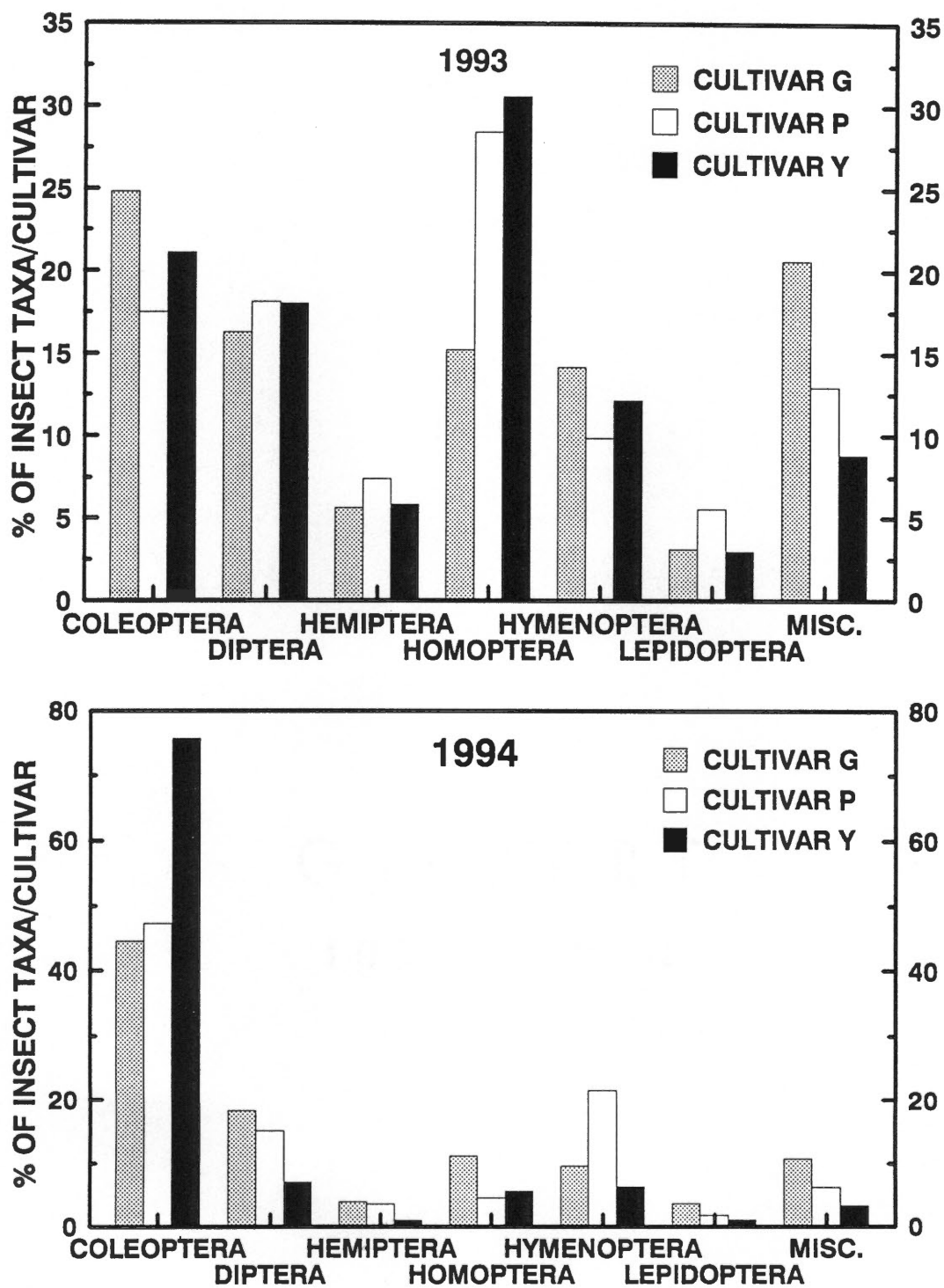


Fig. 26. Percent of insect taxa collected from cultivars of dogwood during 1993 and 1994 (Plateau Experiment Station).

Table 16. The influence of cultivar on the mean ($\pm$ SD) number of insects collected from dogwoods during 1993 (Plateau Experiment Station, Crossville, TN).

ARTHROPOD TAXA	CULTIVAR ^a		
	G	P	Y
Coleoptera	5.95 $\pm$ 5.40b ^b	4.11 $\pm$ 4.84c	8.65 $\pm$ 6.84a
Homoptera	3.65 $\pm$ 6.88a	6.68 $\pm$ 8.46a	12.30 $\pm$ 17.94a
Hymenoptera	3.40 $\pm$ 4.49b	2.32 $\pm$ 1.70b	4.90 $\pm$ 4.96a
Diptera	3.90 $\pm$ 6.90b	4.26 $\pm$ 5.51b	7.25 $\pm$ 8.19a
Total Number Insects	23.95 $\pm$ 24.01b	23.47 $\pm$ 19.32b	40.20 $\pm$ 30.64a
Total Number Arthropods	27.45 $\pm$ 26.10b	26.21 $\pm$ 20.15b	45.45 $\pm$ 34.08a

^aRefers to the foliage coloration of the three cultivars of dogwood; Cherokee Princess-green (G), Purple Glory-purple (P), First Lady-yellow (Y).

^bMeans within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

Table 17. The influence of cultivar on the mean ($\pm$ SD) number of insects collected from dogwoods during 1994 (Plateau Experiment Station, Crossville, TN).

ARTHROPOD TAXA	CULTIVAR ^a		
	G	P	Y
Coleoptera	10.39 $\pm$ 15.89 ^a ^b	17.18 $\pm$ 39.17 ^a	72.37 $\pm$ 201.99 ^a
Homoptera	2.72 $\pm$ 3.58 ^{ab}	1.65 $\pm$ 2.32 ^b	5.38 $\pm$ 11.02 ^a
Hymenoptera	2.33 $\pm$ 2.97 ^a	7.82 $\pm$ 17.34 ^a	6.00 $\pm$ 5.33 ^a
Diptera	4.44 $\pm$ 3.78 ^a	5.47 $\pm$ 5.50 ^a	6.69 $\pm$ 8.13 ^a
Total Number Insects	24.33 $\pm$ 19.11 ^a	36.29 $\pm$ 47.80 ^a	95.56 $\pm$ 203.59 ^a
Total Number Arthropods	26.61 $\pm$ 20.02 ^a	38.29 $\pm$ 47.76 ^a	99.00 $\pm$ 203.53 ^a

^aRefers to the foliage coloration of the three cultivars of dogwood; Cherokee Princess-green (G), Purple Glory-purple (P), First Lady-yellow (Y).

²Means within a row followed by the same letter are not significantly different ($p > 0.1$), Duncan's multiple range test.

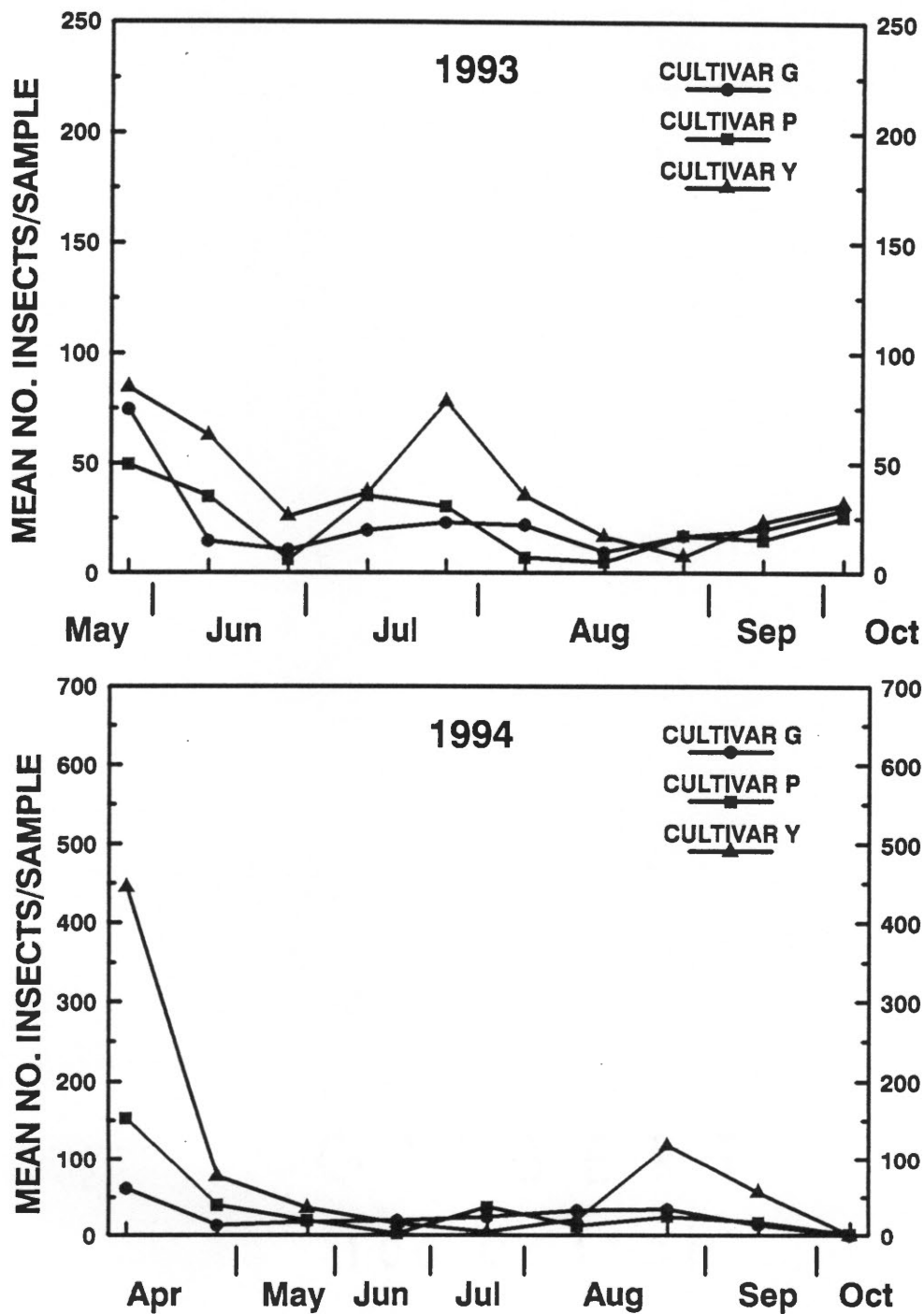


Fig. 27. Mean number of insects per sampling date collected from cultivars of dogwood during 1993 and 1994 (Plateau Experiment Station).

insect densities later in the season could have been caused by several factors, such as the emergence of new generations and the possible effect of control methods used at the Plateau Experiment Station. However, seasonal abundance of insects during 1994 peaked during April, when densities were 3 to 6x greater on cultivar Y than on cultivars G or P (Fig. 27).

iv. Summary

During 1993 and 1994, insect diversity and abundance varied among the three cultivars of dogwood. Overall insect densities were greatest on the yellow foliage of First Lady, cultivar Y. The behavior of some insects may partially explain these greater numbers of insects on yellow foliage. Yellow is the major component of reflected sunlight from the green leaves of plants (Johnson and Mueller 1988). Data, testing the attractiveness of insect traps, have shown that lighter colors, such as yellow and light green, are more attractive than darker colors (Yudin and Mitchell 1987). Johnson and Mueller (1988) observed that significantly greater numbers of homopterans (leafhoppers and aphids) were captured on yellow sticky traps. In this study, members of Homoptera were among the most commonly collected insects on cultivar Y.

The attractiveness of homopterans to the color yellow and to yellow foliage is important for several reasons. Planthoppers occur on a variety of plants, including forest, orchard trees, and many field and vegetable crops. These insects feed mainly on the leaves and cause several types of injury to the plant (Borror et al. 1989). Some

insects also are able to vector plant diseases, such as Pierce's disease of grape, potato yellow dwarf, and curly top in sugar beets (Borrer et al. 1989). Because insects are capable of transporting viable conidia of *D. destructiva* (Colby 1993, Holt 1995), homopterans may have a significant role in the epidemiology of dogwood anthracnose in urban and forested areas.

CHAPTER IV

CONCLUSION

The flowering dogwood, *Cornus florida* Link., is a valuable ornamental throughout the southeastern United States, where it is also an important food source for wildlife (Chellemi et al. 1992). In the last decade the dogwood has become threatened by a fungal disease, dogwood anthracnose (caused by *Discula destructiva* Redlin). Symptoms include leaf spots, twig blights, and limb/trunk cankers, which lead to the eventual death of the tree (Hibben and Daughtrey 1988).

Little information is available about environmental conditions that may predispose a tree to conidia of *D. destructiva*, which is believed to be dispersed by wind or rain. In most cases, some type of mechanical injury often allows for the introduction of the pathogen (Daughtrey et al. 1988). Researchers have suggested that insect species also may play an important role in the epidemiology of dogwood anthracnose. Colby (1993) observed that, under laboratory conditions, insects were capable of transporting viable conidia of *D. destructiva*. Unfortunately, little information is available on the insect communities associated with dogwoods in forest and nursery environments.

Mortality of the flowering dogwood is extremely high in forested areas, such as the Great Smoky Mountains National Park, where dogwood density has declined in recent years (Mielke and Daughtrey 1989, M. T. Windham, personal communication). Because of concern about the possible loss of dogwoods from the forest ecosystem, a two-year

research project was initiated to determine insect taxa associated with the flowering dogwood in forest and nursery environments. The objectives of this research were to: 1) identify insect taxa associated with anthracnose-infected (diseased) and non-infected (healthy) dogwoods in a natural setting, 2) monitor the seasonality of selected insects, 3) compare insect densities on anthracnose-infected and non-infected dogwoods, and 4) compare insect densities among dogwood cultivars in a natural/ornamental setting.

The most abundant insect orders collected in The Great Smoky Mountains National Park were Coleoptera, Hymenoptera, and Diptera. Significant differences in densities of Coleoptera, Diptera, and Homoptera, as well as the total number of insects and arthropods, were found among sampling dates, sites, and tree types. Greater numbers of insects were observed in 1993, when Diptera comprised approximately 50% of all insect orders represented.

In 1993, peak densities of insects were found in June; however, peak densities were observed during July in 1994. Seasonal abundance varied among the sites. In 1993, peak densities of insects were found in mid to late June at Cades Cove and Rich Mountain, while densities were greatest in July at Mt. Sterling. Peak densities among sites differed in 1994 from those in 1993. In 1994, insect densities were greatest in early June at Rich Mountain, and in mid July at Cades Cove, while those at Mt. Sterling peaked in July. Environmental conditions, such as harsh weather and cooler temperatures, may have contributed to delays in peak densities of insects at Mt. Sterling, the high elevation site. In this study, insect densities were greatest early in the season

when incidence of *D. destructiva* occurs at its highest levels (M. T. Windham, personal communication).

Percent composition of insect orders was similar for healthy and diseased trees. More insects, numerically, were collected from healthy than diseased trees, but no significant differences were documented between tree types within a year. Insect densities, when averaged across all sampling dates were similar and peaked in late June, in 1993, and mid July, in 1994.

The most common insect orders collected at the Plateau Experiment Station, Crossville, TN, were Coleoptera, Homoptera, and Diptera. More insects were collected in 1994 than in 1993, and significant differences among sampling date and cultivar were detected.

In 1993, Homoptera was the most abundant of the insect orders on dogwoods, at Crossville; however, no significant differences were observed. Coleoptera, Diptera, Hymenoptera, and the total number of insects and arthropods were greatest on the first sampling date. In 1994, Coleoptera was the most abundant of the insect orders collected. Densities of Coleoptera were greatest on the first sampling date, while densities of Homoptera were significantly greater on the seventh sampling date.

Insect diversity and abundance varied among the three cultivars of dogwood, each with a different foliage coloration (green-Cherokee Princess, purple-Purple Glory, and yellow-First Lady). Overall insect densities were greatest on the yellow foliage of First Lady (cultivar Y) than on the Cherokee Princess (cultivar G) or Purple Glory (cultivar

P). Coleoptera was the most abundant insect order represented on each of the three cultivars of dogwood.

In 1993, densities of Coleoptera, Diptera, and Hymenoptera, as well as, the total number of insects and arthropods were significantly greater on cultivar Y than on the other two cultivars. Densities of Homoptera were not significantly different among cultivars, although more (ca. 2 to 3x) were collected from cultivar Y than G or P. In 1994, Homoptera were significantly greater on cultivar Y (First Lady). Insect densities also were greater (ca. 3 to 6x) on this cultivar than on G or P. Studies, testing the attractiveness of insect traps, have shown that lighter colors, such as yellow, are more attractive to many insects than darker colors (Yudin and Mitchell 1987). Johnson and Mueller (1988) observed that significantly greater numbers of Homoptera were captured on yellow sticky traps. No other significant differences were detected among cultivars in 1994, although densities of Coleoptera were numerically greater (ca. 4 to 6x) on cultivar Y than on any other cultivar.

Seasonal abundance of insect orders was similar for each cultivar. Insect densities, in 1993, on each cultivar peaked in late May and those on cultivar Y peaked again in late July; on the other hand, densities, in 1994, peaked during April and again in August on cultivar Y.

Previous greenhouse, laboratory, and field studies have demonstrated that insects can disseminate viable conidia of *D. destructiva* to healthy dogwood foliage and that the foliage can develop lesions symptomatic of dogwood anthracnose (Colby 1993). Because insect densities are greatest when incidence of conidia of *D. destructiva* are present,

insects may play an important role in the epidemiology of dogwood anthracnose. This research will provide a better understanding of the insect taxa associated with dogwood and may be useful in the development and implementation of management programs, especially in nursery environments.

REFERENCES CITED

- Anderson, R. L.** 1991. Results of the 1990 dogwood anthracnose impact assessment and pilot test in the southeastern United States. USDA For. Ser. South. Region Prot. Rep. R8-PR 20, 70 pp.
- Anderson, R. L., P. C. Berrang, J. L. Knighten, K. A. Lawton, and K. O. Britton.** 1993. Pretreating dogwood seedlings with simulated acidic precipitation increases dogwood anthracnose symptoms in greenhouse-laboratory trials. Can. J. For. Res. 23: 57-58.
- Anderson, R. L.** 1990. Results of the 1989 dogwood anthracnose pilot test in the southeastern United States. USDA For. Ser. South. Region Prot. Rep. R8-PR 18, 70 pp.
- Anonymous.** 1991. Growing and maintaining healthy dogwoods. USDA Forestry Report R8-FR 14. March.
- Barrett, S. C. H. and K. Helenurm.** 1987. The reproductive biology of the arboreal forest herbs. I. Breeding systems and pollination. Can. J. Bot. 5: 2036-2046.
- Boring, L. R., C. D. Monk, and W. T. Swank.** 1981. Early regeneration of a clear-cut southern appalachian forest. Ecology 62: 1244-1253.
- Borror, D. J., C. A. Triplehorn, and N. F. Johnson.** 1989. An introduction to the study of insects, 6th ed. Saunders College Publishing. Philadelphia, 875 pp.
- Brown, D. A., M.T. Windham, A. S. Windham, and E. T. Graham.** 1991. Dogwood anthracnose: Questions and answers. The Univ. Tennessee Agric. Exp. Sta. Res. Report 91-06. March. 7 pp.

- Bruck R. I. and L. F. Grand.** 1993. Epidemiology of *Discula destructiva* on *Cornus florida*, pg. 60. In: Proceedings of the 1993 Dogwood Anthracnose Working Group, May 5-7, Chattanooga, TN.
- Byther, R. S. and R. M. Davidson, Jr.** 1979. Dogwood anthracnose. Ornamentals Northwest. Newsletter 3: 20-21.
- Chellemi, D. O. and K. O. Britton.** 1992. Influence of canopy microclimate on incidence and severity of dogwood anthracnose. Can. J. Bot. 70: 1093-1096.
- Chellemi, D. O., K. O. Britton, and W. T. Swank.** 1992. Influence of site factors on dogwood anthracnose in the Nantahala Mountain Range of Western North Carolina. Plant Dis. 76: 915-918.
- Colby, D. M.** 1993. Arthropod dissemination of *Discula destructiva* conidia on *Cornus florida*. M.S. Thesis. The University of Tennessee, 48 pp.
- Daughtrey, M. L. and C. R. Hibben.** 1983. Lower branch dieback, a new disease of northeastern dogwoods. (Abstr.) Phytopathology 73: 365.
- Daughtrey, M. L. and C. R. Hibben.** 1984. Dogwoods, will they survive? Plant and Gardens 39(4): 13-15.
- Daughtrey, M. L., C. R. Hibben, and G. W. Hudler.** 1986. A guide to dogwood anthracnose. American Nurseryman 163: 73-74.
- Daughtrey, M. L., C. R. Hibben, and G. W. Hudler.** 1988. Cause and control of dogwood anthracnose in northeastern United States. J. Arbor. 14: 159-164.

- Dirr, M.A.** 1990. Manual of woody landscape plants: Their identification, ornamental characteristics, culture, propagation and uses, 4th ed. Stipes Pub. Co. Champaign, IL. 1007 pp.
- Eyde, R. H.** 1988. Comprehending *Cornus*: Puzzles and progress in the systematics of the dogwoods. Botanical Rev. 54: 234-351.
- Grant, J. F.** 1993. Insect species associated with dogwood: The good, the bad, and the ugly, pg. 11. IN: Proceedings of the 1993 Dogwood Anthracnose Working Group, May 5-7, Chattanooga, TN.
- Hagan, A. K. and J. M. Mullen.** 1993. Dogwood anthracnose affecting flowering dogwood in Alabama. Highlights Agric. Res. 40(1): 5 pp.
- Hibben, C. R. and M. L. Daughtrey.** 1988. Dogwood anthracnose in northeastern states. Plant Dis. 72: 199-203.
- Holt, H. L.** 1995. Incidence of arthropod infested with conidia of *Discula destructiva* Redlin in forest and cage environments. M.S. Thesis. The University of Tennessee, 48 pp. In press.
- Horsfal, J. G. and R. W. Barratt.** 1945. An improved grading system for measuring plant disease. Phytopathology 35: 655.
- Johnson, M. P. and A. J. Mueller.** 1988. Threecornered alfalfa hopper response to six sticky trap colors. Southwestern Entomol. Soc. 13: 101-105.
- LaBerge, W. E. and D. W. Ribble.** 1972. A revision of the bees of the genus *Adrena* of the Western Hemisphere. Part V. Trans. Amer. Entomol. Soc. 98: 271-357.

- Mielke, M. E. and M. L. Daughtrey.** 1989. How to control and identify dogwood anthracnose. USDA For. Ser. Report NA-GR-18. 8pp.
- Mielke, M. E. and K. Langdon.** 1986. Dogwood anthracnose threatens Catoclin Mountain Park. Park Science (Winter): 6-8.
- Mitchell, W., P. Gibbs, and C. Martin.** 1988. Flowering dogwood, *Cornus florida*: Section 7.5.9., United States Army Corp of Engineers Wildlife Resource Management Manual Technical Report EI-88-9, United States Army Waterways Experiment Station, Vicksburg, MS.
- Neely, D., and E. B. Himeliek.** 1963. Temperature and sycamore anthracnose severity. Plant Dis. Rep. 47: 171-175.
- Redlin, S. C.** 1991. *Discula destructiva* sp. Nov., cause of dogwood anthracnose. Mycologia 83: 633-642.
- Redman, C. E., E. P. King, and I. F. Brown, Jr.** 1969. Tables for converting Horsfal-Barratt ratings scores to estimated mean percentages. Elanco Products Co., Indianapolis, IN.
- Rogers, L. E. and J. F. Grant.** 1990. Infestation levels of dogwood borer (Lepidoptera: Sesiidae) larvae on dogwood trees in selected habitats in Tennessee. J. Entomol. Sci. 25: 481-485.
- Salogga, D. S. and J. F. Ammirati.** 1983. *Discula* species associated with anthracnose on dogwood in the Pacific Northwest. Plant Dis. 67: 1290.
- Santamour.** 1989. Susceptibility of flowering dogwood of various provenances to dogwood anthracnose. Plant Dis. 73: 590-591.

- S.A.S. Institute Inc.** 1989. SAS-STAT users guide version 6. 4th edition. Vol. 2. Cary, NC. 846 pp.
- Schneeberger, N. F. and W. Jackson.** 1989. Dogwood anthracnose at Catoctin Mountain Park. U.S.D.A. For. Ser., Northeastern Area State and Private Forestry, Broomall, PA (unnumbered report).
- Smith, V. L.** 1991. Spring rainfall and cool temperatures favor development of dogwood anthracnose. *Frontiers Plant Sci.* Fall, 4 pp.
- Trigiano, R. N., B. J. Bassam, G. Caetano-Anolles, L. M. Bell, K. R. Weaver, and M. T. Windham.** 1993. Physiological and molecular aspects of dogwood anthracnose fungi, pg. 34-38. IN: *Proceedings of the 1993 Dogwood Anthracnose Working Group*, May 5-7, Chattanooga, TN.
- Venkatasubbaiah, P. and W. S. Chilton.** 1991. Toxins produced by the dogwood anthracnose fungus *Discula* spp. *J. Nat. Products* 54: 1293-1297.
- Walton, G. S.** 1984. Flowering dogwood decline due to drought, disease and cold winters. *Frontiers Plant Sci.* 37(1): 7-8.
- Webber, J. F. and J. N. Gibbs.** 1989. *Insect-fungus interactions*. Academic Press, San Diego, CA, 344 pp.
- White, R. E.** 1983. *Peterson field guides: Beetles*. Houghton Mifflin Co., Boston, 368 pp.
- Windham, A.S., M. T. Windham, and C. H. Hadden.** 1991. Disease of flowering dogwood. *University Tennessee Agric. Ext. Service Report SP370F*. July.

Yudin, L. S. and W. C. Mitchell. 1987. Color preference of thrips (Thysanoptera: Thripidae) with reference to aphids (Homoptera: Aphididae) and leafminers in Hawaiian lettuce farms. *J. Econ. Entomol.* 80: 51-55.

APPENDIX

Table A1. Table listing some of the insect taxa represented in samples from the Great Smoky Mountains National Park during 1993 and 1994.

ORDER	FAMILY	GENUS	SPECIES
Collembola	Entomobryidae	--	--
Blattaria	Blattellidae	--	--
Coleoptera	Alleculidae	--	--
	Anobiidae	--	--
		<i>Petalium</i>	--
	Buprestidae	--	--
	Cantharidae	--	--
	Carabidae	--	--
	Cerambycidae	--	--
	Chrysomelidae	--	--
	Coccinellidae	--	--
	Curculionidae	--	--
	Dermestidae	--	--

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
	Elateridae	--	--
	Eucnemidae	--	--
	Lagriidae	--	--
	Lampyridae	--	--
	Lathridiidae	--	--
	Lycidae	--	--
	Melandryidae	--	--
	Mordellidae	--	--
	Rhipiceridae	--	--
	Scarabaeidae	--	--
	Scolytidae	--	--
		<i>Ips</i>	--
		<i>Ips</i>	<i>pini</i>

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
Diptera	Silphidae	--	--
	Staphylinidae	--	--
	Tenebrionidae	--	--
	Aceroceridae	--	--
	Agromyzidae	--	--
	Anthomyiidae	--	--
	Asilidae	--	--
	Bibionidae	--	--
	Bombyliidae	--	--
	Calliphoridae	--	--
	Cecidomyiidae	--	--
	Ceratopogonidae	--	--

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
	Chironomidae	--	--
		<i>Cardiocladius</i>	<i>obscurus</i>
	Chloropidae	--	--
	Dolichopodidae	--	--
	Empididae	<i>Leptozeza</i>	<i>disparilis</i>
		<i>Stilpon</i>	--
	Lauxaniidae	--	--
	Muscidae	--	--
	Mycetophilidae	--	--
	Phoridae	--	--
	Pipunculidae	--	--
	Platypezidae	--	--
	Rhagionidae	<i>Rhagio</i>	--

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
	Sarcophagidae	--	--
	Scatopsidae	--	--
		<i>Colobostema</i>	--
	Sciaridae	--	--
	Simulidae	--	--
	Sphaeroceridae	--	--
	Stratiomyidae	--	--
	Tachinidae	--	--
	Tipulidae	--	--
Hemiptera	Coreidae	--	--
	Corimelaenidae	--	--
	Largidae	--	--

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
Homoptera	Miridae	--	--
	Nabidae	--	--
	Pentatomidae	--	--
	Aphidae	--	--
	Cercopidae	--	--
	Cicadellidae	--	--
	Cixiidae	--	--
	Delphacidae	--	--
Hymenoptera	Membracidae	--	--
	Bethylidae	--	--
	Braconidae	--	--
	Ceraphronidae	--	--
	Diapriidae	--	--

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
	Diprionidae	--	--
	Encyrtidae	--	--
	Eucoilidae	--	--
	Eulophidae	--	--
	Eupelmidae	--	--
	Formicidae	--	--
	Ichneumonidae	--	--
	Megaspilidae	--	--
	Mymaridae	--	--
	Platygastridae	--	--
	Pteromalidae	--	--
	Scelionidae	--	--
		<i>Ioris</i>	<i>binotatum</i>

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
		<i>Paridris</i>	<i>larviceps</i>
		<i>Probaryconus</i>	<i>striatus</i>
		<i>Scelio</i>	<i>strativentris</i>
		<i>Trissolcus</i>	<i>euschistus</i>
	Sphecidae	--	--
	Torymidae	--	--
Isoptera	Rhinotermitidae	--	--
Mecoptera	Panorpidae	--	--
Microcoryphia	Machilidae	--	--
Neuroptera	Chrysopidae	--	--
Orthoptera	Acrididae	--	--
	Gryllidae	--	--
		<i>Oecanthus</i>	<i>fultoni</i>

Table A1. (continued)

ORDER	FAMILY	GENUS	SPECIES
	Tettigoniidae	--	--
Psocoptera	Psocidae	--	--

VITA

D. Scott Neitch was born Marion, Virginia, on December 7, 1969. He attended elementary schools in Marion, Virginia, and graduated from Marion Senior High School in June, 1988. The following August he entered Carson-Newman College, Jefferson City, Tennessee, and in December, 1992, recieved a Bachelor of Arts Degree in Biology. In the winter of 1993, he accepted a research assistantship at The University of Tennessee, Knoxville, and began study toward a Master's degree under the supervision of Dr. Jerome F. Grant and Dr. Mark T. Windham. In May of 1995, he recieved his Master of Science Degree with a major in Entomology and Plant Pathology. D. Scott Neitch is a member of the Entomological Society of America and the Tennessee Entomological Society.