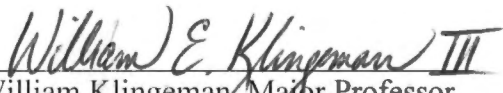
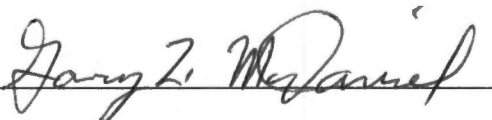
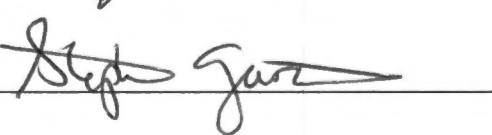


To the Graduate Council:

I am submitting herewith a thesis written by Deborah Ruth Ketchersid entitled "Dogwood Production Challenges: Budwood Production and Whitefringed Beetle Management." I have examined the final paper 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 Ornamental Horticulture and Landscape Design.


William Klingeman, Major Professor

We have read this thesis and
recommend its acceptance:

Acceptance for the Council:


Vice Provost and Dean of Graduate Studies

AG-VET-MED.

Thesis
2003
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DOGWOOD PRODUCTION CHALLENGES:
BUDWOOD PRODUCTION AND WHITEFRINGED BEETLE MANAGEMENT

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Deborah Ruth Ketchersid

August 2003

Dedication

This thesis is dedicated to Dr. Bill Klingeman, Harald, Alex, and Amy Neubauer, my parents, William and Lee Ketchersid, my brothers Bill and John Ketchersid, my sister, Beth Rodriguez, Abbi, Morgan, Josh, and Julie, Charlene Schwenk, Chris and Julie Turner, Riki and Herby DeWees, and the rest of my family and friends. Thank you for all the prayers, love, and encouraging words.

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Abstract

Dogwoods are one of Tennessee's most important nursery crops. Yet, dogwoods are challenged by several disease and insect pests in production and landscape systems. Powdery mildew and dogwood anthracnose are diseases that severely impact native stands, production fields, and landscape plantings of dogwoods. Researchers at the University of Tennessee have developed the 'Appalachian' series of dogwoods: 'Appalachian Spring' is resistant to dogwood anthracnose. 'Jean's Appalachian Snow,' 'Karen's Appalachian Mist,' and 'Kay's Appalachian Blush' are resistant to powdery mildew. Unfortunately, to reproduce the desirable genetic traits found in these trees, these cultivars must be propagated by bud grafting. Low availability of budwood has slowed release to commercial growers and, in turn, the public. Our efforts sought to find an optimum nitrogen fertility rate for budwood production in five commercially important dogwoods. Results indicate that although bud numbers were not affected by fertility treatment, 5.3 kg/m³ (9 lbs/yd³) of Osmocote 18-6-12 yielded optimum shoot growth and caliper in sufficiently irrigated dogwoods. This study also demonstrated that management practices, including proper planting time and water availability, play a crucial role in dogwood performance. Finally, different species and cultivars of dogwood responded differently to higher rates of nitrogen fertility, underlining the fact that growers need to tailor their production practices to the specific species and cultivars that they produce.

Whitefringed beetle larvae (*Naupactus leucoloma*) girdle roots of young seedling liners. In Tennessee, flowering and kousa dogwood (*Cornus florida* and *C. kousa*) have been affected by larval injury. In an attempt to quantify the damaging capacity of

whitefringed beetle larvae flowering and kousa dogwoods were infested with 0, 1, 3, 6, or 9 larvae and grown for two months in 2002 and again in 2003. Larval damage was most severe in pots with 6 larvae. Young, seedling liners with few lateral and fibrous roots were most affected by larval root injury. Severe root injury resulted in stunted growth and in some cases death of the tree.

Whitefringed beetle adults are parthenogenic. Adult fecundity and longevity are directly affected by host plant leaf tissue. The impact of ornamental food resources on longevity and fecundity of whitefringed beetles has not been assessed. Foliage of 10 common ornamental species, a common weed, and peanut were fed to 360 individually caged whitefringed beetle adults during 2002. Fecundity and longevity were recorded. Kobus magnolia (*Magnolia kobus*) induced greatest longevity in beetles. Witchhazel (*Hamamelis virginiana*) and the two dogwood species, which can experience extensive root damage in the field, did not yield high longevity and fecundity in whitefringed beetles. Still, these plants should not be grown near ornamentals that enhance fecundity, like kobus magnolia or yellowwood (*Cladrastis kentukea*). Infested fields should also be kept free of weeds and high-risk crops should be rotated within a field on three to four year intervals. Inclusion of a cover crop, like sudax, oats, or a small grain or cereal can alleviate populations of whitefringed beetles, while leguminous cover crops, like red clover, should not be planted where whitefringed beetles are a concern. Finally, the presence of adult beetles should be monitored and adults should be targeted with insecticidal sprays as soon as they emerge. Since adults emerge throughout the season, continuous monitoring for adults and possible repeat insecticide treatments will be necessary.

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Nomenclature

EC: Electrical conductivity measured in microsiemens (μS)

cm: centimeters

g: grams

in: inches

kg: kilogram

km: kilometer

l: liter

lb: pound

m: meter

ml: milliliter

mm: millimeter

oz: ounces

ppm: parts per million

μS : microsiemens

Part 1: Literature Review

Current Challenges to Nursery Production In Tennessee

Tennessee's Nursery Industry

Nursery production in Tennessee dates back to the 1800's. Tennessee growers initially produced fruit trees. Prior to World War II, consumers had little interest in products other than fruit trees. It was not until after the war, that Tennessee growers began to concentrate their production on ornamental plants.

Nursery production totaled \$20 million in 1972 and grew to \$100 million in 1981. At that time, among row crops grown in Tennessee, only soybeans, corn, and tobacco were of greater value. In 1984, there were 767 certified nurserymen in the state, with 25,168 acres under production (Glasgow 1985). In 1986 nursery and greenhouse crops were the number one agricultural crop in Tennessee, with an estimated value of \$205 million that year (Bryan 1988). By 1995, Tennessee had 950 licensed producers. They were cultivating about 42,000 acres with an estimated value exceeding \$150 million (Nursery Extension Program 2002). Today, fruit trees make up only 3% of nursery crops grown in Tennessee. Deciduous trees make up 39.5% of Tennessee's nursery production (Brooker et al. 2000). Flowering trees, like dogwoods make up 27% of production (Nursery Extension Program 2002). In 1984, the flowering dogwood and its cultivars claimed 16% of Tennessee's nursery production effort (Glasgow 1985). In 1998, Tennessee's dogwood sales were \$6.1 million (Gardner et al. 2002). Tennessee dogwoods accounted for 23.2% of the nation's sales and the state ranked number one in dogwood production in 1998 (Klingeman et al. 2001). Many counties in Tennessee produce seedlings, which were sold to out-of-state nursery growers. When these unfinished dogwoods are taken into account, six counties in the State supply 80% of the nation's dogwoods (Gardner et al. 2002).

There are nursery producers all over the state, but the center of Tennessee's nursery industry is in Middle Tennessee—five counties around McMinnville, Tennessee. The majority of nursery producers are found in Warren County. In 1987, Tennessee had 663 nursery producing farms growing on 22,160 acres. In Warren County, 334 of those farms comprised 14,148 of the 22,160 acres in production. The location, soils, and climate of this county make it ideal for nursery production (Hill 1990).

Dogwoods: A Niche Commodity for Tennessee Producers

Most dogwoods are either shrubs or small trees and are used for ornamental purposes. They can be divided into two groups: those with red fruit and those with blue-black fruit. Most of the species with red fruit have large showy bracts surrounding a terminal cluster of tiny true flowers. All of these are trees except for the bunchberry, a low-growing ground cover that is found in northern climates. Most of the blue-fruited dogwoods are shrubs. They have flat-topped flowers in tiny clusters called cymes or umbels. They do not have the large, showy bracts for which the flowering dogwood is famous.

Cornus florida, the native flowering dogwood, belongs to the red-fruited group. It grows to be a small tree and is considered one of the most beautiful trees in the world. The tree has ornamental value in all seasons: a glorious flower; green foliage; red berries; brilliant red, fall color; and a nice winter silhouette (University of Tennessee Agricultural Extension Service 1969). Most of the flowering dogwoods found in the wild have white bracts. The first pink flowered tree was found in Virginia in 1731 by the field botanist Mark Catesby, but naturally occurring pinks or reds are unusual (Glasgow 1985). The species has been cultivated so that many different types are now available. They can

have large, white, pink, or red bracts; variegated leaves; double bracts; weeping or dwarf growth habits; and other special characteristics like disease resistance or drought tolerance (Witte et al. 2001).

Dogwoods are in the family *Cornaceae* and belong to the genus *Cornus*. The genus name derives from *Cornu*, which is Latin for horn—an allusion to the hard wood of the plant (Harkness 1964). *Cornus florida* and *Cornus kousa* together are two of the most commercially popular dogwood species. *Cornus florida*, the flowering dogwood, as previously mentioned, is native to the Eastern United States from the Gulf of Mexico and central Florida to east Texas, Oklahoma and Arkansas to Chicago and southern New England. The trees normally grow 12-20 feet tall with an average trunk caliper of 6-12 inches. The tree is considered to be medium-lived in the landscape, but can live up to 100 years under good conditions. The plant flowers in mid-spring. Four showy bracts with notched tips, expand and turn white, centered around a cluster of four or twenty tiny true flowers with four petals, four stamens and one stigma. In the fall, red berries are produced that are valued as food for birds and wildlife. They were once made into jam by the pioneers in the United States, as well. There are a few yellow-fruited forms of this species. The tree has distinctive bark that is broken into small square blocks. The flowerbuds resemble buttons and occur on upturned horizontal branches in winter. More than eighty cultivars of this species have been developed from seed or mutations over the years and breeding for better plants is still under way. As previously mentioned, there is an occasional a pink or red dogwood found in the wild, but most are propagated by bud grafting. Unnamed selections are often sold as ‘*Rubra*’, which apparently means any pink type of dogwood. Most pink and red varieties are not as winter hardy or as heat

tolerant as the white cultivars. They have a unique red tinge on their new foliage and especially brilliant red fall color. Another mutation in *Cornus florida* is variegated foliage. Variegation occurs when mutations block development of chlorophyll in one or more layers of leaf tissue. The variegated leaf is usually cream, yellow, or golden in places where chlorophyll had been blocked, because of the presence of xanthophylls and carotene pigments that are present in the tissue, but usually masked by the green of the chlorophyll. It is possible for several layers of leaf tissue to be effected independently, resulting in leaves with multicolor variegations, blotches, marginal bands, or irregular splashes along leaf veins. Often variegation persists more strongly if plants are grown in full sun. Sometimes in shade, the chlorophyll will eventually develop throughout the entire leaf, causing the variegation to fade. Variegated plants have less chlorophyll than normal plants, so they develop at a slower pace and have fewer bracts. It is easier for the white or yellow part of the leaf to scorch when stressed and these parts of the leaf also begin to show fall color earlier than the greener parts of the leaf (Witte et al. 2001).

There are many popular cultivars of *Cornus florida*. Recently, an Alabama study evaluated 38 *Cornus* cultivars for growth and mortality patterns in that state (Hardin, et al. 2002). “Dogwoods for American Gardens,” publication 1670 of the University of Tennessee Agricultural Extension Service gives an up to date and extensive list of the most popular cultivars available (Witte et al. 2001).

Cornus kousa, the Japanese or Chinese dogwood is native to China, Japan, and Korea. This tree will grow in the United States anywhere the native flowering dogwood grows. Kousa dogwoods are considered to be more drought tolerant, require more sunlight, and be more cold hardy than flowering dogwood (Hardin, et al. 2002). Kousa

blooms have four-pointed flower bracts that appear a few weeks later than those of the flowering dogwood. The foliage on this tree develops before the bracts appear. The bracts are long-lasting and are displayed above the leaves on long flower stems. The fruit is large, red, round, and edible. The fruits hang under the branches on long stalks as they mature. When mature, these trees have beautiful flaking mottled bark patterns on a smooth trunk. Sometimes kousa bracts become tinted with pink during cool weather or stress. Growers would like to select a variety with bracts that are considered truly pink. ‘Heartthrob’ is a new introduction that has deep pink or red blooms. There are about 70 different cultivars of *Cornus kousa* that have been selected for different special features, like size, bloom, hardiness, or habit. A good reference for kousa cultivars is “Dogwoods for American Gardens,” publication 1670 of the University of Tennessee Agricultural Extension Service.

Several pests and diseases plague dogwoods. Often, poor cultural practices cause a decline in the physical condition of the tree, leaving it open for infestation by insects and diseases. Hot, dry weather, full-sun, and accidental injuries with garden tools can provide the opening through which pests enter the plant tissues (Witte et al. 2001).

The dogwood borer, *Synanthedon scitula* (Harris), is the most destructive insect pest of the dogwood. The larvae damage the tree by boring under the bark on the trunk and at the base of older branches. Usually, the tree will not die from feeding injury unless there are many larvae in one tree. The insect favors trees grown in full sun, therefore native trees growing in the understory are seldom attacked. Often trees attacked by dogwood borers have been first stressed or injured in some way. Damage can be prevented by protecting the trunk from larvae or removing larvae after it is in the trunk.

Some ways to prevent injury are to prune in late winter to provide time to heal quickly in spring; mulch around trees to avoid lawnmower injury; spray the lower limbs and trunk with insecticide to kill newly hatched larvae (Witte et al. 2001).

Two spotted spider mite, *Tetranychus urticae* (Koch), populations can build in hot, dry weather and damage dogwood leaves. Spider mites suck cellular fluids from the leaves. After heavy feeding injury, the leaf will become yellow, bronzed, or completely killed. Mites are found on the underside of the leaf and one sign of their presence is webbing, which will be present on the tree. Mites can be controlled, once detected, by insecticides or horticultural oils (Witte et al. 2001).

Another insect pest of the dogwood is the whitefringed beetle, *Naupactus leucoloma* (Boheman). The larval stage of this insect gnaws into the roots causing severe injury or girdling. Young, seedling liners are most affected. The plants will yellow, wilt, and eventually die as a result of larval feeding (Young et al 1950). Whitefringed beetle larvae are hard to control with soil insecticides, therefore the recommended practice is to target the adults (Zehnder 1997). Adults begin to emerge in June and can be detected by scouting for feeding injury, which appears as a characteristic c-shaped scar on the leaf margin.

There are several diseases that will attack dogwoods, especially when trees have been weakened by environmental or cultural practices. Two diseases, which recently began to have a serious impact on dogwoods, are dogwood anthracnose and powdery mildew. Since 1988, native stands and landscape plantings of flowering dogwoods have been severely impacted by these diseases. Consequently, nursery sales and production of dogwoods have declined (Klingeman et al. 2001).

Dogwood anthracnose is caused by the fungal pathogen *Discula destructive*.

Symptoms include lesions with purple or reddish borders, leaf and twig blights, epicormic branching, and limb and trunk cankers. The disease is accelerated by cool, wet weather; shaded environments; high elevations; high humidity; or north-facing slopes. Good cultural practices can prevent this disease. Trees should be placed in a sunny location, with plenty of air circulation. Furthermore, trees should only be purchased from reputable nurseries to avoid purchase of an infected plant. Some dogwoods have resistance to this pathogen. Most *Cornus kousa*, *C. alternifolia*, *C. sericea*, *C. controversa*, and *C. mas* are resistant. ‘Appalachian Spring,’ a cultivar of the flowering dogwood is resistant to dogwood anthracnose (Windham et al. 1998).

Powdery mildew in dogwoods is caused by *Erysiphe* (sect. *Microspora*) *pulchra* (Cooke and Peck). The disease is characterized by white aerial hyphae on the leaf surface. Severe infection can cause trees to be stunted and distort the foliage. Severe infestation may also result in a reduction in winter hardiness, because the disease interferes with plant photosynthesis and metabolism, causing it to have a lower supply of carbohydrates to sustain it through dormancy. Powdery mildew is favored by warm, dry weather followed by cool nights. High relative humidity is the key to development of powdery mildew. The disease can be controlled by spraying with appropriate fungicides, if spraying is started at the early stages of the infection. There are some trees with resistance to powdery mildew. ‘Cherokee Brave’ is a red cultivar of flowering dogwood that appears to be resistant. The UTIA experiment station has developed three cultivars of *Cornus florida* that are resistant to powdery mildew. They include ‘Karen’s Appalachian Blush,’ Kay’s Appalachian Mist,’ and ‘Jean’s Appalachian Snow.’ These

white-bracted cultivars are not expected to be commercially available until 2005 (Witte et al. 2001).

Dogwoods are obligate outcrossers, therefore there some genetic variability exists in every new crop of seed. Specific cultivars cannot be produced from seed and must be produced by other methods (Witte et al. 2001). In Tennessee, dogwoods are usually produced in two ways. The most popular method is bud grafting. The process requires a certain degree of expertise in correctly inserting the bud. In 1984, the average cost to produce a 4 to 6 foot flowering dogwood from a budded seedling was \$5.47 (Glasgow 1985). The other popular method of production of dogwood cultivars is by growing them from rooted cuttings. The cost to produce a 4 to 6 foot flowering dogwood from a rooted cutting in 1984 was \$7.35 per tree. In 1989, the cost to produce a 5 to 6 ft dogwood from a cutting rose to \$9.64 per tree in a small nursery and \$8.30 per tree in a medium size nursery (Johnson and Tilt 1989). Production from cuttings costs more because the cuttings have to be overwintered in a greenhouse, as well as the added cost of propagation materials, such as mist irrigation systems, and greenhouse equipment. Cuttings also have a much lower survival rate in the field (Glasgow 1985).

Although bud grafting and rooted cuttings are the most popular methods of producing dogwood cultivars, these processes are time consuming and labor intensive. Researchers are working to produce dogwoods through tissue culture, but to date there has not been consistent success. Growers and researchers alike are interested in ways to speed growth of cultivars and increase the number of buds produced. With more buds, growers and researchers will be able to increase the stock of valuable cultivars much more quickly. One possible method of speeding bud production in dogwoods is to

increase the amount of nitrogen fertilizer applied to young plants. If it could be shown that a high concentration of nitrogen greatly increases the bud production in young dogwoods, researchers and producers alike would benefit.

Whitefringed Beetle

Whitefringed beetles [*Naupactus leucoloma* Boheman (Coleoptera: Curculionidae)] were first discovered in the United States in 1936. Initially found in Florida, they quickly spread throughout the southeastern United States. As they spread, a concern began to grow about the potential damage they could inflict on agricultural crops. Scientists and farmers soon had their answers--whitefringed beetles became a serious threat to agricultural crops. In 1938, populations of adult whitefringed beetles in a cotton field in Alabama were estimated to exceed 240,000 per acre, or 48 adults per plant (Young and App 1939). Within 16 years of introduction, the beetles could be found on more than 360,000 acres in the southeastern United States. During the initial migration, economic damage to crops from larval feeding was severe. One farmer suffered a 94% crop loss in potatoes due to injury from feeding by whitefringed beetle larvae (Young et al. 1950). In response, the Federal Government instituted quarantine measures to restrict the spread of the whitefringed beetles.

Recognizing the potential threat from whitefringed beetle larvae to agricultural crops, researchers and farmers have attempted to control the problem. The USDA published several pamphlets on how to combat whitefringed beetles beginning in 1939 (Young and App 1939; Hernderson and Padget 1949; Young et al. 1950; USDA 1972). In Texas, when the pest was first discovered, the state was urged to take action to protect crops that might be threatened (Eggart, et al 1990). In Alabama, methods were

investigated for controlling the pest in sweet potato crops (Zehnder 1997). Workers in agricultural commodities that are threatened by crop damage from whitefringed beetles have recognized the threat and taken steps to combat it. However, the ornamental nursery industry has been slower to realize the danger of whitefringed beetles, although, as early as 1946, inspectors in Georgia identified whitefringed beetle populations in nurseries (Gross et al. 1972). Recently, an isolated infestation of whitefringed beetles in a California residential community was thought to have been introduced by containerized ornamentals (Zehnder 1997).

The whitefringed beetle has been in Tennessee since 1948. Because of the rapid population development and the high probability of establishment once a population is founded, the whitefringed beetle represents a potential threat to Tennessee ornamental production. Most nurserymen are not expected to recognize whitefringed beetles as pests. Once the beetle adults were identified, one nurseryman realized that he had always had whitefringed beetles on his land, but had never targeted them specifically as a pest to his nursery plants (Ketchersid, unpublished data). One reason for this may be that the visible adults do not do significant damage. Subterranean larval feeding injury could easily be attributed to some other problem or pest. Plants whose roots have been girdled appear to be drought stressed. Growers may assume drought stress is the only problem. Observations suggest that whitefringed beetles may contribute significant economic injury to ornamental crops in Tennessee including, *Cornus kousa*, *Cornus florida*, *Magnolia sieboldii*, *Cladrastis kentukea*, *Hydrangea quercifolia* and *Hamamelis virginiana* (DRK, personal observations).

Much of the research and writing concerning the whitefringed beetle has focused on the problems it causes in other areas of agriculture. However, significant economic damage from larval feeding in Tennessee nurseries has been observed. A thorough investigation into the biology and behavior of the whitefringed beetle, within ornamental production systems, is necessary to begin to understand the potential economic damage this insect may cause to the Tennessee nursery industry. The information collected from previous research on the beetles in other areas of agriculture can be used as a starting point for assessing viable management strategies for whitefringed beetles in the ornamental nursery system.

History and Range of Whitefringed Beetle Populations

The whitefringed beetle was accidentally imported to the United States in the early 1900's from South America. The beetles probably entered the country at various southern ports on goods and ships coming from the pests' native areas. On their native continent, whitefringed beetles inhabit an area that ranges from 23 to 29 degrees south latitude to a southern limit of 40 degrees south latitude. The temperature in this geographic region, which includes Argentina, Brazil, Chile and Uruguay, ranges from a 14° C to a 21° C (57° F to 70° F) isotherm (Henderson and Padgett 1949). In Chile, the beetles range from the irrigated district of La Serena south to Angol. In Argentina whitefringed beetles are found in the provinces of San Juan, La Pampa, and Rio Negro. The beetles are generally distributed throughout the country of Uruguay. In Brazil, they are found in limited numbers, mostly in Rio Grande do Sul (Henderson and Padgett 1949).

In September 1936, beetles were collected in Okaloosa County Florida. The Florida Agricultural Experiment Station's Division of Insect Identification analyzed the

specimens and identified them as the whitefringed beetle; the species that is now called *Naupactus leucoloma*. Later that same year, more beetles were found in Okaloosa and Walton Counties in Florida. Shortly after, they were discovered in Covington and Geneva Counties in Alabama. During 1937, whitefringed beetles were detected in Louisiana and Mississippi. Despite a Federal quarantine, which was enacted in 1939, and numerous state quarantines and restrictions that attempted to limit the movement of whitefringed beetles, the insects were found in North Carolina in 1942, Georgia in 1946, and Tennessee in 1948 (Gross et al. 1972). By July 1975, Tennessee and most other states had repealed their quarantines because of failure to restrict the spread of the beetle (TCA Chapter 0080-6-8). Almost the entire Southeastern United States now hosts populations of these beetles. They range as far west as Arkansas and north into Kentucky and Virginia (Barnes 1971). Isolated populations also exist in parts of Texas, New Mexico, and California. In October 1986, the first adult was found at Buffalo Springs Lake, Texas. By September 1987, adults and larvae were identified on alfalfa in New Mexico (Eggert et al. 1990). An isolated infestation of whitefringed beetles has been discovered in a residential area near Riverside, California, feeding on white clover, *Melilotus alba* (Zehnder 1997). In the United States, scientists have mapped a potential range for the beetles that is comparable to the latitude and temperature isotherm ranges identified in South America. This information suggests a northern limit of Philadelphia, Pennsylvania, with the tip of Florida existing as the southern limit of potential infestation. Potentially, the range of the whitefringed beetle could include large expanses of the western United States, which have not yet received any whitefringed beetle populations (Henderson and Padgett 1949). In addition to temperature and latitude, other factors must

affect whitefringed beetle distribution. Soil type, temperature in winter, and land usage may have an impact as well. Chilean whitefringed beetles inhabit areas with varying amounts of rainfall, ranging from 20 to 100 inches a year. This variability suggests that abundant rainfall is not a critical factor for development, thus rainfall has not been considered to have a major role in determining whitefringed beetle range (Henderson and Padgett 1949). Recently, research indicates that the beetles need a warm and fairly moist environment (Matthiessen and Learmonth 1992). They do not thrive in dry areas, which could explain the reason that they do not exist in regions of the western United States that lie within their potential range.

Beyond North America, the beetles are now found in southeastern Australia in New South Wales, New Zealand, and South Africa (Eggert, et al 1990). Whitefringed beetles are thought to have entered parts of South Africa in imported fodder. They were first identified in 1941 at Rosebank, Capetown. They subsequently spread to Stellenbosch, Urendal, Koehe Kap, Robertson Beuford Wet, Upington, and in 1972 the irrigated area of the Lower Orange River (De Jager et al. 1987).

Economic Impact of Whitefringed Beetle Populations

In their native South America, adult whitefringed beetle populations are thinly distributed. Still, the larvae are damaging to certain plants in their native range. Damage is most severe in areas of South America where the beetles have been accidentally introduced (Matthiessen and Learmonth 1995). Generally, beans, strawberries, lettuce, peppers, and nursery plants are plagued by the damaging grubs (Berry 1947).

Throughout Chile, damage to beans and lentils is common. Near Angol, Chile, severe damage has also been observed on nursery stock and lettuce (Berry 1947). Potatoes and

alfalfa are crops that suffer severe damage from whitefringed beetle larvae throughout South America (Berry 1947).

In New Zealand, whitefringed beetles are commonly found in pastures and lucerne in many parts of the North Island as well as several localities on the South Island. Damaged plants include lucerne, pasture species, exotic forest seedlings, peas, and potatoes (East 1977). In southwestern Australia, whitefringed beetle larvae are particularly troublesome pests in potato production (Matthiessen and Learmonth 1992). Beetles that have migrated to South Africa, especially the Lower Orange River irrigation area, cause severe damage to lucerne (De Jager et al. 1987).

Despite early quarantine measures, several crops in the United States have suffered damage from the whitefringed beetle including: peanuts, cotton, velvetbean, soybean, lespedeza, lima bean, okra, potato, cowpea, chufa, corn, tomato, and clovers (Eggert et al. 1990 and Young et al. 1950). The economic extent of losses among these crops that can be attributed to the whitefringed beetle has been largely unexplored. Although, a few crop loss figures have been reported. Whitefringed beetle larvae reduced peanut production an average of 15% when no control methods were employed (Young et al. 1950). When the beetle spread to Texas in 1986, many crops, including cotton, peanuts, soybean, alfalfa, corn, potatoes, wheat, and sunflower seeds, were threatened. A preliminary study urged producers and the state of Texas that to take steps to control whitefringed beetles. It would be economically favorable if the state implemented a suppression program (Eggert et al. 1990). In Alabama, sweet potato production has been plagued by damage from whitefringed beetle larvae. Larvae in the 4th-7th instar stages target the sweet potato crop in September, during the crop's last few

weeks before harvest. The economic damage is severe and scientists are searching for methods to control the pest problem in Alabama (Zehnder 1997). Comparatively lighter populations of beetles than would be necessary to destroy field crops threaten truck and garden crops. Strawberry plants are especially susceptible to larval damage and some garden plantings have been completely destroyed (Young et al. 1950).

Surveys for beetles in 1946, detected an infestation in Georgia ornamental nurseries (Henderson and Padget 1949). An isolated infestation of whitefringed beetles was encountered in a residential area near Riverside, California. The beetles were found feeding on *Melilotus alba*, white clover. Evidence suggests that this population was introduced from infested containers of ornamental plants (Zehnder 1997). In Tennessee, plant injury from whitefringed beetles has been encountered in ornamental nurseries during 2000, 2001, and 2002 (DRK, personal observations).

In infested crops, larval feeding on the roots causes economic damage. Injured plants will become chlorotic, wilt, and die. If damage is slight, plants will survive in a weakened and unusable state. Crop damage is typically not uniform over a widespread area. In a single field, one end of a row may be destroyed, while the opposite end seems untouched (Young et al. 1950; DRK, personal observations). Furthermore, if a stand is destroyed by larvae and then the field is replanted, the subsequent crop may be destroyed. Often a crop will have to be abandoned and the producer suffers the economic loss of fertilizer, seed, and labor involved in preparing and planting the field, along with any profit that may have been anticipated from the planting. Severity of crop damage is seldom sustained in the same field for more than 2 or 3 consecutive years. One hypothesis is that larvae may eliminate all food resources. Once reduced, larval

populations may again reach injurious proportions if light infestations are allowed to persist for 1 or 2 years in a field that had been previously infested with injurious numbers (Young et al. 1950).

Taxonomy of the Whitefringed Beetle

When whitefringed beetles were first discovered in the United States, they were assigned to the genus *Graphognathus* (Buchanan 1939). The species in question were originally considered to belong in the genus *Naupactus* Dejean. In 1939, Buchanan separated the genus *Pantomorus* from the *Naupactus* group because *Pantomorus* specimens had reduced humeri and the absence of metathoracic wings, which are present in the *Naupactus* group. *Graphognathus* became a subgenus. Originally, four subgenera were recognized within *Graphognathus* Buchanan, including *P. (G.) leucoloma* (Boheman) and *P. (G.) peregrinus* (Buchanan), *Atrichonotus* Buchanan, *Asynonychus* Crotch, and *Phacepholis* Horn. Buchanan described the four North American species of *Pantomorus*, subgenus *Graphognathus*: *P. (G.) minor*, *P. (G.) pilosus*, *P. (G.) striatus*, and *P. (G.) dubius* in 1942. Buchanan (1947) later raised the subgenus *Graphognathus* to generic rank. These were the three species he included in the genus—*G. leucoloma* (designated as type species), *G. peregrinus*, and *G. minor*. Six North American subspecies were placed within *G. leucoloma*: *G. l. leucoloma*, *G. l. pilosus*, *G. l. striatus*, *G. l. dubius*, *G. l. fecundus*, and *G. l. imitator*. In 1975 *G. l. fecundus* was raised to full species and considered a synonym of *G. l. imitator* (Warner 1975). The remaining subspecies of *G. leucoloma* were synonymized as well (Warner 1975). *G. leucoloma*, *G. minor*, *G. peregrinus*, and *G. fecundus* became the four valid species in North America.

In 1986, *G. fecundus* was established as a synonym under *G. leucoloma* (Wibner and O'Brien 1986).

When Buchanan established the genus *Graphognathus*, he had not compared it with the South American species of *Naupactus*, only with the species of *Pantomorus* found in the U.S.A. The study of the South American *Naupactus* indicates that *N. albolateralis* and *N. tucumanensis* are very similar to *Graphognathus*. One character used by Buchanan to diagnose *Graphognathus* was the presence of a shallow sulcus bounded on each side by a blunt carina, which extends from the lower edge of the sulcus to the lower edge of each mandible. The character can only be found in *G. leucoloma* and lacks generic or species group importance (Lanteri and Marvaldi 1995). The genitalia of the species assigned to *Graphognathus* are like those of the species of *Naupactus* and do not allow generic differentiation. For example, the presence of rows of setae beside the baculi is one of the most important characters to diagnose *Naupactus* and it is also present in *G. leucoloma*, *G. peregrinus*, and *G. minor*. The few features that differentiate the species of *Graphognathus* from *N. albolateralis* and *N. tucumanensis* cannot be considered as generic. Therefore *Graphognathus leucoloma*, *G. peregrinus*, and *G. minor* can be joined with two species found only in South America. *Naupactus* and *Graphognathus* are now considered synonyms. The *Naupactus leucoloma* species group now describes the five species of whitefringed beetles native to South America. *N. leucoloma*, *N. peregrinus*, and *N. minor* have been introduced to areas outside of South America, while *N. albolateralis* and *N. tucumanensis* are found only in South America (Lanteri and Marvaldi 1995).

One good way to differentiate between the different species of *Naupactus* found in the United States is by examining the genitalia. The spermathecae differ in *N. leucoloma*, *N. peregrinus*, and *N. minor*. In *N. leucoloma* the spermatheca is subcylindrical, the ramus is not developed, the cornu is strongly curved, and it is longer than in the other species. *Naupactus minor* differs from *N. leucoloma* because it is smaller with less convex eyes, shorter and more recumbent setae, a more elongate pronotum, and a broader corbel plate on the hind tibiae. *Naupactus peregrinus* is smaller than *N. leucoloma* and *N. minor*. The lateral carinae of rostrum is indistinct, humeri is strongly reduced, and setae on posterior half of pronotum are basally directed (Lanteri and Marvaldi 1995).

Biology of the Whitefringed Beetle

Whitefringed beetle eggs are approximately 0.9 mm (0.04 in) in length and 0.5 mm (0.02 in) in width. Eggs are oval and whitish when laid, but over time darken to a cream color (Barnes 1971). Eggs are laid in masses of 20-60 eggs per mass (May 1975). Egg masses are covered with a sticky, bubbly mucus that cements them to each other and to objects on which they are deposited. Deposition substrates typically include sticks, stones, plant stems, roots, or even soil and eggs are normally deposited in shaded places beneath plants (Barnes 1971). The mucus hardens into a protective film that enables the eggs to withstand drought (May 1975). In the greenhouse, adult whitefringed beetles will oviposit on small fir strips placed in their cage, especially if the sticks are shaded. They also deposit eggs in corners, cracks and under other hard objects (DRK, personal observations). The greatest egg-laying activity occurs between 12:00 p.m. and 4:30 p.m. (Barnes 1971).

Once laid, eggs require 21 days, on average, to mature (Bass and Barnes 1969). After this period is complete, larvae will eclose naturally, under optimum conditions, ranging in time from egg maturity to about 30 days. Eggs laid in poor conditions, or during the fall and winter, can take at least 100 days to hatch (Barnes 1971). Moisture is required for larvae to eclose. In the laboratory, newly matured eggs will hatch in as little as 24 hours, after soaking in distilled water (DRK, personal observations). Prior to eclosion, mold may grow on the egg masses, but the mold does not have a significant impact on egg viability (Gross et al. 1972). In the laboratory, larvae will continue to eclose for a period ranging from 24 hours to a week. After eggs reach maturity, they can be held for up to 8 months at proper temperature and moisture (Gross et al. 1972). Eggs should be stored in a dessicator at 18.3°C (64.9°F) with 95% relative humidity. Humidity can be maintained by placing a sulfuric acid solution in the dessicator.

Upon hatching, newly eclosed larvae are less than 1 mm (0.039 in) long. For the first 50 days, the weight of the larvae remains less than 5 mg (0.00018 oz). Laboratory assays at 25.5° C (77.9°F) reveal that developing larvae molt through 11 instars before pupation (Gough and Brown 1991). The first nine instars last about 1-2 weeks each (Gough and Brown 1991). The tenth instar spans 3-4 weeks. The eleventh instar extends indefinitely because it can be prolonged for months until conditions are appropriate for pupation (Gough and Brown 1991). It is difficult to collect and measure young larvae in the field, so the 11 instars and duration of each stage have only been recorded on larvae reared to adulthood in the laboratory (Gough and Brown 1991).

As they develop, larvae are pale yellow in color. Larvae are legless, with a small, round, brown head, which is tucked back into the pro-thorax. Only the mandibles

protrude and they are designed for gnawing (May 1975). The body is plump, apodous, and slightly c-shaped. The mid-region is enlarged. The body consists of twelve segments interrupted by two sublateral, longitudinal grooves extending the length of the body (Young et al. 1950). The body segments are curved and bulging on the dorsal side and flattened on the ventral. All twelve body segments, except the prothoracic and the ninth abdominal segments, are definitely plicated and sparsely covered with setae. Above the longitudinal grooves, on each side of the body, small breathing pores, or spiracles are present. These are found on all segments except the second, third, and twelfth. There are nine pairs of spiracles located on the prothoracic and first eight abdominal segments (Cherry 1971; Young et al. 1950). Mature larvae are about 14.0 mm (~0.5 inches) long and (Cherry 1971).

Larvae can be found at different depths in the soil depending on what stage of their life cycle they are completing. Larvae enter the soil after hatching and move downward to typical depths of 7.6-27.9 centimeters or 3-11 inches. Most larvae can be found in the upper 22.86 cm (9 in) of the soil, although they have been found at depths greater than 60.96 cm (24 in). Larvae are deepest in the soil column in fall and winter. They return to the upper layers of soil in spring. Because the oviposition period for the adults extends through the summer and into fall, larvae of various ages and sizes can be found in the soil at any one time (Cherry 1971; Young et al. 1950).

After hatching, the larvae burrow into the ground and begin feeding as soon as an acceptable food source is found. Newly emerged larvae are capable of surviving for weeks without food. In 1937, newly eclosed larvae survived an average of 24.2 days without any food at all. One of these larvae survived for 73 days without food (Young

and App 1939). The ability of the first instar larvae to withstand long periods without food, coupled with the wide variety of potential host plants lend a competitive edge to the whitefringed beetle larvae. In Tolga, Australia, the ability to survive for long periods without food and to withstand desiccation, allow whitefringed beetles to survive Tolga's characteristic long dry fallow period (Gough and Brown 1991).

The entire larval stage is spent underground, where larvae may feed on more than 240 different species of plants. Larvae gnaw into the roots removing cortical tissue and can cause severe damage to the plant (Young et al. 1950). Although, the larvae can survive on many different plant species, laboratory tests have demonstrated that among larvae fed different field crops, peanuts cause fastest growth and development (Gough and Brown 1991). Once larvae are fully-grown, they cease feeding for about 7-14 days to prepare for pupation (Gough and Brown 1991). At this time, larvae begin to construct a pupal cell. The cell's inner surface is covered with a secretion from the insect that makes it almost waterproof (Young et al. 1950).

The pupal stage of the whitefringed beetle occurs in the upper 7.6 cm (3 in) of the soil (Young et al. 1950). Usually the pupae are found at the base of the larval host plant. Exarate, adactitious pupae are white and approximately 11.5 mm (0.45 in) long. There are twelve segments including the head, three thoracic segments, and eight abdominal segments. Short curved spines are found on each segment (Cherry 1971). The pupal stage lasts for about thirteen days during warm weather conditions. Warm moist conditions stimulate pupal development. Newly formed adults remain in the pupal cell for several days to allow their bodies to harden (Young et al. 1950). These newly formed adults are equipped with a pair of cusps. There is one cusp attached to the anterior face

of each mandible. These devices are used for cutting the way through and out of the soil. Shortly after emergence from the soil, the adults will lose the cusps, but a scar on the anterior of each mandible remains, which indicates the location of the discarded appendage (Young and App 1939).

Upon emergence from the soil, the adult whitefringed beetle will usually crawl onto a nearby plant to rest for a few hours, while allowing the body to completely harden. Often, shortly after emergence, adults can be found in clusters on a plant (Young et al. 1950).

The adult beetles are 9.0 to 12.7 mm long (0.35-0.5 in). They are gray in color, with a light band of setae along the outer margins of the wing covers. There are two paler longitudinal lines that run along each side of the thorax and the head, one above and one below the eye. The body is covered with short pale hairs. The elytra are fused, so whitefringed beetles are unable to fly (Young et al. 1950). Movement is accomplished by crawling. One adult beetle may crawl as much as 0.4 kilometers (0.25 mile) in search of food (Young and App 1939). There are six mouthpart components in the adult. These consist of a pair of mandibles, a pair of maxillae, the hypopharynx, and the labium. The mandibles bear a definite cutting edge and are very prominent (Young et al. 1950).

After hardening, the next action for the adult is to search for food. If food is nearby the beetle will not travel very far. Adult beetles begin to lay eggs from 5-25 days after emergence. Certain foliage, such as peanuts, soybeans, velvetbeans, cocklebur, and ragweed, cause the preoviposition period to be shorter than it is for beetles fed on grasses (Young et al. 1950). The egg-laying period ranges from 30 to 60 days (Young et al. 1950). It is more pronounced during the afternoon hours, especially sunny afternoons.

During cloudy or rainy periods there is a reduction in eggs laid (Cherry 1971). Once temperatures drop below 4.44° C (40° F) egg laying practically ceases (Young et al. 1950). Most beetles do not survive much longer after egg laying is concluded. The average lifespan of the adult is 90 days, although some may live as many as 150 days (Young et al. 1950). Certain foliage seems to increase longevity. For example, beetles fed on peanuts, cotton, goldenrod, lambsquarters, ragweed, and smartweed lived longer than those fed on legumes (Cherry 1971; Young et al 1950).

Adult whitefringed beetles in the United States are all female. No males have been found in the United States. Although, bisexual populations of *Naupactus leucoloma* have been identified in Argentina, Uruguay, and Paraguay. Males are present in native areas, but have not been identified in any area where the beetles have been introduced. Males are generally smaller than females (Lanteri and Marvaldi 1995). In the United States, the beetles reproduce by parthenogenesis. Because mating is not necessary, the spread of the beetles is facilitated. A single insect could potentially begin a new population of beetles (Cherry 1971). Egg laying potential is enormous. Beetles fed on peanut foliage at Floral, Alabama, are reported to have deposited an average of 1,590 eggs (Young et al. 1950):

Normally, in the United States the life cycle of the whitefringed beetle lasts only one year (Barnes 1971). In South America and New Zealand the beetles are reported to have one, two, or even three year life cycles (Berry 1947). In Alabama a few larvae have exhibited a two-year period of development. At Gulfport, Mississippi, a three-year life cycle was observed. In Greene County, Tennessee, the beetles have also exhibited both a one- and two-year life cycle (Cherry 1971).

Host Plants of the Whitefringed Beetle

Adult whitefringed beetles have been observed feeding on over 385 known plant species distributed among 41 orders (Young et al. 1950). In the field, beetles feed on over 170 species of plants, including field, garden, and truck crops, weeds, ornamental shrubs and flowers, wild bushes, vines, and trees. Some of the most common host plants are alfalfa, beautyberry, beggarweed, blackberry, camphor, cocklebur, coffeeweed, cotton, dahlia, dewberry, gallberry, kudzu, lespedeza, lima bean, okra, peanut, ragweed, soybean, strawberry, teaweed, and velvetbean (Young et al. 1950). Whitefringed beetles do not usually cause uniform damage to crops and fields. Within a stand, damage will vary from a slight trace in one section of a field to total destruction in another, with some spots untouched (Young et al. 1950). Although the beetles feed on a diverse range of plants, research suggests that certain plants are preferred. In random diggings under many different plants in an infected field, larvae are often found more abundantly under certain species than others (Henderson and Padget 1949). Some of the plants that were found to be preferred food sources include most field and garden crops, and plants such as dogfennel, *Polypremum*, evening-primrose, goldenrod, ragweed, broomsedge, wild geranium, plantain, wild lettuce, dock, *Euthamia*, sheepsorrel, and various briars (Henderson and Padget 1949).

In the field, larvae have been observed feeding on 240 species of plants. Some of the most common being, alfalfa, beans, carelessweed (pigweed), carrot, chrysanthemum, chufa, clover, cocklebur, corn, cotton, cowpea, curled-dock, Irish potato, lupine, mustard, oat, peanut, peas, ragweed, soybean, strawberry, sweetpotato, tobacco, and velvetbean, and have been recorded feeding on acorns, peach seeds, pecan, and tung nuts. Larvae

also eat the roots of young woody plants, such as peach, pecan, tung, willow, dogwood, yellowwood, magnolia, and witch hazel (Young et al. 1950; DRK, personal observations). Larvae feed on the outer layers of roots or the outer portions of underground tubers. They eat portions of the cambium and its underlying tissues. Feeding larvae usually gnaw large cavities into the roots and have been known to burrow deeply into potatoes and other large tubers. Generally, larvae are expected to cause more plant damage to those plants that have a taproot than those with a fibrous root system (Barnes 1971).

In the laboratory, adults have fed on 215 species of plants (Young et al. 1950). Normally, adult beetles will feed upon most plants having leaves that can be cut with their mandibles. Because they are not voracious feeders, they usually do little economic damage as adults. The beetle straddles the leaf margin, cuts the leaf edge, and cuts away leaf strips leaving a characteristic semicircular scar on the margin. Often, fecal droppings can be found on the leaves near these semicircular cuts. Adults have feeding preferences as well. In the field, they prefer plants with smooth leaves and stems to plants with hairy stems and foliage. They also prefer plants with large, broad leaves (Young et al. 1950).

Host plant species have a major influence on population dynamics of several pasture pests. Several studies indicate that whitefringed beetle populations are seriously affected by host plant species (East 1977). Early tests of whitefringed beetle adults, fed on different host plants, indicated that the longevity, oviposition period, and fecundity were profoundly impacted by the type of host plant. Of the plants tested, adult beetles fed on peanut foliage had the highest rates of fecundity (Young and App 1939). Later studies demonstrated that the average fecundity of adults fed on legumes was more than

20 times greater than that of individuals fed on grasses and cereals, because of greater longevity and higher oviposition rate. The results of these tests indicated that oviposition of adult whitefringed beetles is influenced directly by the quality of their immediate food resources. Eggs are not developed from fat reserves accumulated from earlier larval or adult feeding (East 1977). By controlling or altering adult food resources, larval populations could be managed.

Management and Control of Whitefringed Beetles

When the threat of serious economic damage from whitefringed beetles was first recognized in the United States, a major effort was initiated to eradicate the beetles. Investigation teams journeyed to the South American homeland of the insects to ascertain the potential danger of the pest to the United States—search for natural enemies; assess host plant range; and scout for males (Berry 1947). At the same time in the United States, barrier ditches, ‘trap crops,’ and flamethrowers were used to combat the spread of the beetles. The most extreme measures, like flamethrowers, were abandoned quickly, but the attempts to control the spread of the beetles continued in earnest. A U.S. Federal Quarantine was established in 1939, accompanied by restrictions and regulations in many individual states. State and independent employees were urged to work closely with Federal officials, to routinely survey for whitefringed beetle, even in areas that were not normally considered to be within its potential host range. Federal inspectors were instructed to watch closely for crop and weed injury that looked similar to the damage common to whitefringed beetle larvae (Rohwer 1953). Inspectors were told to dig up any suspected plants and check for larvae. Because larvae were difficult to detect, the most important means of finding adults was to survey for the presence of adults and signs of

adult feeding. Behavioral characteristics of the beetles were exploited. For example, when beetles are disturbed they will typically fall from the plant and remain motionless or “play dead” for a short period of time. Adults can be found on the ground under or near host plants. State officials were encouraged to send employees to areas that were infested with whitefringed beetles to be trained in inspection techniques. The states were urged to include surveys for whitefringed beetle populations in all routine inspections conducted. Several areas, including railyards, shipping yards, and nursery and agricultural stockyards, were designated as crucial to the dissemination of the pest. These areas were subject to continuous scrutiny. All ports of entry into the United States, especially those into the Southeast which received goods from South America; railroad and truck transportation centers and distribution points; points where scrap metal was received; military installations; nurseries; places that had received nursery stock from the southeast; and farm crop processing or storage areas; were considered to be high risk areas (Rohwer 1953). Because railroad transport was considered to be the primary mode of dispersal for the beetles, railyards and tracks were sprayed with a herbicide—sodium arsenite-fuel oil. This herbicide mixture killed all vegetation, except for grasses, as well as any beetles that were sprayed or ate contaminated plant material. The use of this herbicidal mixture was abandoned due to its high expense and toxicity to livestock (Henderson and Padgett 1949).

Investigations of South American whitefringed beetle habitats revealed that beetle populations are light and that economic damage from this pest is seldom severe (Berry 1947). Scientists hypothesized that in South America natural enemies or competitors control whitefringed beetle populations. A search for insects, birds, disease-producing

organisms, or nematodes that could be used as a method of natural control for the beetle was undertaken. In South America no such natural enemies were consistently found (Berry 1947). Two species of birds, however, fed heavily on the whitefringed beetle larvae. Both of these birds are abundant in Chile. The Tiuque, *Milvago chimango chimango* (Viellot) and the Quelteque, *Belonopterus chilensis chilensis* (Molina) are found in fields by the hundreds, immediately after cultivation, which brings the grubs to the surface. Reports suggest that these birds are attracted to the sound of a tractor, meaning that the sound of the tractor causes the birds to fly to that vicinity and search the fields for larvae (Berry 1947).

The only other evidence of a natural enemy was found in the United States. In September 1940, a *Diplogaster* nematode was found inside a whitefringed beetle larva. Several experiments and tests were conducted, but the researchers concluded that, although these nematodes are frequently associated with whitefringed beetle larvae in high numbers, they are not necessarily larval parasites. While a very small number of *Diplogaster* nematodes actually killed whitefringed beetle larvae, the majority of the nematodes were found externally on the larvae or had entered after the larvae had died (Harlan et al. 1971). Another nematode, *Neoaplectana dutkyi*, has been tested on populations of whitefringed beetles in Louisiana. Laboratory evaluations indicated that this nematode was effective on the larvae of *Naupactus peregrinus*. This nematode, *Neoaplectana dutkyi*, was introduced into fields with larval populations of whitefringed beetle. The plot that had received the most nematodes had 38% fewer larvae after testing. Results of a second test were insignificant, despite successful lab evaluations. The following year, however, experimental fields again had a large larval population

(Harlan et al. 1971). To date, no natural enemies have been found that reliably influence whitefringed beetle populations.

Methods of controlling whitefringed beetles have varied in time. Chemical control of whitefringed beetle populations was initiated in 1938, with the use of calcium arsenate (Henderson and Padgett 1939). Chlorinated hydrocarbon insecticides such as, chlordane, heptachlor, aldrin, dieldrin, and DDT replaced this highly toxic chemical. Most of these chemicals may no longer be used (Golden and Bass 1979). Whitefringed beetles have been difficult to control by chemical methods. In 1968, of 38 pesticides screened and reported for beetle control, only six-- lindane, Sandoz 6538, dieldrin, dyfonate, heptachlor, and thionazin, were significantly toxic to whitefringed beetle (Todd 1968). Also, populations of the insect have developed a resistance to dieldrin (Harlan et al. 1972). As regulations regarding pesticide use are increased, many of the traditional chemicals have been restricted or withdrawn from the market. As a result, several additional chemicals have been tested for use on controlling whitefringed beetles. Diflubenzuron reportedly caused reproductive inhibition in adults (Ottens and Todd 1979). Abate killed all larvae in tests when used at the level of 4000 ppm (Harlan 1974). In 1990, carbaryl was suggested as the least costly and most effective chemical available for whitefringed beetle control (Eggert et al. 1990).

Historically, soil insecticides have had low efficacy on whitefringed beetles. Efficacy of soil insecticides may be reduced by leaching, hot soils, dry soil surfaces, and unincorporated insecticides. For this reason, application of adulticides may be an effective alternative to soil insecticides (Zehnder et al. 1998). Carbaryl can be used as an adulticide. Gross and Harlan (1975) reported that suppressing and retaining adult

populations is feasible regardless of the size of the initial population, therefore management of adults is a viable strategy. Zehnder (1997) reported that, in Alabama sweet potatoes, the greatest challenge was timing of the insecticide applications to achieve optimum control. Traditionally, the insecticides are applied in May at planting time. However, because larvae must reach 4th-7th instar before they are big enough to do significant damage, sweet potatoes do not receive any significant damage until September. Sweet potatoes planted in mid-April, can be harvested 3-4 weeks earlier and the potatoes would not be in the ground in September when larval injury is greatest. In addition to an earlier planting date, foliar insecticides can be used to kill adults during the summer. Whitefringed beetles cause characteristic feeding injury on leaves. Feeding injury is related to the abundance of adult beetles in the first few weeks of feeding each summer. Field scouting for notched leaves is easier than inspection for adults. By this method, foliar sprays, which cause less of a threat to soil and ground water contamination, can be applied as needed (Zehnder 1997).

Chemical soil fumigants can also be used. This method is considered effective, but costly. Although, methyl bromide has been the common fumigant used, methyl isothiocyanate is much more toxic to whitefringed beetle larvae (Henderson and Padgett 1949). However, methyl isothiocyanate is rapidly absorbed into the soil, which precludes field use of the chemical in low quantities. In high quantities, the use of the chemical is too costly (Matthiessen et al. 1996). Methyl bromide is being removed from the market, so alternative fumigants would have to be considered.

Various cultural methods can be used to control whitefringed beetles. In South America, a few practices have been developed that keep larval damage to a minimum.

The common approach is to maintain well-cultivated soil. Farmers plow early and then cross plow before seeding. Cultivation helps decrease larval populations (Berry 1947). In Chile, a special method has been developed to combat whitefringed beetle larval damage in irrigated beans. When the soil is cultivated, the loose soil is thrown up around the base of the bean plants. Then plants are irrigated immediately. This actually helps the beans grow more vigorously, but does not reduce larval populations (Berry 1947).

The USDA recommends specific steps for cultural control of beetles (Young, et al. 1950). Oats or small grains should be planted on infested portions of fields. No more than 25% of land each year should be planted in summer legumes. High-risk crops should be rotated within a field on three to four year intervals. Corn should not be interplanted with peanuts, soybeans, or velvetbeans. Broadleaved weeds should be prevented from growing in corn, which should be fertilized heavily. It is advantageous to turn under a winter manure crop. Disking at one hundred day intervals in June and July will help to kill pupae in the soil. Also, the addition of extra organic matter in the soil will reduce the number of plants killed by whitefringed beetles (Young et al. 1950).

In New Zealand, research has suggested that since it is difficult to control larvae by chemical reduction, elimination of legumes may suppress larval populations in pasture. The suggested approach is to sow a summer cereal crop, for example--summer oats, and keep the field free of weeds and legumes for at least two summers. This should decrease larval populations sufficiently to reduce damage (East 1977).

Literature Cited

- Barnes, E. E. 1971. Laboratory rearing techniques for the white-fringed beetle. Ph.D. Dissertation, Auburn Univ., Auburn, AL.
- Bass, M. H. and E. E. Barnes. 1969. A laboratory rearing technique for the white-fringed beetle. J. Econ. Entomol. 62: 1512-1513.
- Berry, P. A. 1947. Investigations on the white-fringed beetle group in South America. J. Econ. Entomol. 40: 705-09.
- Brooker, J. R., R. A. Henson, and S. C. Turner. 2000. Trade flows and marketing practices within the United States nursery industry: 1998. Southern Cooperative Series Bulletin, 397.
- Bryan, H. D. 1988. An economic analysis of the marketing trends of the wholesale nursery industry in Tennessee. M. S. Thesis, University of Tennessee, Knoxville, TN.
- Buchanan, L. L. 1939. The species of *Pantomorus* of America north of Mexico. USDA., Publication 341: 1-39.
- Buchanan, L. L. 1947. Four new species of whitefringed beetles (subgenus *Graphognathus*) from the southeastern part of the United States (Coleoptera: Curculionidae). Bulletin Brooklyn Entomol. Soc. 37: 107:110.
- Buchanan, L. L. 1947. A correction and two new races in *Graphognathus* (white-fringed beetles) (Coleoptera: Curculionidae). J. Wash. Acad. Sci. 37: 19-22.
- Cherry, E. T. 1977. Biology of the whitefringed beetle. M.S. Thesis, University of Tennessee, Knoxville, TN.

- De Jager, J., K. Lategan and M. C. van der Westhuizen. 1987. Some aspects of the biology of the white-fringed beetle *Graphognathus leucoloma* (Coleoptera: Curculionidae), in Lower Orange River irrigation area of South Africa. *Phytophylactica* 21: 259-263.
- East, R. 1977. Effects of pasture and forage crop species on longevity, fecundity, and oviposition rate of adult white-fringed weevils: *Graphognathus leucoloma* (Boheman). *NZ J. Exp. Agric.* 5: 177-181.
- Eggert, S. D., R. T. Ervin, and E. Segarra. 1990. Economic analysis of controlling a potential pest threat to Texas: whitefringed beetle. *Appl. Agric. Res.* 5: 77-81.
- Gardner, J. G., D. B. Eastwood, J. R. Brooker, J. B. Riley, and W. E. Klingeman. 2002. Consumers' willingness-to-pay for powdery mildew resistant flowering dogwoods. U. T. Institute of Agriculture, Department of Agricultural Economics, Research Series, 02-02.
- Glasgow, T. E. 1985. Production systems and costs for producing flowering dogwood (*Cornus florida*) cultivars from budded seedlings and rooted cuttings in Tennessee, 1984. M. S. thesis, University of Tennessee, Knoxville.
- Golden, W. H. and M. H. Bass. 1979. Whitefringed beetle: toxicity of soil incorporated insecticides to larvae. *J. Geor. Entomol. Soc.* 14: 244-247.
- Gough, N. and J. D. Brown. 1991. Development of larvae of the whitefringed weevil, *Graphognathus leucoloma* (Coleoptera: Curculionidae), in Northern Queensland. *Bull. Entomol. Res.* 81: 385-393.
- Gross, H. R. and D. P. Harlan. 1975. Evaluation of preventative adulticide treatments for control of whitefringed beetles. *J. Econ. Entomol.* 68: 366-368.

- Gross, H. R., Jr., J. A. Mitchell, Z. A. Shaw, and G. R. Padgett. 1972. Extended storage of eggs of whitefringed beetles. *J. Econ. Entomol.* 65: 731-733.
- Hardin, B. R., D. J. Eakes, C. H. Gilliam, G. J. Keever, and J. D. Williams. 2002. Growth and mortality of dogwood cultivars in Alabama. *J. Environ. Hort.* 20: 16-20.
- Harkness, D. J. 1964. The dogwood in legend and literature: a program manual for clubs and schools. Pamphlet, University of Tennessee Special Collections Library, Knoxville, TN.
- Harlan, D. P. 1974. Whitefringed beetles: control of larvae in nursery containers and phytotoxicity of Abate. *J. Econ. Entomol.* 67: 804-805.
- Harlan, D. P., Z. A. Shaw, G. R. Padgett, and J. A. Mitchell. 1971. Parasitism of *Neoaplectana dutkyi* in white-fringed beetle larvae. *J. Nematol.* 3: 280-283.
- Harlan, E. P., E. F. Bartlett, E. F. Pittman, G. R. Padgett, J. A. Mitchell, and Z. A. Shaw. 1972. Resistance to Dieldrin in larval whitefringed beetles. *J. Econ. Entomol.* 65: 1260-1263.
- Henderson, C. F. and L. J. Padgett. 1949. White-fringed beetles: distribution, survey, and control. USDA-Agric. Res. Admin., Bur. Entomol. Pl. Quar.
- Hill, D. G. 1990. Characteristics of Warren County nursery producers, their farm operations, contacts with extension, and their use of selected fertilization practices. M. S. Thesis, University of Tennessee, Knoxville, TN.
- Johnson, L. A. and K. M. Tilt. 1989. Planning budgets for nursery stock and Christmas trees. Agricultural Extension Service, The University of Tennessee, Knoxville. EC1019.

- Klingeman, W. E., J. R. Broker, D. B. Eastwood, J. B. Riley, B. K. Behe, and P. Knight. 2001. Consumer perceptions of landscape characteristics, disease and pest problems, and the value of powdery mildew resistant dogwoods. UT Institute of Agriculture, Department of Agricultural Economics, Research Series 07-01.
- Lanteri, A. A. and A. E. Marvaldi. 1995. *Graphognathus* Buchanan a new synonym of *Naupactus* Dejean and systematics of the *N. leucoloma* species group (Coleoptera: Curculionidae). *Coleopterists Bull.* 49: 206-228.
- Matthiessen, J. N., J. M. Desmarchelier, L. T. Vu, and M. A. Shackleton. 1996. Comparative efficacy of fumigants against hatchling whitefringed beetle (Coleoptera: Curculionidae) larvae and their sorption by soil. *J. Econ. Entomol.* 89: 1372-1378.
- Matthiessen, J. N. and S. E. Learmonth. 1992. Enhanced survival and reproduction of whitefringed beetle (Coleoptera: Curculionidae) with irrigation of pasture in a dry summer environment. *J. Econ. Entomol.* 85: 2228-2233.
- Matthiessen, J. N. and S. E. Learmonth. 1995. Impact of the soil Insects African black beetle, *Heteronychus arator* (Coleoptera: Scarabaeidae) and whitefringed weevil, *Graphognathus leucoloma* (Coleoptera: Curculionidae), on potatoes and effects of soil insecticide treatments in Southwestern Australia. *Bull. Entomol. Res.* 85: 101-111.
- May, B. M. 1975. Whitefringed weevil, *Graphognathus leucoloma* (Boheman), life-cycle. DSIR Information Series No. 105/12.
- Nursery Extension Programs. 2002. <http://www.ark.edu>.

- Ottens, R. J. and J. W. Todd. 1979. Effects of host plant on fecundity, longevity, and oviposition rate of a whitefringed beetle. *Ann. Entomol. Soc. Amer.* 72: 837-839.
- Rohwer, G. G. 1953. White-fringed beetle surveys in noninfested states. *J. Econ Entomol.* 46: 1094-95.
- Senn, L. H., Jr. 1969. Chemicals, host plants, and light as attractants for adult white-fringed beetles, *Graphognathus* sp. (Coleoptera: Curculionidae). Ph.D. Dissertation, University of Georgia, Athens, GA.
- Todd, D. H. 1968. Laboratory evaluation of insecticides against white-fringed weevil [*Graphognathus leucoloma* (Boheman) (Coleoptera: Curculionidae)]. *NZ J. Agric. Res.* 11: 903-910.
- USDA. 1972. Controlling white-fringed beetles. Washington, D. C.
- University of Tennessee Agricultural Extension Service. 1969. The flowering dogwood in Tennessee. PB 589.
- Warner, R. E. 1975. New synonyms, key and distribution of *Graphognathus*, whitefringed beetles (Coleoptera: Curculionidae), in North America. U. S. Dept Agric. Coop. Econ. Ins. Rep. 25: 855-60.
- Wibner, G. J., and C. W. O'Brien. 1986. Annotated checklist of the weevils (Curculionidae: sensu lato) of South America (Coleoptera: Curculionoidea).
- Windham, M. T., E.T. Graham, W. T. Witte, J. L. Knighten, and R. N. Trigiano. 1998. *Cornus florida* 'Appalachian Spring': a white flowering dogwood resistant to dogwood anthracnose. *Hortsci.* 33: 1265-67.
- Witte, W. T., Windham, M. T., Windham, A. S., Hale, F. A., Fare, D. C., and W. K.

- Clatterbuck. 2001. Dogwoods for American gardens. University of Tennessee Agricultural Extension Service, PB 1670.
- Young, H. C. and B. A. App. 1939. Biology of the white-fringed beetle (*Naupactus leucoloma* Boh). USDA: Bur. Entomol. Pl. Quar. Washington, D. C.
- Young, H. C., B. A. App, J. B. Gill, and H. S. Hollingsworth. 1950. White-fringed beetles and how to combat them. USDA: Circ. 850.
- Zehnder, G. 1997. Population dynamics of whitefringed beetle (Coleoptera: Curculionidae) on sweet potato in Alabama. *Envir. Entomol.* 26: 727-735.
- Zehnder, G. W., T. H. Briggs, and J. A. Pitts. 1998. Management of whitefringed beetle (Coleoptera: Curculionidae) grub damage to sweet potato with adulticide treatments. *J. Econ. Entomol.* 91: 708-714.

Appendix 1A: Glossary of Terms

baculi: in female Coleoptera, a rodlike apophyses (an elongate projection from the exoskeleton, wither internally or externally) of tergum or sternum.

carina: a keel or ridge.

corbel plate (usually simply referred to as corbel): an ovate area at the distal end of the tibia in Coleoptera, surrounded by a fringe of minute bristles: when the articular cavity is on the side, above the tip, the corbel is closed; when the cavity is at the extreme tip, the corbel is open.

cornu (plural, cornua): refers to parameres.

coxa: the basal segment of the leg.

elytron (elytra pl.): a thickened, horny, or leathery front wing.

humeri (pl.): shoulder or front basal part of the wings.

hypopharynx: a median mouth part structure just in front of the labium.

labium: the lower lip, or hindmost mouth part structure.

mandible: jaw.

maxillae (pl.): pair of mouth parts just behind the mandible.

plicated: folded; with folds; impressed with striae to produce the appearance of having been folded or pleated.

pronotum: the first of the three nota or thoracic segments toward the head.

ramus: a branch.

rostrum: beak or snout.

setae (pl.): bristles or hairs.

spermathecae (pl.): part of female genitalia.

spiracles: an external opening of the tracheal sytem, breathing pore.

sulcus: a groove formed by an infolding of the body wall.

tibiae (pl.): the leg segment between the femur and tarsus.

Definitions taken from:

Borror, D. J. and R. E. White. 1970. A field guide to insects: America north of Mexico.

New York: Houghton Mifflin.

Borror, D. J., Triplehorn, C. A., and N. F. Johnson. 1989. An introduction to the study of insects. 6th ed. Chicago: Saunders College Publishing.

Appendix 1B: Figures

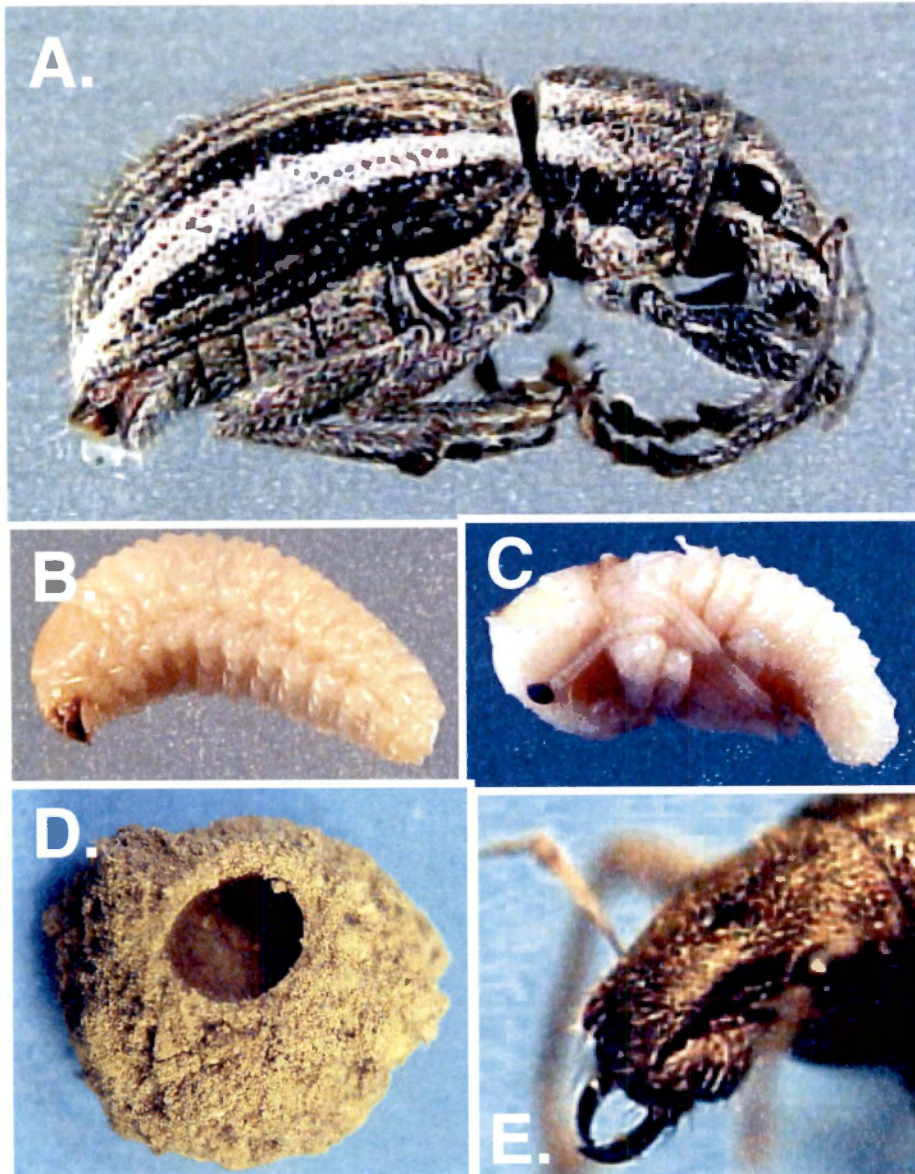


Figure 1.1: The Life Stages of the Whitefringed Beetle. A. WFB Adult, B. WFB Larvae, C. WFB Pupae, D. WFB Pupal Cell, E. WFB Newly Emerged Adult with Cusps.



A. Adult Feeding

B. Girdled Root
of
Dogwood



C. Wilted Leaves as a
result of root injury.

Figure 1.2: Whitefringed Beetle Feeding Injury.



Figure 1.3: Optimum Site for Adult Collection.



Figure 1.4: Adults Found Under Weeds in Field Production Rows.

Introduction

Dogwoods are obligate outcrossers: they do not pollinate their own flowers. This enables genetic variability to exist in every crop of seed. As a result, specific cultivars cannot reliably be reproduced from seed and they must be produced by other methods (Witte et al. 2001). In Tennessee, the majority of dogwoods are produced in two ways—from cuttings or by budding. Dogwood cultivars can be grown from rooted cuttings. The cost to produce a 4 to 6 foot flowering dogwood from a rooted cutting, in 1984, was \$7.35 per tree. In 1989, the cost to produce a 5 to 6 ft dogwood from a cutting rose to \$9.64 per tree in a small nursery and \$8.30 per tree in a medium size nursery (Johnson and Tilt 1989). Production from cuttings is more expensive because the cuttings have to be overwintered in a greenhouse, which requires the added costs of propagation materials, including mist irrigation systems and greenhouse equipment. Cuttings also have a much lower survival rate in the field (Badenhop and Glasgow 1985). Researchers are working to produce dogwoods through tissue culture, but to date, there has not been consistent success. For these reasons, the most common method is by bud grafting. Successful budding involves grafting the bud wood of a specific cultivar onto a seedling liner grown for rootstock. A degree of technical expertise is required to successfully and economically produce grafted cultivars. In 1984, the average cost to produce a 4 to 6 foot flowering dogwood from a budded seedling was \$5.47 (Badenhop et al. 1985).

Both growers and researchers alike are interested in ways to speed the growth rate of dogwood cultivars and increase the number of buds produced. With more buds, growers and researchers can increase the stock of valuable cultivars much more quickly, allowing rapid production and sale of these highly desirable plants. Increased numbers of

buds would allow researchers to develop trees more quickly; enabling the disease-resistant trees to be used in economic impact and environmental studies.

One possible method of speeding bud production in dogwoods is to increase the amount of fertilizer applied to young plants. Research indicates that increasing the rate at which nitrogen fertilizer is applied to shade trees, such as flowering dogwood 'Barton' (*Cornus florida*); red maple 'October Glory' (*Acer rubrum*); and pin oak, (*Quercus palustris*) [Muenchh] may lead to increased growth (Wright and Hale 1983). Nitrogen treatments were 168 kg/ha (150 lb/acre) and 329 kg/ha (300 lb/acre). After the first year the dogwoods treated with 329 kg/ha nitrogen had increased trunk diameter, caliper and height as opposed to the dogwoods treated with 168 kg/ha of nitrogen. Differences were not apparent after three years of growth. Still, growers might be able to take advantage of a method that increases the growth of very young trees (Wright and Hale 1983).

Container grown red maples treated with 300 ppm nitrogen, (the highest of three rates of nitrogen), produced a second growth flush, yielding four to five new shoots per tree on lateral branches, and demonstrated increased growth, delayed fall color, and longer leaf retention than trees treated with either 50 or 150 ppm nitrogen (Gilliam et al. 1980).

Finally, a study using sycamore trees, (*Platanus occidentalis* L.), determined that sycamores treated with 200 ppm nitrogen over a three-year period had greater height and volume than those treated with 100 ppm nitrogen during each of those three years (Kitzmiller 1972). We hypothesize that increasing the nitrogen fertilization of dogwoods grown in containers will result in increased growth and consequently, the production of more buds on each stem. Our research objective was to compare the budwood

production of commercially important dogwood cultivars grown under different fertilization rates.

Materials and Methods

Three experiments were established using five fertility treatments of 18-6-12 Osmocote (Scott's-Sierra, Maryville, OH) applied at rates of 3.6, 5.3, 7.1, 8.9, 10.7 kg/m³ (6, 9, 12, 15, 18 lb/yd³). These experiments were conducted at Commercial Nursery in Decherd, Tenn. and UT Institute of Agriculture in Knoxville, Tenn. All trees in each of the three experiments were potted into containers at Commercial Nursery on May 1, 2002, using an amended pine-bark medium. The medium consisted of 5.35 m³ of composted pine bark, 2.1 m³ Lambert's "Black Bale" peat (Lambert's, Riviere-Ouelle, Quebec, Canada), 0.38 m³ sand, 1.4 kg Magna Grow (magnesium sulfate heptahydrate); (PQ Corp., Valley Forge, PA), and 0.71 l Ridomil Gold fungicide (mefenoxamTM); (Syngenta, Greensboro, NC). Plants at both locations were grown on gravel, under 55% shade. The trees were irrigated as needed with low angle, Wobbler solid-set sprinklers with a 0.5 cm (3/16 in.) red (#12) nozzle (Senninger Irrigation, Orlando, FL). Initial data collected included tree caliper and growth indices [(height + width 1 + width 2)/3]. The trees were grown for one complete season. At three-week intervals throughout the season, the VPI Pour-Through extraction technique was used to collect leachate samples following irrigation (Wright 1984). The leachate samples were measured with an Orion nitrate probe (ion selective meter) (Thermo Electron, Beverly, MA) and tested with a Myron L Ultrameter (Myron L, Carlsbad, CA) for electrical conductivity and pH. At the end of the growing season, following leaf senescence, the length of five terminal shoots per tree, growth indices, tree caliper, and a count of buds were taken. For statistical

analysis eight variables were used--height, caliper, growth index, number of laterals on the stem, total shoot length, total number of laterals, total number of nodes, and total number of buds measured per tree. The mixed model analysis of variance was completed on the data, along with diagnostic tests formulated into a macro program created by Dr. Arnold Saxton of the University of Tennessee. Diagnostic tests included the Shapiro-Wilk test for normality, Extreme Observations, Stem-Leaf Plot, Normal Probability Plot, and a check of equality of standard deviations. Statistical significance was determined based on $\alpha=0.05$.

Experiment 1: Cold-stored, bare-rooted C. florida 'Cherokee Brave' and 'Cherokee Princess' grafted liners

Trees were potted into 3.78 l (1 gal) containers (Lerio, Mobile, AL) and arranged in a completely randomized design at Knoxville and Decherd. Trees were measured in Knoxville and Decherd at the end of the growing season in December 2002. Because of high mortality at the Decherd site, only the trees grown in Knoxville were subjected to statistical analysis.

Experiment 2: 3.78 l (1 gal) C. florida 'Cherokee Brave' and 'Cloud 9' transplanted into 11.3 l (3 gal) containers

Trees were arranged in a randomized block design at both locations. The 7.1kg/m³ fertility treatment was excluded in the 'Cloud 9' cultivar to accommodate the number of available plants. Data was taken at the end of the growing season in December 2002 at both locations. The same measuring system was used as in experiment 1.

Experiment 3: Container grown Cornus kousa 'Milky Way'

Originally in 0.9 liter containers (1 quart), the 'Milky Way' kousas were newly bud grafted. These budded liners were transplanted into 3.78 l (1 gal) pots (Lerio, Mobile, AL) and arranged in a randomized block design at both the Decherd and Knoxville locations. The kousa dogwoods were measured in December 2002 at both locations. The same set of measurements was taken as in experiments 1 and 2.

Results

Hot, dry weather during 2002 coincided with a breakdown of the irrigation system at the Decherd site. Although consistent cultivation practices were attempted across locations, unforeseen challenges caused many plants to be lost at both locations. As a result, only the Knoxville data were analyzed in Experiments 1 and 2. Experiment 3 data was analyzed from both locations.

Pour Through Measurements

Electrical Conductivity (EC) readings, measured in microsiemens (μS), averaged by location and date measured throughout the season show that at Knoxville there were higher initial conductivities and corresponding evidence of nutrient leaching (Figure 2.1)¹. By June 12, the EC in Decherd had begun to rise. The EC peaked in July, then declined until it remained consistent for the rest of the season. In Knoxville, after the initial peak around 1,000 μS , EC values dropped and stayed low throughout the season.

At Decherd, the well water has historically been high in alkalinity, but pH tests throughout the season recorded a steady pH around 6.0 (Figure 2.1). The pH was

¹ All figures are located in Appendix 2B at the end of this section.

consistent both in Decherd and Knoxville. Although, a slight rise in pH in October at both locations is not readily explained.

The nitrate concentrations, averaged by location and date and graphed over time, follow the same trend as the EC values (Figure 2.1). At Knoxville, the highest observed nitrate concentration was on 22 May, after which readings dropped and remained consistently low all season. At Decherd, the concentrations of nitrate recovered rose in June, peaked in July, and fell consistently until they leveled off in September and October.

Experiment 1: Cold-stored, bare-rooted C. florida 'Cherokee Brave' and 'Cherokee Princess' grafted liners

The cold-stored, bare-rooted *Cornus florida* 'Cherokee Princess' dogwoods were subjected to the stress of being cold stored late into the season. After planting (May 1, 2002), initial growth was slow and high mortality occurred. The only variable differing statistically by fertility treatment was total nodes ($F=2.77$; $df=4, 31$; $P<0.043$). (Table 2.1, 2.2)²

Experiment 2: 3.78 l (1 gal) C. florida 'Cherokee Brave' and 'Cloud 9' transplanted into 11.3 l (3 gal) containers

Few of the 'Cherokee Brave' and 'Cloud 9' dogwoods at Decherd survived the entire season. As a result, only data from Knoxville were analyzed for statistical significance. Because the 7.1 kg/m³ treatment was not included for 'Cloud 9,' data from trees receiving this treatment were excluded from statistical consideration.

² All tables are located in Appendix 2A at the end of this section.

Neither total buds, total nodes, total laterals, nor the number of laterals on the main stem differed by cultivar (range: $F=0.13$ to 2.15 ; $df=1, 41$; $P>0.05$ to 0.7), by fertility (range: $F=0.21$ to 0.43 ; $df=3, 41$; $P>0.05$ to 0.9), or cultivar by fertility (range $F=0.06$ to 1.16 ; $df=3, 41$; $P>0.05$ to 0.97) (Table 2.3, 2.4). Caliper was not different by cultivar ($F=3.22$; $df=1, 41$; $P>0.0801$). Yet, caliper differed by fertility treatment ($F=3.37$; $df=3, 41$; $P<0.0275$) and cultivars responded differently to fertilization ($F=3.41$; $df=3, 41$; $P<0.0264$) (Figure 2.2). A difference in caliper size was evident following the 8.9 kg/m^3 treatment. At 3.6 kg/m^3 and 5.3 kg/m^3 'Cloud 9' average caliper was greater than that of 'Cherokee Brave,' but at 8.9 kg/m^3 'Cloud 9' caliper size declined and continued to drop at 10.7 kg/m^3 , while 'Cherokee Brave' average caliper remained consistent across treatment levels.

The total shoot length of 'Cherokee Brave' and 'Cloud 9' differed by cultivar ($F=12.7$; $df=1, 41$; $P<0.001$) and by fertility treatment ($F=3.55$; $df=3, 41$; $P<0.0226$). Yet, cultivars demonstrated different responses to fertilization ($F=3.38$; $df=3, 41$; $P<0.0271$). 'Cloud 9' responded to 3.6 kg/m^3 and 5.3 kg/m^3 with increased length. Shoot length declined at 8.9 kg/m^3 and dropped sharply at 10.7 kg/m^3 (Figure 2.3). 'Cherokee Brave' growth averages were not inhibited at high levels of fertilizer, like those of 'Cloud 9.'

Finally, growth index did not differ by cultivar ($F=4.32$; $df=1, 41$; $P>0.441$). However, growth indices were affected by fertility treatment ($F=3.26$; $df=3, 41$; $P<0.0308$), although cultivars responded similarly to nitrate levels ($F=2.26$; $df=3, 41$; $P>0.0956$). Growth exhibited a quadratic pattern across nitrate levels, peaking at 5.3 kg/m^3 and declining thereafter (Figure 2.4).

Experiment 3: Container grown Cornus kousa 'Milky Way'

The *Cornus kousa* 'Milky Way' dogwoods survived in high numbers at both locations and could be compared statistically across locations. The number of laterals on the main stem and the total number of laterals were not different for the 'Milky Way' trees either by location or fertility treatment. Nor was there an interaction between location and fertility treatment (Table 2.5, 2.7). Total buds and total nodes differed by location ($F=12.7$; $df=1, 55$; $P<0.0007$ and $F=6.2$; $1, 55$; $P<0.0162$) (Table 2.6). Differences in total buds ($F=0.86$; $df=4, 55$; $P>0.49$) and total nodes ($F=1.21$; $df=4, 55$; $P>0.32$) were not attributed to fertilization and there was no interaction between location and fertility treatment ($F=1.08$; $df=4, 55$; $P>0.37$ and $F=1.56$; $df=4, 55$; $P>0.2$).

Total shoot length differed among the 'Milky Way' trees by location ($F=34.7$; $df=1, 55$; $P<0.0001$) and by fertility treatment ($F=2.6$; $df=4, 55$; $P<0.046$). The interaction between fertility treatment and location was not significant ($F=0.57$; $df=4, 55$; $P>0.68$). *Kousa* total shoot length averages at Decherd were consistently lower than total shoot length averages at Knoxville. The 3.6 kg/m^3 amendment produced the greatest shoot lengths at both locations with an average of 49.4 cm in total shoot length at Decherd and an average of 69.3 cm total shoot length at Knoxville. Trees receiving the 3.6 kg/m^3 and 5.3 kg/m^3 fertility treatments produced greater shoot length than those receiving the 10.7 kg/m^3 treatment (Figure 2.5).

Caliper measurements were different by location ($F=108.7$; $df=1, 55$; $P<0.0001$), but were not different by fertility treatment ($F=2.34$; $df=4, 55$; $P>0.066$), although there was an interaction between location and fertility treatment ($F=6.04$; $df=4, 55$; $P<0.0004$) (Figure 2.6). Caliper was consistently greater at Knoxville than at Decherd. Although

the fertility treatment did not produce significant differences in tree caliper, the response of the kousas to fertility treatments at the different locations differed. At Knoxville, caliper peaked at the 7.1 kg/ m³ rate and then declined slightly over the higher fertilizer rates. At Decherd, there was a continuous decline in caliper as fertility treatment was increased.

Finally, growth index differed by location ($F=77.7$; $df=1, 55$; $P<0.0001$) and fertility treatment ($F=2.9$; $df=4, 55$; $P<0.0299$). There was an interaction between location and fertility treatment ($F=2.63$; $df=4, 55$; $P<0.0422$) (Figure 2.7). At Knoxville, the growth index was consistently greater than at Decherd. The 7.1 kg/m³ fertility treatment produced the greatest average growth index, while at Commercial Nursery the 3.6 kg/m³ treatment produced the greatest average growth index. At Knoxville, the growth response to fertilizer rose slightly as nitrate increased, until growth peaked at 7.1 kg.m³ and declined with increasing fertilization. At Decherd, there was a consistent decline in growth as fertilization increased.

Discussion

Pour Through Analysis

Nutrient recovery was consistently different across locations. Nitrate recovery was averaged by fertility treatment and date at each location and graphed (Figure 2.8). Although the nutrient release pattern varied somewhat by fertility treatment, the same trend for release at each location was present across fertility treatments. Pour-through data from the 11.3 l pots were separated from the 3.78 l pots. Pot size contributed to differences in nitrate recovery (Figures 2.9, 2.10). A smaller pot has a greater surface to

volum ratio and would have less temperature buffering capacity. This explains why more nutrients were recovered from the 3.78 l containers earlier in the season.

Osmocote 18-6-12 is a controlled-release fertilizer (CRF) formulated to last 8 to 9 months at an average production temperature of 21.1° C (70° F). Temperature is the most important factor affecting the nutrient release from CRF. It affects nutrient diffusion across the coating (Kochba et al. 1990). At temperatures over 29.4° C (85° F), the release of nutrients is accelerated. Considerations must be made to amend the release rate predictions of the fertilizer. The Osmocote label indicates that growers in the southern United States can expect temperatures about 26° C (80° F) and, therefore, a 6 to 7 month release rate. Osmocote 18-6-12 becomes highly reactive when the average daily temperature exceeds 29.4° C (85° F). CRFs stored at high temperatures (37.8° C or 100° F) could have up to 60% higher release than that stored at 26° C (80° F) (Cabrera 1997). The age of the fertilizer at use can also affect release rate. The method of fertilizer application will increase release. Incorporating Osmocote into the mix produces a faster nutrient release than when the fertilizer is applied as a topdressing (Cabrera 1997; Meadows and Fuller 1984). Topdressing typically reduces nutrient losses from the medium. As nutrients are released from topdressed fertilizers, they travel throughout the growing medium, increasing the likelihood of being retained by the medium and absorbed by the plant. In the case of resin- and polymer coated CRF materials like Osmocote, intermittent drying of topdressed fertilizer between irrigation events may also slow down the diffusion (leakage) of nutrients through the fertilizer coating. Conversely, if the fertilizer is incorporated throughout the medium, nutrients released from the lower section of the pot will be more prone to leaching than to plant uptake and retention by the

growing medium. Higher temperatures and moisture conditions inside the container will also be more conducive to higher nutrient releases by incorporated fertilizers. Careful attention must be paid to nutrient release during and right after periods of temperature fluctuation, particularly following high temperatures. Heavy irrigations with clear water may be needed to leach out excessive levels of fertilizer salts during these periods of high temperature (Cabrera 1997).

Nitrate recovery in Knoxville was consistently low because plants were irrigated for an average of one hour a day. Leaching of fertilizer nutrients is expected to have been high. In July, when container temperatures exceeded 29.4° C (85° F), there was not a surge in nutrient release from pots. Plant performance indicates that the nutrients could not have been entirely lost in runoff and that the plants were able to uptake some nitrogen.

The timing of fertilizer treatment is very important. In comparison to trees fed all season-long with constant liquid feed, trees fed only for the first month and then switched to supplemental feeding once a week obtained similar height when measured at the end of the season. Although, trees fed all season received 63-55% more fertilizer than those fed only for the first month (Struve and Rose 1998). It is likely that the greater availability of nitrate levels early in the 2002 growing season was of more benefit to dogwoods at Knoxville than it would have been later in July. In fact, fertilization recommendations for field grown trees that have only one flush of growth a season, like dogwoods, suggest early spring or fall fertilization (Rose 1999).

In contrast to Knoxville, where water was readily available to plants, less irrigation water was available at the Decherd nursery. Pots did not receive enough water

to leach nutrients, which were being rapidly released by high temperatures. This observation is supported by high nitrate readings in July, reflecting a rapid release of nutrients corresponding with higher ambient temperatures. Rapid nitrate release in Decherd was indicated by declining nitrate recovery values as the irrigation was made available and washed excess nutrients from the pot.

Experiment 1: Cherokee Princess

Among the eight variables analyzed statistically, only total nodes showed any differences by nitrogen treatment. Yet, there is no evidence of a biological explanation, related to fertility, that explains those differences. Therefore, the results of this study do not indicate a difference in bud number or growth by fertility treatment. Trees were also cold stored too late into the season (1 May) and were not able to overcome the stress suffered. This observation is supported by previous research, indicating that it is possible to obtain 100% survival on bare-root dogwood planted as late as 6 May (in Alabama) but cultural conditions must be ideal and monitored very carefully (Askew et al. 1985). In both Decherd and Knoxville, the survival of the bareroot trees was limited, despite efforts to maintain high cultural standards.

Experiment 2: 'Cherokee Brave' and 'Cloud 9'

'Cherokee Brave' and 'Cloud 9' grown in Knoxville had greater shoot extension and elongation between nodes. Yet, there was no significant impact on the bud development of trees based on fertility treatments. Dogwoods trees have one flush of growth a season. It is possible that the fertility treatments provided during the 2002 growing season will not impact bud development until the 2003 growing season because bud numbers may have been predetermined in 2001, prior to the start of the fertilization

experiment. The 'Cherokee Brave' and 'Cloud 9' trees will be grown during the 2003 season and buds will be counted and analyzed statistically for differences at the end of that season.

Growers are interested in growth index and caliper as opposed to bud number when producing trees for sale. Although this study does not support the role of increased nitrogen fertility on increased numbers of vegetative buds, this data can be of use to the grower who is trying to maximize the size of his plants for sale. The 5.3 kg/m³ rate yielded optimal growth for flowering dogwoods provided adequate water, thus limiting the additional expense and concerns about nutrient runoff associated with higher rates of fertilizer.

The interaction between fertility and cultivar type suggests that 'Cherokee Brave' is more tolerant to high levels of fertility than 'Cloud 9' cultivars of *Cornus florida*. At high levels of fertility 'Cloud 9' had inhibited growth whereas there was no inhibition in the growth of 'Cherokee Brave.' When planning management and fertility regimes, information on cultivar specific plant performance can give the grower an advantage in tailoring the growing regime to the individual needs of the specific cultivar in question.

Experiment 3: 'Milky Way'

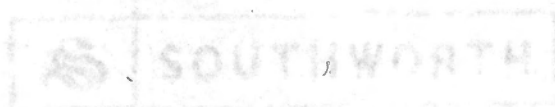
'Milky Way' trees exhibited the most profound differences in growth, affected by fertility and location of the three groups of experimental trees. These trees were newly budded shoots that had extended only a few centimeters by May, when the fertility treatments were initiated. All the shoot length present on the trees was generated during the 2002 season. Greater numbers of 'Milky Way' survived at both locations. The location by fertility interactions exhibited among the kousas indicate that in Knoxville

growth was consistent over all fertility treatments and greater than in Decherd. In Decherd, the trees exhibited an inhibited pattern of growth as fertility treatment increased.

The maximum growth trend appears between the fertility levels of 3.6 and 7.1 kilograms per cubic meter. Shoot length was greatest at the 3.6 kg/m³ rate, while growth index peaked at 7.1 kg/m³. There is no evidence from plant performance during this trial that *Cornus kousa* 'Milky Way' would experience increased growth from nitrogen fertility greater than 7.1 kg/m³.

The overwhelming differences in growth response by location can best be explained by differences in the watering regime at the two locations. The water added to trees was not measured precisely, but estimates are that, in Knoxville, trees received anywhere from 4 to 6 times more water on average per day. In design of the experiment, sprinkler heads for water delivery were correlated in order to align practices at both locations, but duration of watering duration was not precisely coordinated. The weather conditions and water needs were not similar across locations, so the trees were grown under normal size-specific production standards. Growth differences attributed to water available to the trees suggests that when working with fertility rates, the lowest availability nitrogen fertility rate is sufficient.

Literature Cited



- Askew, James C., C. H. Gilliam, H. G. Ponder, and G J. Keever. 1985. Transplanting leafed-out bare root dogwood liners. Hortscience. 20: 219-21.
- Badenhop, M. B. and T. E. Glasgow. 1985. A production system and costs for propagating dogwood cultivars from softwood cuttings. J. Environ. Hortic. 3: 49-62.
- Badenhop, M. B., Witte, W. T. and T. E. Glasgow. 1985. Production systems and costs for producing balled and burlapped trees of Dogwood cultivars, Tennessee, 1984. Bull. Tenn. Agric. Exp. Stn: 637-66.
- Cabrera, R. 1997. Let the Nutrients Flow. . . Slowly. American Nurseryman 185: 32-37.
- Gilliam, C. H., S. M. Still, S. Moore, and M. E. Watson. 1980. Effects of three nitrogen levels on container-grown *Acer rubrum*: foliar analysis, nutrition, wood ornamentals. Hortscience 15: 641-42.
- Johnson, L. A. and K. M. Tilt. 1989. Planning budgets for nursery stock and Christmas trees. Agricultural Extension Service, The University of Tennessee, Knoxville. EC1019.
- Kitzmilller, J. H. 1972. Response of sycamore (*Platanus occidentalis* L.) families to nitrogen fertilization. Raleigh, NC: School of Forest Resources, North Carolina State University. Technical Report. No. 48.
- Kochba, M., S. Gambash and Y. Avnimelech. 1990. Studies on Slow Release Fertilizers: I. Effects of Temperature, Soil Moisture, and Water Vapor Pressure. Soil Science 149: 339-343.
- Meadows, W. A. and D. L. Fuller. 1984. Plant quality and leachate effluent as affected

- by rate and placement of Osmocote and SREF on container grown woody
ornamentals. Proc. SNA Res. Conf. 29: 75-9.
- Rose, M. A. 1999. Nutrient use patterns in woody perennials: implications for increasing
fertilizer efficiency in field-grown ornamentals. HortTechnology 9: 613-17.
- Struve, D. K. and M. A. Rose. 1998. Early-Season Fertilization Reduces Fertilizer Use
Without Reducing Plant Growth. J. Environ. Hort. 16: 47-51.
- Witte, W. T., Windham, M. T., Windham, A. S., Hale, F. A., Fare, D. C., and W. K.
Clatterbuck. 2001. Dogwoods for American gardens. University of Tennessee
Agricultural Extension Service, PB 1670.
- Wright, R. D. 1984. The pour through method: a quick and easy way to determine a
medium's nutrient availability. American Nurseryman. 160: 109-10.
- Wright, R. D. and E. B. Hale. 1983. Growth of three shade tree genera as influenced by
irrigation and nitrogen rates: *Acer rubrum*, *Quercus palustris*, *Cornus florida*,
woody ornamentals. J. Environ. Hortic. 1: 5-6.

Appendix 2A: Tables

Table 2.1: Effects of Fertilizer Rate on 'Cherokee Princess' Mean Values.

<u>Fertility Rate</u>	<u>Growth Index</u>	<u>Laterals On Stem</u>	<u>Caliper</u>	<u>Total Buds</u>	<u>Total Shoot Length</u>	<u>Total Laterals</u>	<u>Total Nodes</u>
3.6 kg/m ³	42.0	15.8	7.97	40.1	77.4	10.5	37.9a
5.3 kg/m ³	38.7	11.4	8.21	31.4	66.4	5.5	28.8ab
7.1 kg/m ³	35.6	10.1	7.48	38.1	54.1	9.0	35.4a
8.9 kg/m ³	34.8	12.1	7.55	23.6	41.8	5.4	21.1b
10.7 kg/m ³	32.5	7.8	7.38	36.8	55.0	7.0	28.3ab
<u>F-Value</u>							
Fertility	1.71	2.56	0.88	1.44	2.22	1.82	2.77*

Means are least square mean estimates created by the mixed model analysis of variance in SAS. Means in the same column with no similar letters are different by Fisher's protected LSD test ($\alpha=0.05$). *F*-value: $*=P<0.05$.

Table 2.2: 'Cherokee Princess' ANOVA Summary of Fixed Effects.

<u>Variable</u>	<u>Fixed Effect.</u>	<u>Ndf</u>	<u>Ddf</u>	<u>F-value</u>	<u>P-Value</u>
Growth Index	Fertility	4	31	1.71	0.1737
Laterals	Fertility	4	31	2.56	0.0583
Caliper	Fertility	4	31	0.88	0.4872
Total Buds	Fertility	4	31	1.44	0.2436
Total Shoot Length	Fertility	4	31	2.22	0.0892
Total Laterals	Fertility	4	31	1.82	0.1503
Total Nodes	Fertility	4	31	2.77	0.0443*

*Significant at $P < 0.05$, as determined by mixed model analysis of variance in SAS.

Table 2.3: Effects of Fertilizer Rate on 'Cherokee Brave' and 'Cloud 9' Mean Values.

<u>Fertility Rate</u>	<u>Growth Index</u>	<u>Laterals On Stem</u>	<u>Caliper</u>	<u>Total Buds</u>	<u>Total Shoot Length</u>	<u>Total Laterals</u>	<u>Total Nodes</u>
'Cherokee Brave'							
3.6 kg/m ³	84.3	17.1	13.0ab	60.1	234.4a	11.4	65.4
5.3 kg/m ³	89.0	14.1	13.2ab	74.5	232.5ab	12.5	74.9
8.9 kg/m ³	82.6	18.2	13.4ab	89.5	201.0ab	13.6	75.6
10.7 kg/m ³	85.8	17.5	13.1ab	101.62	232.1ab	14.1	95.3
'Cloud 9'							
3.6 kg/m ³	81.0	17.0	13.2ab	109.3	171.2ab	14.0	88.4
5.3 kg/m ³	93.3	18.1	14.1a	102.1	235.6a	16.0	103.1
8.9 kg/m ³	71.3	16.1	11.9bc	84.1	164.8b	15.5	85.8
10.7 kg/m ³	55.8	13.4	10.0c	95.4	85.2c	15.8	91.1
<u>F-Value</u>							
Cultivar	4.32	0.13	3.22	1.66	12.67***	2.15	1.56
Fertility	3.26*	0.23	3.37*	0.21	3.55*	0.36	0.43
Cultivar x Fertility	2.26	1.15	3.41*	1.16	3.38*	0.06	0.39

Means are least square mean estimates created by the mixed model analysis of variance in SAS. Mean separation performed by LSD mean separation on variables with a significant anova test ($\alpha=0.05$). Means in the same column with no similar letters are different. *F*-value: *= $P<0.05$, **= $P<0.01$, ***= $P<0.001$.

Table 2.4: 'Cherokee Brave' and 'Cloud 9' ANOVA Summary of Fixed Effects.

<u>Variable</u>	<u>Fixed Effects</u>	<u>Ndf</u>	<u>Ddf</u>	<u>F-value</u>	<u>P-value</u>
Total buds	cultivar	1	41	1.66	0.2044
Total buds	fertility	3	41	0.21	0.8855
Total buds	cultivar x fertility	3	41	1.16	0.3366
Laterals	cultivar	1	41	0.13	0.7155
Laterals	fertility	3	41	0.23	0.8771
Laterals	cultivar x fertility	3	41	1.15	0.3402
Caliper	cultivar	1	41	3.22	0.0801
Caliper	fertility	3	41	3.37	0.0275*
Caliper	cultivar x fertility	3	41	3.41	0.0264*
Total Shoot Length	cultivar	1	41	12.67	0.001*
Total Shoot Length	fertility	3	41	3.55	0.0226*
Total Shoot Length	cultivar x fertility	3	41	3.38	0.0271
Total laterals	cultivar	1	41	2.15	0.15
Total laterals	fertility	3	41	0.36	0.7838
Total laterals	cultivar x fertility	3	41	0.06	0.9788
Total nodes	cultivar	1	41	1.56	0.2192
Total nodes	fertility	3	41	0.43	0.7348
Total nodes	cultivar x fertility	3	41	0.39	0.7589
Growth Index	cultivar	1	41	4.32	0.441
Growth Index	fertility	3	41	3.26	0.0308*
Growth index	cultivar x fertility	3	41	2.26	0.0956

*Significant at $P < 0.05$, as determined by mixed model analysis of variance in SAS.

Table 2.5: Effects of Fertilizer Rate on *Cornus kousa* 'Milky Way' Mean Values.

<u>Fertility Rate</u>	<u>Growth Index</u>	<u>Laterals On Stem</u>	<u>Caliper</u>	<u>Total Buds</u>	<u>Total Shoot Length</u>	<u>Total Laterals</u>	<u>Total Nodes</u>
Decherd							
3.6 kg/m ³	32.5bc	6.6	6.08cd	26.6	49.4	6.6	24.9
5.3 kg/m ³	27.4cd	5.4	5.26de	24.0	47.1	5.4	19.8
7.1 kg/m ³	16.6e	2.1	4.48ef	13.4	33.1	2.1	9.9
8.9 kg/m ³	18.5de	3.5	4.79ef	14.8	42.0	3.5	11.9
10.7 kg/m ³	13.3e	3.4	3.67f	12.9	24.9	3.4	8.9
Knoxville							
3.6 kg/m ³	43.0ab	4.0	6.82bc	29.5	69.3	4.0	20.7
5.3 kg/m ³	42.6ab	4.3	7.29b	33.5	66.1	4.3	22.9
7.1 kg/m ³	49.3a	4.7	8.82a	40.5	60.7	4.7	27.9
8.9 kg/m ³	42.6ab	4.7	7.54b	31.7	60.7	4.7	23.4
10.7 kg/m ³	38.4ab	2.6	7.32b	25.8	58.9	2.6	18.0
F-Value							
Location	77.7***	0.06	108.7***	12.75***	34.7***	0.06	6.16*
Fertility	2.9*	1.59	2.34	0.86	2.6*	1.59	1.21
Location x Fertility	2.63*	1.65	6.04***	1.08	0.57	1.65	1.56

Means are least square mean estimates created by the mixed model analysis of variance in SAS. Mean separation performed by LSD mean separation on variables with a significant anova test ($\alpha=0.05$). Means in the same column with no similar letters are different. F-value: *= $P<0.05$, **= $P<0.01$, ***= $P<0.001$.

Table 2.6: Effect of Location on *Cornus kousa* 'Milky Way' Total Buds, Total Nodes, and Total Shoot Length.

<u>Location</u>	<u>Total Buds</u>	<u>Total Nodes</u>	<u>Total Shoot Length</u>
Decherd	18.34b	15.06b	39.30b
Knoxville	32.21a	22.57a	69.12a
<u>F-Value</u>	12.75***	6.16*	34.7***

Means are least square mean estimates created by the mixed model analysis of variance in SAS. Mean separation performed by LSD mean separation ($\alpha=0.05$). Means in the same column with no similar letters are different. *F*-value: *= $P<0.05$, ***= $P<0.001$.

Table 2.7: *Cornus kousa* 'Milky Way' ANOVA Summary of Fixed Effects.

Variable	Fixed Effects	Ndf	Ddf	F-value	P-value
Laterals	location	1	55	0.06	0.8054
Laterals	fertility	4	55	1.59	0.1899
Laterals	location x fertility	4	55	1.65	0.175
Caliper	location	1	55	108.68	0.0001*
Caliper	fertility	4	55	2.34	0.066
Caliper	location x fertility	4	55	6.04	0.0004*
Growth Index	location	1	55	77.65	0.0001*
Growth Index	fertility	4	55	2.9	0.0299*
Growth Index	location x fertility	4	55	2.63	0.0442*
Total Buds	location	1	55	12.75	0.0007*
Total Buds	fertility	4	55	0.86	0.4941
Total Buds	location x fertility	4	55	0.57	0.6843
Total Shoot Length	location	1	55	34.7	0.0001*
Total Shoot Length	fertility	4	55	2.6	0.0299*
Total Shoot Length	location x fertility	4	55	0.57	0.6843
Total Laterals	location	1	55	0.06	0.8054
Total Laterals	fertility	4	55	1.59	0.1899
Total Laterals	location x fertility	4	55	1.65	0.175
Total Nodes	location	1	55	6.16	0.0162*
Total Nodes	fertility	4	55	1.21	0.3184
Total Nodes	location x fertility	4	55	1.56	0.1968

*Significant at $P < 0.05$, calculated by mixed model analysis of variance in SAS.

Appendix 2B: Figures

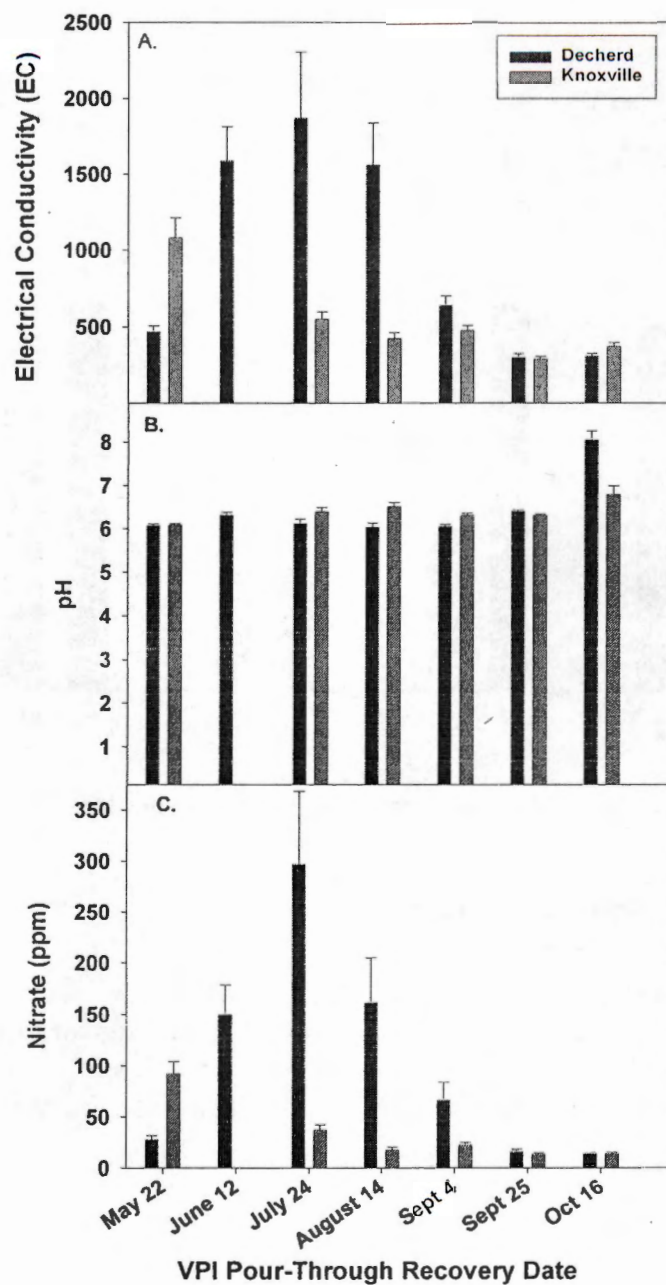


Figure 2.1: Summary of VPI Pour-Through Data. A: Electrical conductivity values averaged by date and location; B. pH values averaged by date and location; C. Nitrate values averaged by date and location; Error bars represent standard error of the mean.

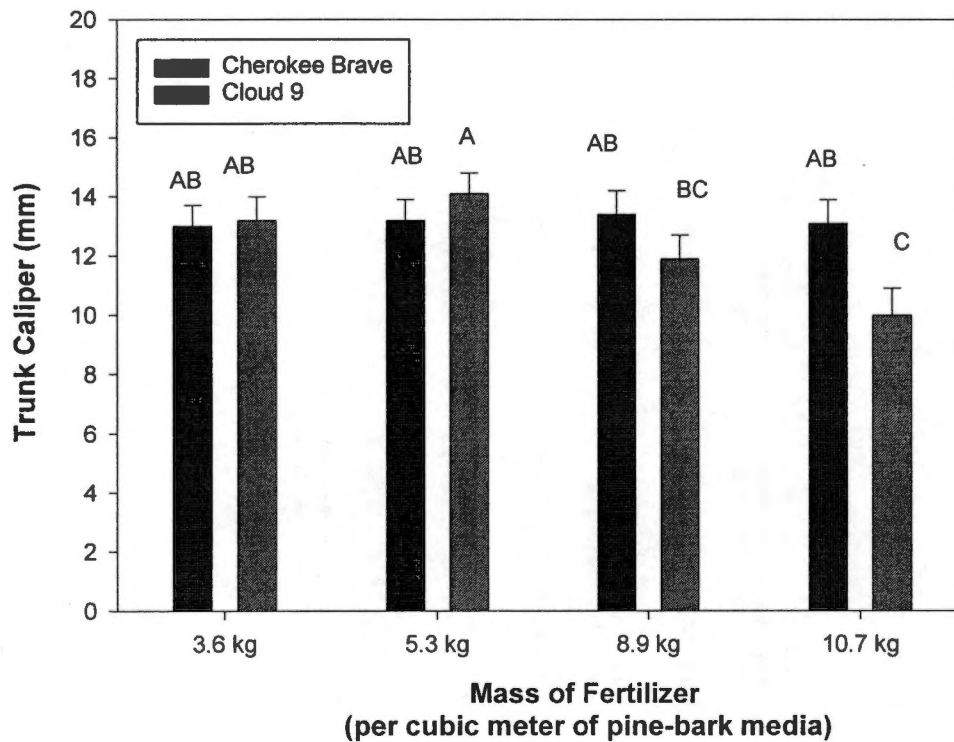


Figure 2.2: Mean Caliper Values of 'Cherokee Brave' and 'Cloud 9' Cultivars Show Different Responses to Fertilizer. Means are least square mean estimates from the mixed model analysis of variance in SAS. Error bars represent standard error. Means separated by LSD mean separation ($\alpha=0.05$). Bars with no similar letters are different.

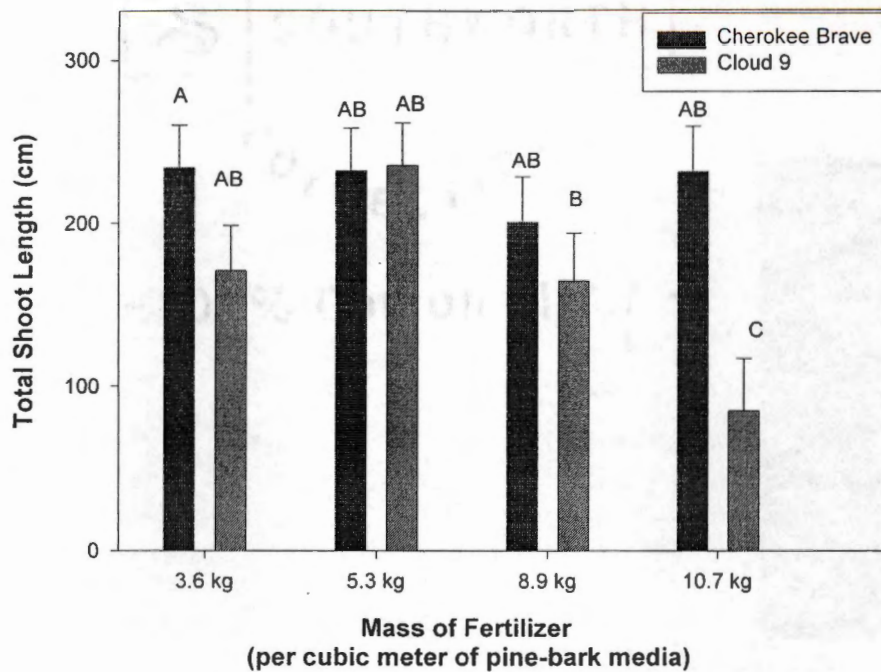


Figure 2.3: Total Shoot Length of 'Cherokee Brave' and 'Cloud 9' Cultivars Showing Different Responses to Fertilizer. Means are least square mean estimates from the mixed model analysis of variance in SAS. Error bars represent standard error. Means separated by LSD mean separation ($\alpha=0.05$). Bars with no similar letters are different.

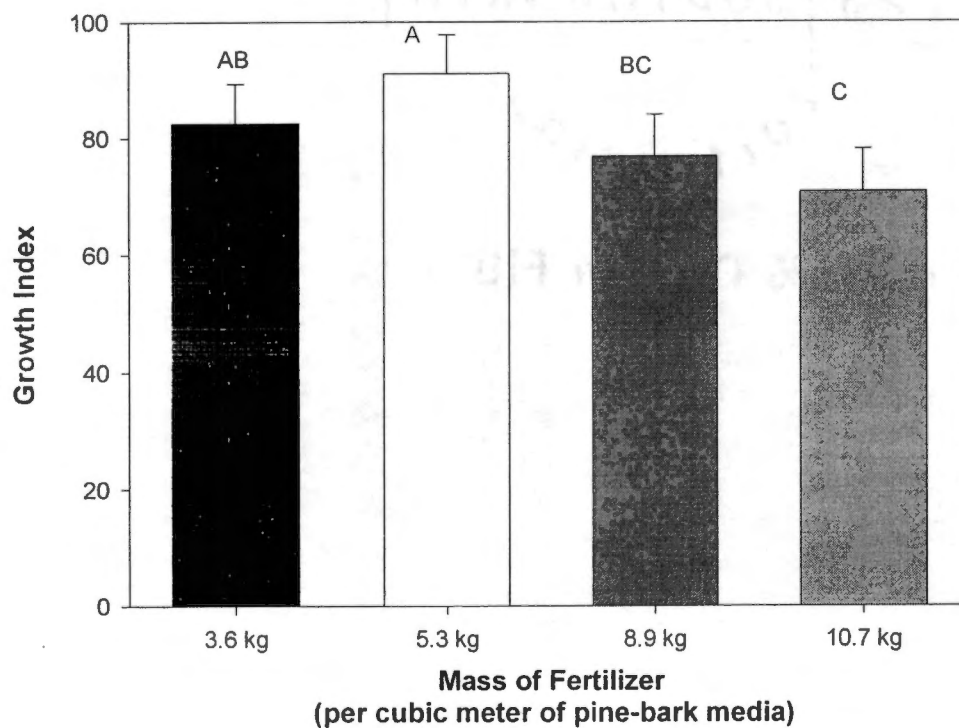


Figure 2.4: Growth Index Combined Response of 'Cherokee Brave' and 'Cloud 9' Dogwoods Receiving Different Fertility Treatments. Means are least square mean estimates from the mixed model analysis of variance in SAS. Error bars represent standard error. Means separated by LSD mean separation ($\alpha=0.05$). Bars with no similar letters are different.

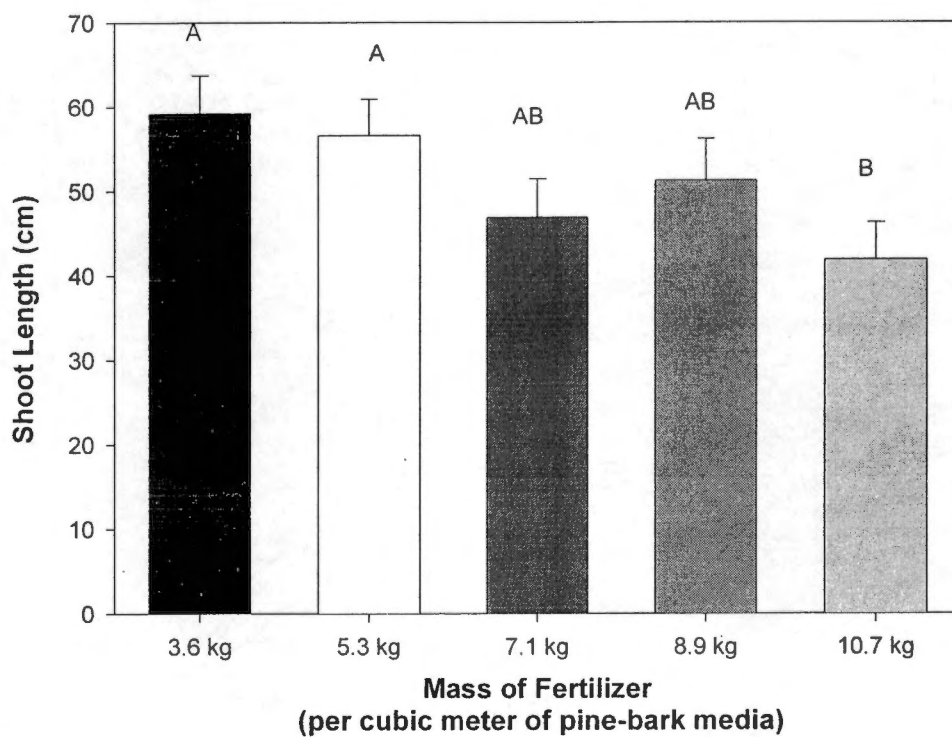


Figure 2.5: Shoot Length Response of Kousa Dogwoods to Fertility Treatments at Knoxville and Decherd Combined. Means are least square mean estimates from the mixed model analysis of variance in SAS. Error bars represent standard error. Means separated by LSD mean separation ($\alpha=0.05$). Bars with no similar letters are different.

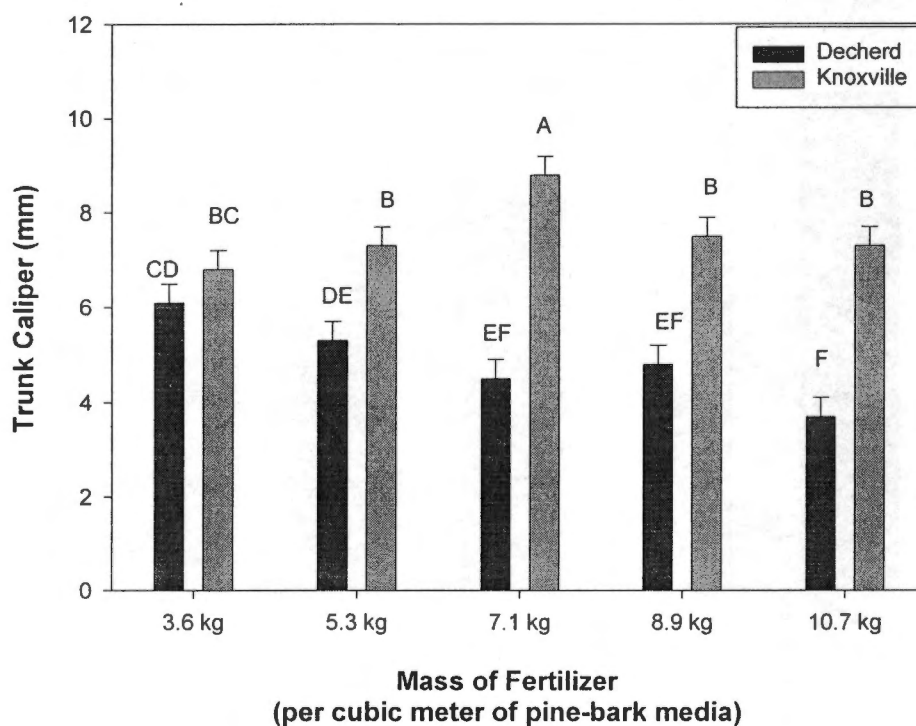


Figure 2.6: Caliper Size of *C. kousa* 'Milky Way' Responded Differently to Fertility Across Locations. Means are least square mean estimates from the mixed model analysis of variance in SAS. Error bars represent standard error. Means separated by LSD mean separation ($\alpha=0.05$). Bars with no similar letters are different.

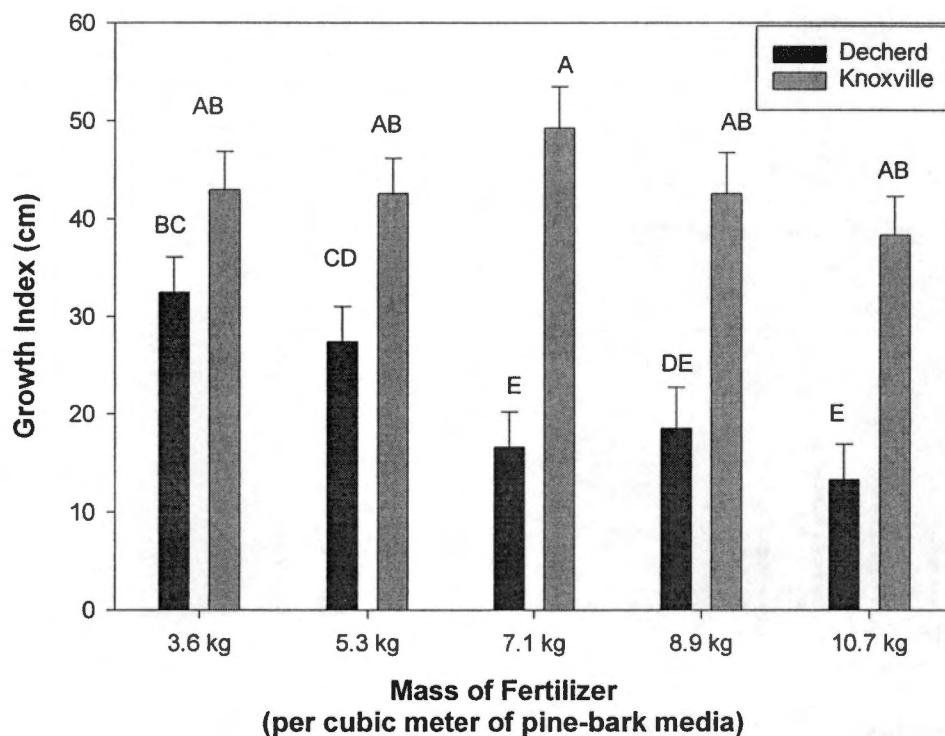


Figure 2.7: Growth Index of *C. kousa* 'Milky Way' Responded Differently to Fertility Across Locations. Means are least square mean estimates from the mixed model analysis of variance in SAS. Error bars represent standard error. Means separated by LSD mean separation ($\alpha=0.05$). Bars with no similar letters are different.

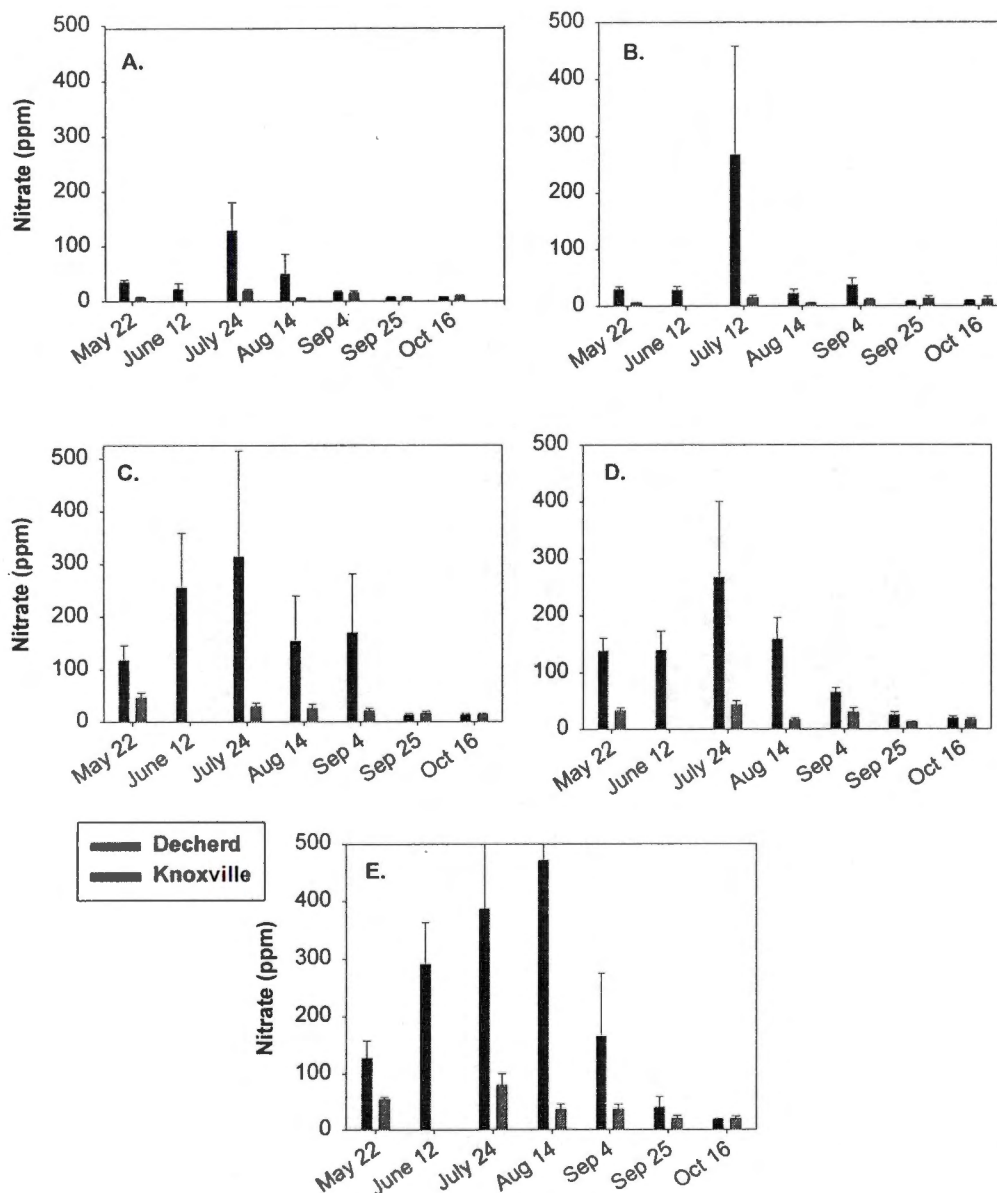


Figure 2.8: Nitrate Captured from VPI Pour-Through Extraction Averaged by Fertilizer Rate for Each Date Tested. A. 3.6 kg/m³ fertilizer; B. 5.3 kg/m³ fertilizer; C. 7.1 kg/m³ fertilizer; D. 8.9 kg/m³ fertilizer; E. 10.7 kg/m³ fertilizer. Error bars represent standard error of the mean.

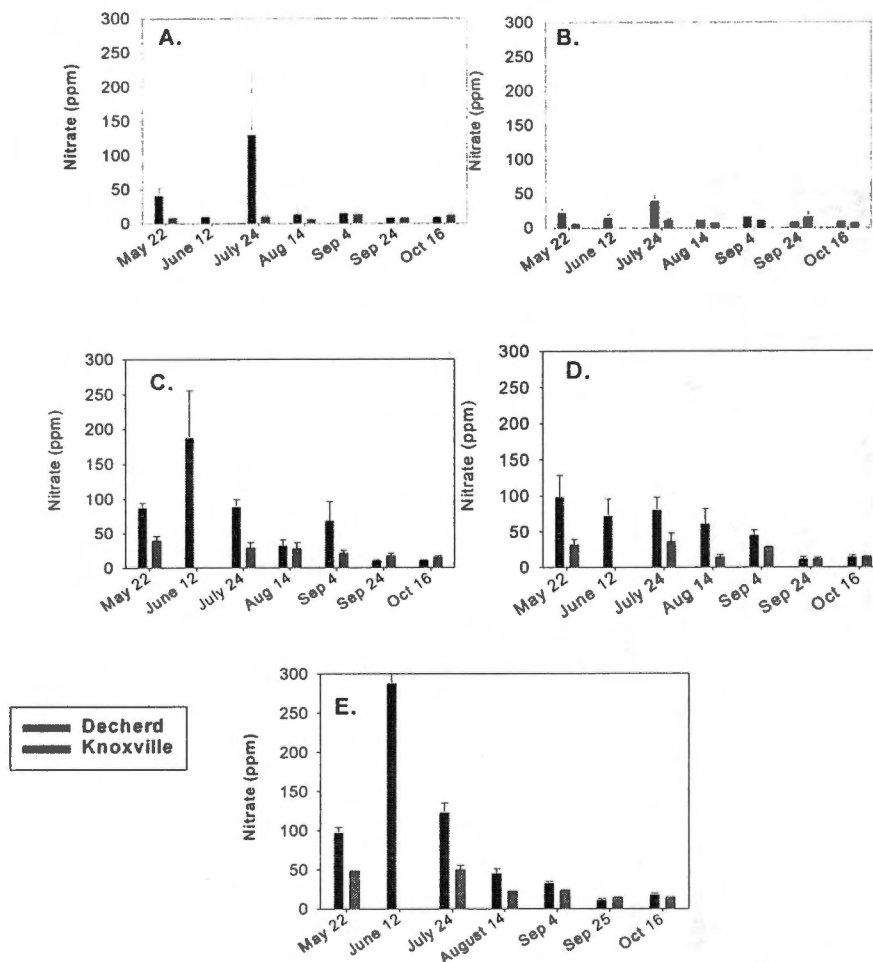


Figure 2.9: Nitrate Captured from 3.78 l Containers Averaged by Fertilizer Rate and Date. A. 3.6 kg/m³ fertilizer; B. 5.3 kg/m³ fertilizer; C. 7.1 kg/m³ fertilizer; D. 8.9 kg/m³ fertilizer; E. 10.7 kg/m³ fertilizer. Error bars represent standard error of the mean.

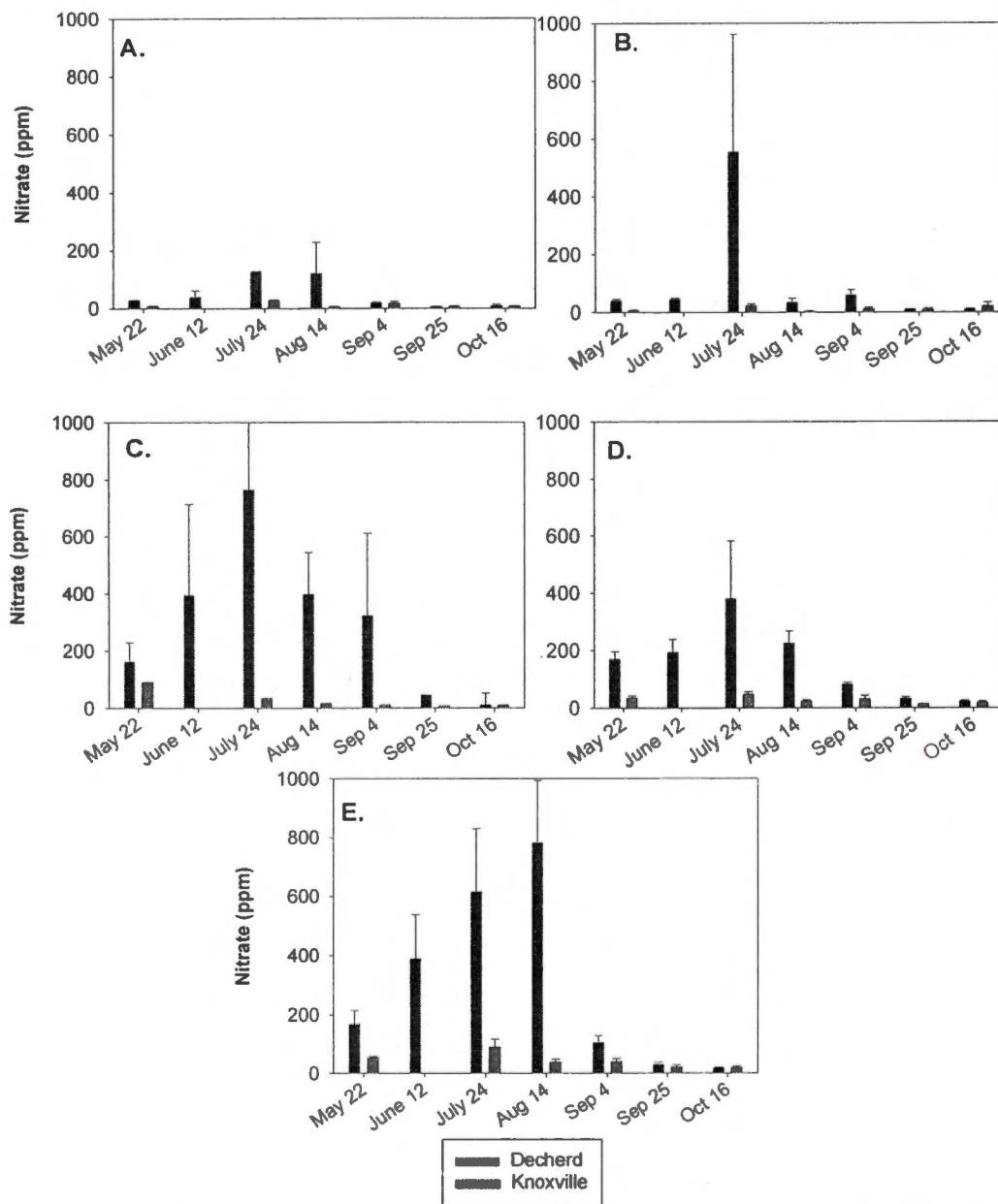


Figure 2.10: Nitrate Captured from 11.3 l Containers Averaged by Fertilizer Rate and Date Tested. A. 3.6 kg/m³ fertilizer; B. 5.3 kg/m³ fertilizer; C. 7.1 kg/m³ fertilizer; D. 8.9 kg/m³ fertilizer; E. 10.7 kg/m³ fertilizer. Error bars represent standard error of the mean.

Part 3: Whitefringed Beetle Larval Feeding on Dogwoods



Introduction

Larval feeding by whitefringed beetles causes severe economic damage to the roots of many agricultural crops (Young et al. 1950). In Alabama sweet, from September through harvest, severe economic damage is inflicted on sweet potatoes, by feeding fourth instar or larger whitefringed beetle larvae (Zehnder 1997). Typically a pest of peanuts, strawberries, and sweet potatoes, whitefringed beetles cause economic damage to nursery crops in Tennessee and other southeastern states. The beetle has been collected in ornamental nurseries since the 1940's in the United States and in South America (Berry 1947 and Gross et al. 1972). The extent of the potential economic threat from the whitefringed beetle to the nursery industry has not been quantified. However, nurserymen and researchers have observed plant injury attributed to whitefringed beetle larvae feeding on several plant hosts, including dogwoods. Some seedlings and liners have been severely injured and when these plants are dug, roots show evidence of larval feeding. Plant growth is stunted, foliage yellows, and many plants die (DRK, personal observations).

In Tennessee, dogwoods are one of the most economically important ornamental trees produced. In 1980, dogwoods made up 16% of Tennessee's ornamental production (Glasgow 1984). Tennessee produced dogwoods accounted for 23.2% of the dogwood trees sold from nurseries in the United States in 1998, more than the next two leading states—North Carolina and Oregon, combined (Klingeman et al. 2001). Because of their importance to the industry and the evidence that they are preferred hosts of whitefringed beetles, the objective of this study is to quantify the response of two types of dogwoods, *Cornus kousa* and *Cornus florida*, to whitefringed beetle larval feeding.

Materials and Methods

Bare-root liners of flowering dogwood (*Cornus florida* L.) and kousa dogwood (*Cornus kousa* (Buerger ex Miq.) Hance) were purchased in 2002 and 2003 from a Tennessee field production nursery. In March, 50 *C. florida* and 50 *C. kousa*, bare root, seedling liners were potted in 7.4 l Classic 900 nursery pots (Nursery Supplies, Inc. Fairless Hills, PA) and arranged in a randomized block design with a 5 x 2 factorial treatment and 10 replications. The pots were filled with Sequatchie, fine-loamy, siliceous, thermic Humic Hapludults, soil pH 7.5, that was sieved with a U.S.A. Standard Testing Sieve with 8.0 mm (5/16 inch) openings. Filled pots weighed an average of 8.7 kg (19.18 lbs) per pot when completely dry. In January and February, whitefringed beetle larvae were field-collected while rows of nursery field stock were dug. In total, 380 larvae were applied to the pots in treatment levels of 0, 1, 3, 6, and 9 larvae per pot. In 2003, one larva was removed from the highest treatment level because of insufficient numbers of field-collected larvae to complete the treatment sets. All combinations were tested for a two month period. In 2002, soil moisture in the pots was maintained at 17 +/- 3% of soil volume and monitored by datalogger outputs. Ten pots were randomly chosen to receive a 20.5 cm (8.07 in) soil moisture probe (Decagon, Pullman, WA). The data was collected on a datalogger, which was programmed to calculate the percentage of soil moisture in the pots. In 2003, based on 2002 results, soil moisture was maintained at approximately 17% weight/volume by irrigating pots with 500 ml on 3-day intervals. The trees were maintained in a greenhouse at 23 +/- 3° C (75 +/- 5° F), 85 ± 5% RH. At the end of the two month feeding period, measurements of tree caliper, growth index ((width 1 + width 2 + height)/3), length of 5 terminal shoots, root dry mass, shoot dry mass, total

leaf dry mass, and number of whitefringed beetle larvae recovered were taken. Root injury was rated on a 1-5 scale where: 1=10% of the root was injured, 2=20% of the root was injured, 3=30% of the root was injured, 4=40% of the root was injured, 5=50% or more of the root was injured. Roots with no visible injury were rated 0. The leaf area was calculated for 10 fully expanded leaves that were selected from each tree. These leaves were dried and weighed. The total leaf dry mass was also calculated.

Measurements were used to provide an estimate of the total canopy area of each tree, such that the ratio of summed leaf area for 10 leaves to the dry mass of 10 leaves was determined and multiplied by the total leaf dry mass for each. Root injury and percent recovery measurements were mathematically transformed using the arcsine transformation in SAS. The transformed means were backtransformed to represent actual measurements. Measurements were analyzed using the mixed model analysis of variance in the SAS software program. Orthogonal contrasts were performed on the larval treatment effect. Statistical significance was determined at the $\alpha=0.05$ probability level. Diagnostic tests were also included in the data analysis in the form of a macro program developed by Dr. Arnold Saxton, University of Tennessee. Diagnostics consisted of the Shapiro-Wilk test for normality, Extreme Observations, Stem-Leaf Plot, Normal Probability Plot, and a check of equality of standard deviations.

Results

In the 2002 growing season, trees were received as small liners, which had few lateral or fibrous roots when planted. Many of the trees were slow to produce leaves. Trees that did not produce leaves were excluded from statistical analysis, if there were no larvae recovered from the pot and no signs of larval root injury were evident. In 2002,

caliper measurements differed by tree species tested ($F=12.2$; $df=1, 78$; $P<0.008$) and by the number of larvae introduced ($F=3.22$; $df=4, 78$; $P<0.02$) (Table 3.1)¹. Orthogonal contrasts were performed on the larval effect, which indicate that caliper measurements showed a quadratic response in caliper size to larval treatments ($P<0.03$). The interaction between plant species tested and number of larvae applied to the pot was also significant ($F=2.96$; $df=4, 78$; $P<0.02$). The caliper growth of flowering dogwood increased as the number of larvae in the pot raised from 6 to 9, while the caliper growth of kousa dogwoods continued to decline (Figure 3.1).²

Growth indices were not different between plant species ($F=2.72$; $df=1, 78$; $P>0.1$). Growth index declined as larval numbers increased ($F=3.34$; $df=4, 78$; $P<0.01$) (Figure 3.2). There was no interaction between plant species and larval treatment ($F=2.02$; $df=4, 78$; $P>0.1$).

Average terminal length (shoot length) differed between kousa and flowering dogwood ($F=16.5$; $df=1, 78$; $P<0.0001$) and by larval treatment ($F=3.78$; $df=4, 78$; $P<0.007$) (Table 3.1). As the numbers of larvae increased per pot, shoot length declined linearly ($P<0.0004$). Flowering and kousa dogwood responded differently to the number of larvae applied per pot ($F=2.54$; $df=4, 78$; $P<0.05$) (Figure 3.3).

Root dry mass differed by plant species tested ($F=62.44$; $df=1, 79$; $P<0.0001$) and by larval treatment ($F=3.16$; $df=4, 79$; $P<0.02$) (Figure 3.4). The root mass response to the larval treatment declined in a linear fashion ($P<0.004$). Shoot dry mass between kousa and flowering dogwoods was different ($F=33.6$; $df=1, 78$; $P<0.0001$). Shoot dry

¹ All tables are found in Appendix 3A located at the end of this section.

² All figures are found in Appendix 3B located at the end of this section.

mass was reduced as the number of larvae added to the pot increased to 6 larvae. Dry mass increased in pots with 9 larvae ($F=3.9$; $df=4, 78$; $P<0.006$), though there was no evidence of an orthogonal response to larval treatment in shoot dry mass (Figure 3.5). Leaf dry mass measurements did not differ by plant species ($F=1.81$; $df=1, 78$; $P>0.18$) or larval treatment ($F=1.88$; $df=4, 78$; $P>0.12$), although flowering dogwood leaf dry mass increased from 6 to 9 larvae per pot, while kousa leaf dry mass continued to decline ($F=2.67$; $df=4, 78$; $P<0.04$) (Figure 3.6). The dry mass of ten randomly selected leaves was different by plant species ($F=16.7$; $df=1, 77$; $P<0.0001$) and by larval treatment ($F=5.2$; $df=4, 77$; $P<0.001$) (Figure 3.7). Dry mass declined linearly as the number of larvae per pot increased ($P<0.0001$).

Root injury differed only by larval treatment effect ($F=25.13$; $df=4, 79$; $P<0.0001$) (Figure 3.8). Root injury ratings indicate a quadratic response to larval treatment, which suggests that root injury was greatest at infestation levels of 6 to 9 larvae per pot and would decline as infestation levels were increased ($P<0.0005$). The number of whitefringed beetles recovered from the pots at the end of the feeding period differed by number of larvae added to the pots ($F=12.2$; $df=4, 79$; $P<0.001$) (Figure 3.9). The number of beetles recovered increased as the infestation level increased ($P<0.0001$).

The amount of laminar expansion observed (the area of 10 fully expanded leaves) demonstrated differences between flowering and kousa dogwoods ($F=33.1$; $df=1, 79$; $P<0.0001$). Foliar area declined in a linear pattern as the number of larvae per pot was increased ($F=4.7$; $df=4, 79$; $P<0.002$) (Figure 3.10). The foliar area responded in a negative linear pattern to larval treatments ($P<0.0002$). Canopy leaf area was different between flowering and kousa dogwoods ($F=4.0$; $df=4, 79$; $P<0.05$) (Table 3.3).

The 2003 growing season yielded somewhat different results than the 2002 season. Seven variables exhibited statistical differences only in the comparison of kousa and flowering dogwoods. There were no differences attributed to larval infestation numbers. These variables included: caliper, growth index, the average of five terminal shoots (shoot length), shoot dry mass, leaf dry mass, dry mass of ten leaves, total area of ten leaves (foliar area), and canopy leaf area. (range: $F=142$ to 17 ; $df=1, 80$; $P<0.05$ to 0.0001) (Table 3.2, 3.3). Root dry mass exhibited no differences by plant species or larval treatment and there was no interaction between the two fixed effects.

Root injury ratings were similar among kousa and flowering dogwoods ($F=0.58$; $df=1, 80$; $P<0.45$), but differed as the numbers of larvae increased ($F=44.5$; $df=4, 80$; $P<0.0001$) (Figure 3.11). Root injury demonstrated a quadratic pattern, in which injury peaked in trees infested with 6 larvae per pot with a rating of 4.0 and declined as the infestation numbers were increased to 9 ($P<0.0002$). Regardless of host plant, similar numbers of whitefringed beetles were recovered. Recovery differed by number of larvae added to the pot ($F=16.7$; $df=4, 80$; $P<0.0001$), exhibiting a quadratic pattern ($P<0.0007$), which peaked in pots treated with 6 larvae, with an average of 2.75 larvae recovered per pot (Figure 3.12). Host plant did not affect percent root recovery from larval damage. The percent of the root injury showing recovery (callus formation) decreased linearly ($P<0.002$) as the numbers of larvae per pot were increased ($F=4.01$; $df=3, 50$; $P<0.01$) (Figure 3.13). Plants treated with a single larva had the greatest recovery from root injury with an average of 48%.

Discussion

Root-feeding larvae of whitefringed beetles can injure their plant hosts in as little as a two-month period of time. *Diaprepes abbreviatus* (L.), another non-native weevil with root feeding larvae, begins to do quantifiable root damage in as little as three weeks (Rogers et al. 2000).

In both seasons, 2002 and 2003, plant growth variables differed between flowering and kousa dogwoods. These differences can be explained biologically, since the two tree species tested have different patterns of growth. The size of tree and amount of root mass influence its susceptibility to larval damage. Larval population also influenced tree growth, but these affects were more evident in the 2002 growing season (Table 3.1). In 2002, bare-rooted liners of both dogwood species had intact primary roots, but few lateral and fibrous roots compared to those planted in 2003. In 2003, larger root masses enabled the dogwoods to compensate for whitefringed beetle larval feeding. Trees were not growth inhibited, though their primary roots showed signs of injury.

In 2002, the growth response to whitefringed beetle larval damage exhibited a quadratic trend. Tree growth was inhibited as the number of larvae per pot increased. Trees infested with 6 larvae were most inhibited, while growth inhibition declined in pots infested with 9 larvae. Growth index, root dry mass, shoot dry mass, dry mass of 10 leaves, and foliar area exhibited a similar growth response. In some cases, the 6 and 9 larvae treatments were not statistically different, but through graphic representation the quadratic pattern is evident. Although the growth patterns of the well-rooted 2003 trees

were not inhibited by larval feeding, the same quadratic response is apparent in the root injury ratings and whitefringed beetle recovery numbers.

In response to larval numbers, 2002 root injury increased linearly, while in 2003 there was a quadratic response to root injury. Plant injury can be expected on young liners infested with as few as 6 larvae per pot. Injury declines as larvae are present in numbers greater than 6. Whitefringed beetle recovery or larval survival exhibited a positive linear trend in 2002, but again in 2003 there was a quadratic trend, with a decline in recovery in trees with larval populations greater than 6.

The decline in root injury and growth inhibition from the 6 to 9 larvae per pot treatments could be attributed to larval competition for food resources. In a study of root weevils, *Diaprepes abbreviatus* (L.), feeding on citrus, higher insect pressure resulted in competition between larvae for root resources (Rogers et al. 2000). Larvae were extracted periodically throughout the trial from the citrus plants being tested. Larval recovery decreased over time. The decline was more pronounced in treatments inoculated with five larvae, suggesting resource competition. In addition, larvae infested at two per seedling, accumulated biomass more rapidly than those in the five-per-seedling infestations. These effects were observed even when larval survival was high and root resources were not limiting (Rogers et al. 2000). The 7.36 l pots used for this experiment are equivalent to a 7,400 cubic centimeter volume of soil. In our study larval numbers greater than 6 per 7,400 cm³ led to competition for food resource. In the field, whitefringed beetle larvae are patchy in distribution, but most often detected in large numbers in preferred feeding niches, such as near the crown areas of tree root systems in field production rows of liners. In these areas, larval populations greater than 6 per 7,400

cubic centimeters of soil are likely to occur and competition would result (DRK, personal observations). Cannibalism among whitefringed beetle larvae has not been described, although field collected larvae, were observed inflicting injury (leading to mortality) upon each other, when held in close proximity (DRK, personal observations). Competition results in lower populations either by lack of food resources or by injury. The impact competition has on reducing larval populations and host plant feeding injury in the field is not known.

In this study, percent root recovery was indicated by callus formation over whitefringed beetle-injured roots. Roots exposed to fewer larvae, had greater recovery from larval damage. Rogers et al. (2000) detected a lethargic period, indicated by a decline in larval weight, in 8th instar *D. abbreviatus* following 79 days of infestation. The lethargic period initiated pupation. A decline in feeding activity before pupation would give roots a chance to begin to recover from larval feeding. This would be particularly likely if the tree were infested with one or three larvae, each at the same developmental stage. In the 2003 study, 14 whitefringed beetle larvae were recovered from trees infested with a single larva per pot. Only five of the recovered larvae had not pupated.

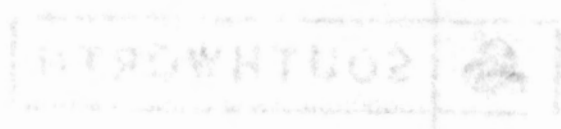
In 2002, the experiment was initiated on 11 April and ran through 11 June. Because pupae and newly eclosed adults were recovered from the roots, the trial began too late in the season to yield an accurate representation of larval injury to trees. The presence of adults and pupae means that root-feeding activity subsided about two weeks before data were collected. The 2003 trial was scheduled to start in early March, but field conditions prohibited larval collection until late March. Despite starting 2 weeks earlier than in 2002, 37 adults and 34 pupae were recovered from the soil in 2003. In total, 141

whitefringed beetles were recovered in 2003, which suggests that 50% percent of the larvae applied to the pots had not been feeding for two weeks prior to data collection. In sweet potatoes, whitefringed beetle larvae do not do significant damage until they reach fourth instar size (Zehnder 1997). In Alabama, the majority of whitefringed beetles reach this size in September, although it is possible to find larvae of various stages throughout the season because of the long oviposition period of the adult beetles (Young et al. 1950; DRK, personal observations). In future, similar research should be started in late winter or in the fall to yield an accurate representation of larval damage.

Literature Cited

- Berry, P. A. 1947. Investigations on the white-fringed beetle group in South America. J. Econ. Entomol. 40: 705-09.
- Glasgow, T. E. 1984. Production systems and costs for producing flowering dogwood (*Cornus florida*) cultivars from budded seedlings and rooted cuttings in Tennessee. M.S. Thesis, University of Tennessee, Knoxville, TN.
- Gross, H. R., Jr., Mitchell, J. A. Shaw, Z. A., and G. R. Padgett. 1972. Extended storage of eggs of whitefringed beetles. J. Econ. Entomol. 65: 731-33.
- Klingeman, W. E., J. R. Broker, D. B. Eastwood, J. B. Riley, B. K. Behe, and P. Knight. 2001. Consumer perceptions of landscape characteristics, disease and pest problems, and the value of powdery mildew resistant dogwoods. UT Institute of Agriculture, Department of Agricultural Economics, Research Series 07-01.
- Rogers, S., C. W. Mc Coy, and J. H. Graham. 2000. Larval growth of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) and resulting root injury to three citrus varieties in tow soil types. J. Econ. Entomol. 93: 380-87.
- Young, H. C. and B. A. App. 1939. Biology of the white-fringed beetle (*Naupactus leucoloma* Boh). USDA: Bur. Entomol. Pl. Quar. Washington, D. C.
- Young, H. C., App, B. A., Gill, J. B., and H. S. Hollingsworth. 1950. White-fringed beetles and how to combat them. USDA: Circ. 850.
- Zehnder, G. 1997. Population dynamics of whitefringed beetle (Coleoptera: Curculionidae) on sweet potato in Alabama. Envir. Entomol. 26: 727-35.

Appendix 3A: Tables



100% Cotton Fiber

Table 3.1: Larval Study 2002—Summary of Dogwood Growth Response to Treatment Effects.

<u>Fixed Effects</u>	<u>Caliper</u>	<u>Growth Index</u>	<u>Shoot Length</u>	<u>Root Dry Mass</u>	<u>Shoot Dry Mass</u>	<u>Leaf Dry Mass</u>	<u>DM10 Leaves</u>
<i>C.florida</i>							
0	05.91ab	48.7	12.4a	11.9	11.6	6.0ab	2.3
1	5.89ab	43.9	8.3bc	9.1	9.5	4.5abcd	1.8
3	5.47bc	47.5	9.8ab	9.2	9.3	4.9abc	2.0
6	5.21cde	41.5	6.5cd	7.08	9.1	3.5cd	1.5
9	6.19a	45.0	7.7bc	9.1	11.5	6.3a	1.7
<i>C. kousa</i>							
0	5.62abc	43.1	6.7cd	5.4	8.6	5.3abc	1.7
1	5.43bcd	47.8	8.0bc	5.0	8.6	4.7abcd	1.6
3	5.53abc	45.4	6.1cd	4.7	6.9	5.5abc	1.6
6	4.76de	40.4	6.3cd	3.6	4.9	3.8bcd	1.2
9	4.71e	40.0	4.1d	2.9	6.7	2.5d	1.1
F-Values							
Dogwood species	12.2***	2.72	16.49***	62.44***	33.57***	1.81	6.7***
Infestation Level	3.22*	3.34*	3.78**	3.16*	3.87**	1.88	5.18**
Species x Infestation	2.96*	2.02	2.54*	0.94	1.7	2.67*	1.0
Orthogonal Contrasts--Infestation Level							
Linear	*	**	***	**	NS	--	***
Quadratic	*	NS	NS	NS	NS	--	NS

Values are least square mean estimates produced by the mixed model analysis of variance in SAS. Means followed by the same letter are not significant. LSD mean separations values are only present if there was a significant interaction between species and infestation ($\alpha=0.05$). Significant *F*-value and contrasts*= $P<0.05$, **= $P<0.01$, ***= $P<0.001$, NS=not significant, --not analyzed.

Table 3.2: Larval Study 2003—Summary of Dogwood Growth Response to Treatment Effects.

Fixed Effects		Caliper	Growth	Index	Shoot Length	Root Dry Mass	Shoot Dry Mass	Leaf Dry Mass	DM10 Leaves
<i>C. florida</i>	0	7.19	44.1	3.6	15.3	20.0	20.0	2.6	0.8
	1	7.61	42.8	3.5	14.0	20.4	20.4	3.2	1.1
	3	7.81	45.9	3.1	18.4	19.2	19.2	2.8	0.9
	6	7.55	42.0	3.6	17.5	20.2	20.2	2.6	0.8
	8	7.91	42.0	3.0	18.9	21.6	21.6	3.0	0.9
<i>C. kousa</i>	0	8.13	55.0	4.8	16.6	25.7	25.7	9.4	0.8
	1	8.44	57.6	5.2	15.4	24.0	24.0	9.2	0.7
	3	8.40	53.8	3.9	18.1	24.8	24.8	10.2	0.8
	6	8.31	53.3	3.6	14.3	23.8	23.8	7.1	0.6
	8	8.28	57.5	4.8	14.3	25.0	25.0	7.3	0.8
<i>F-Value</i>									
Dogwood Species		18.8***	116.63***	16.7***	0.74	17.1***	142.2***		3.15
Infestation Level		1.0	0.66	1.55	0.89	0.24	1.75		0.87
Species x Infestation		0.39	1.56	1.58	0.98	0.25	1.66		0.58

Values are least square means calculated by the mixed model analysis of variance in SAS; *F*-Value: ***= $P < 0.001$.

Table 3.3: Leaf Area and Canopy Leaf Area of Dogwoods Response to Larval Infestation in 2002 and 2003.

<u>Fixed Effects</u>	<u>Leaf Area</u>	<u>Canopy Leaf Area</u>	<u>Fixed Effects</u>	<u>Leaf Area</u>	<u>Canopy Leaf Area</u>
2002			2003		
<i>C. florida</i>			<i>C. florida</i>		
0	377	996	0	111	342
1	303	764	1	148	470
3	306	768	3	124	395
6	227	536	6	109	352
9	273	988	8	128	432
<i>C. kousa</i>			<i>C. kousa</i>		
0	243	818	0	104	1335
1	227	657	1	99	1283
3	185	686	3	114	1547
6	198	674	6	79	910
9	151	359	8	85	857
<u>F-Value</u>					
Dogwood Species	33.1***	4.03*		7.97	83.6***
Infestation Level	4.68**	1.35		1.1	2.4
Species x Infestation	1.37	2.21		0.75	2.41
<u>Orthogonal Contrasts--Infestation Level</u>					
Linear	***	--		--	--
Quadratic	NS	--		--	--

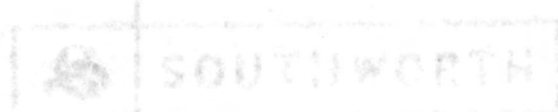
Numbers are least square mean estimates created by the mixed model analysis of variance in SAS; *F*-value and contrasts:
 *= $P < 0.05$, **= $P < 0.01$, ***= $P < 0.001$, NS=not significant, --=not analyzed.

Table 3.4: 2002 and 2003 Root Injury, WFB Recovered, and Percent Root Recovery Response to Larval Infestation.

<u>Fixed</u> <u>Effects</u>	<u>WFB</u> <u>Recovered</u>	<u>Root</u> <u>Injury</u>	<u>% Root</u> <u>Recovery</u>	<u>Fixed</u> <u>Effects</u>	<u>WFB</u> <u>Recovered</u>	<u>Root</u> <u>Injury</u>	<u>% Root</u> <u>Recovery</u>
2002				2003			
<i>C. florida</i>				<i>C. florida</i>			
0	0	0	--	0	0	0	--
1	0.4	0	--	1	0.7	0.9	45
3	0.8	1.5	--	3	1.7	1.4	28
6	2.0	2.3	--	6	2.8	3.0	29
8	2.3	2.3	--	8	1.5	3.2	25
<i>C. kousa</i>				<i>C. florida</i>			
0	0	0	--	0	0	0	--
1	0.5	1.2	--	1	0.7	0.3	54
3	0.7	1.1	--	3	1.4	1.6	62
6	0.6	2.0	--	6	2.7	4.4	20
8	2.3	2.6	--	8	2.6	4.5	10
<u>F-Value</u>							
Dogwood Species	1.68	1.26	--		0.35	0.58	0.13
Infestation Level	12.2***	25.1***	--		16.7***	44.5***	4.01*
Species x Infestation	1.48	1.30	--		1.09	1.43	2.15
<u>Orthogonal Contrasts--Infestation Level</u>							
Linear	***	***	--		***	***	**
Quadratic	***	NS	--		***	***	NS

Values are least square means calculated by the mixed model analysis of variance in SAS; Percent root recovery was not measured in 2002; *F*-value and contrasts: *= $P < 0.05$, **= $P < 0.01$, ***= $P < 0.001$; NS=not significant, --not analyzed;

Appendix 3B: Figures



COLLECTION

100% Cotton fiber

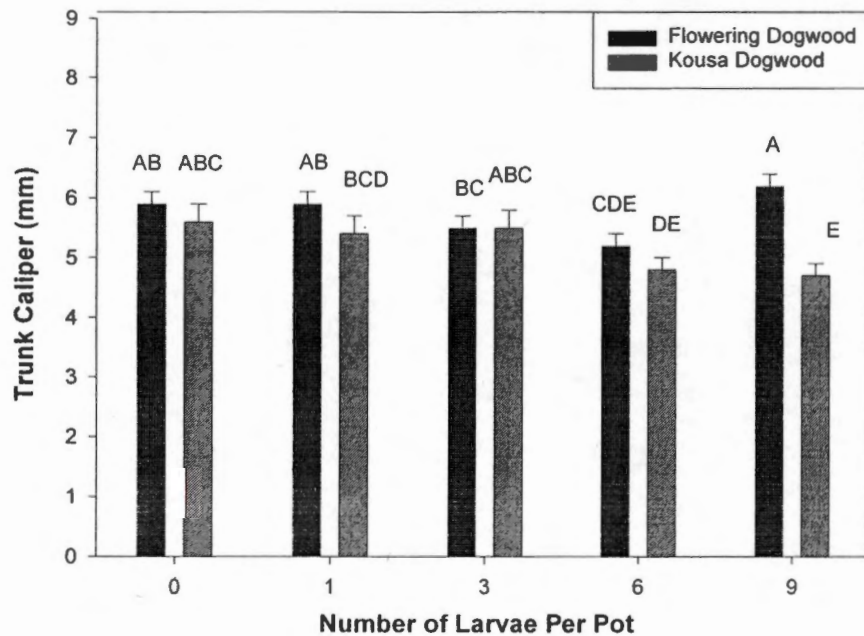


Figure 3.1: Caliper Size Response of Container Grown Dogwood Species Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

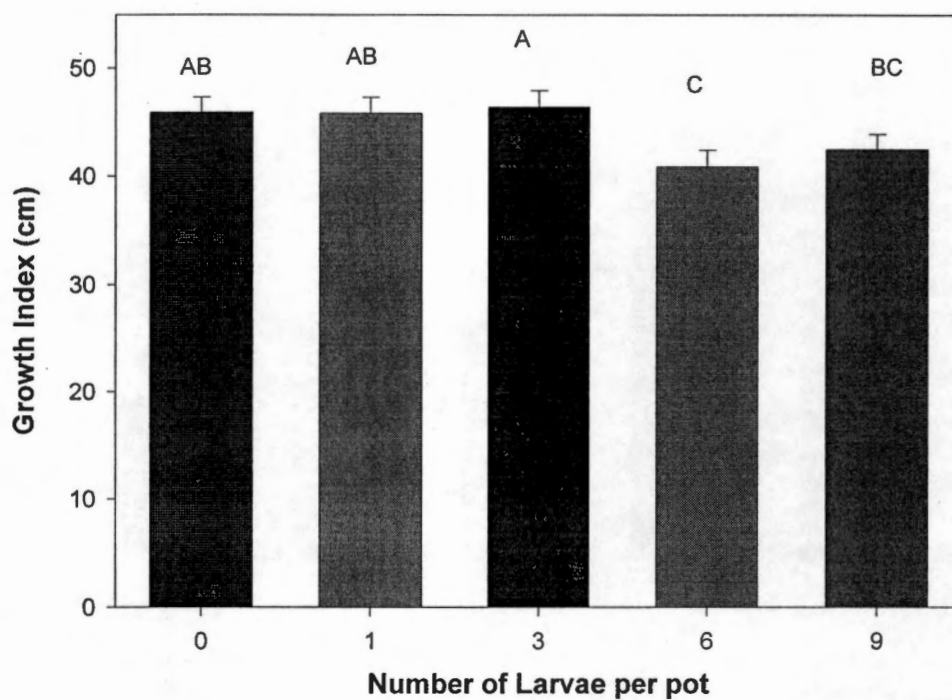


Figure 3.2: Growth Index Response of Container Grown Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

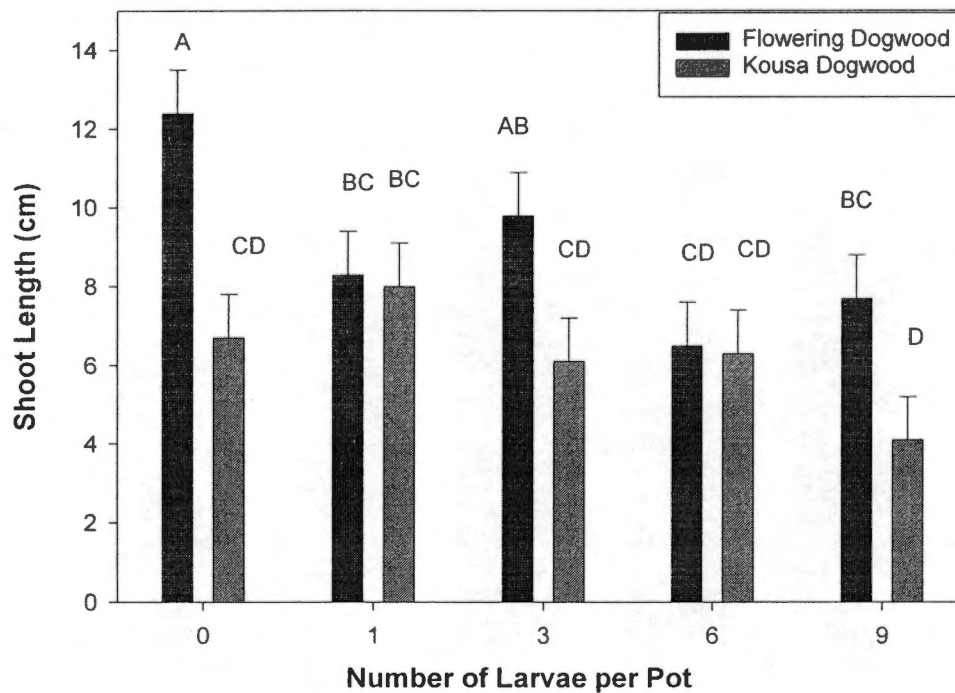


Figure 3.3: Shoot Length (Average of five terminal shoots) Response of Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

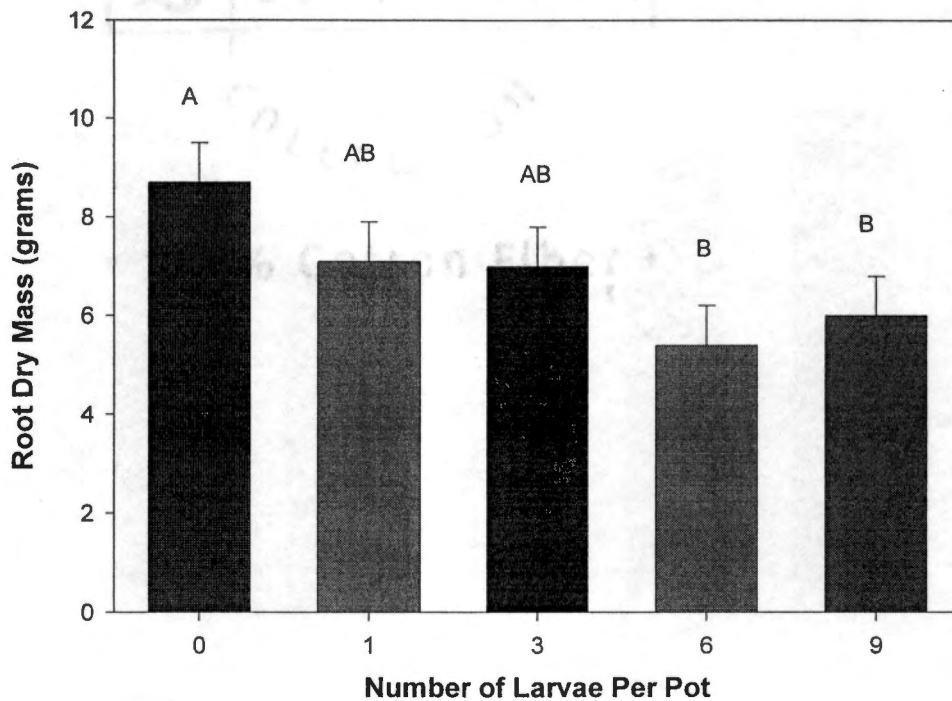


Figure 3.4: Root Dry Mass Response of Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

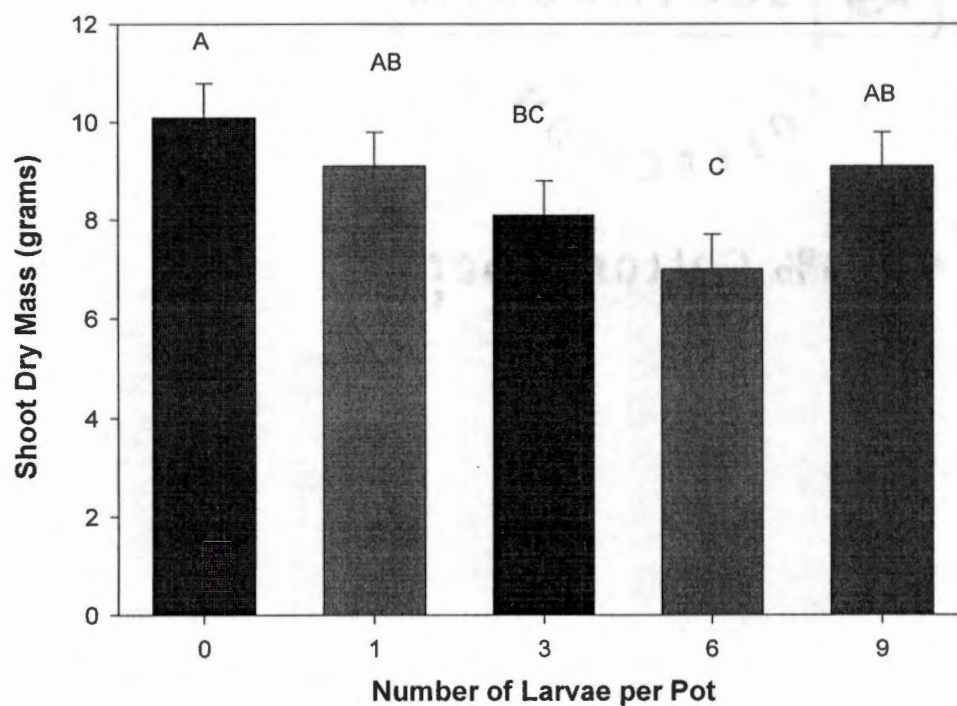


Figure 3.5: Shoot Dry Mass Response of Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

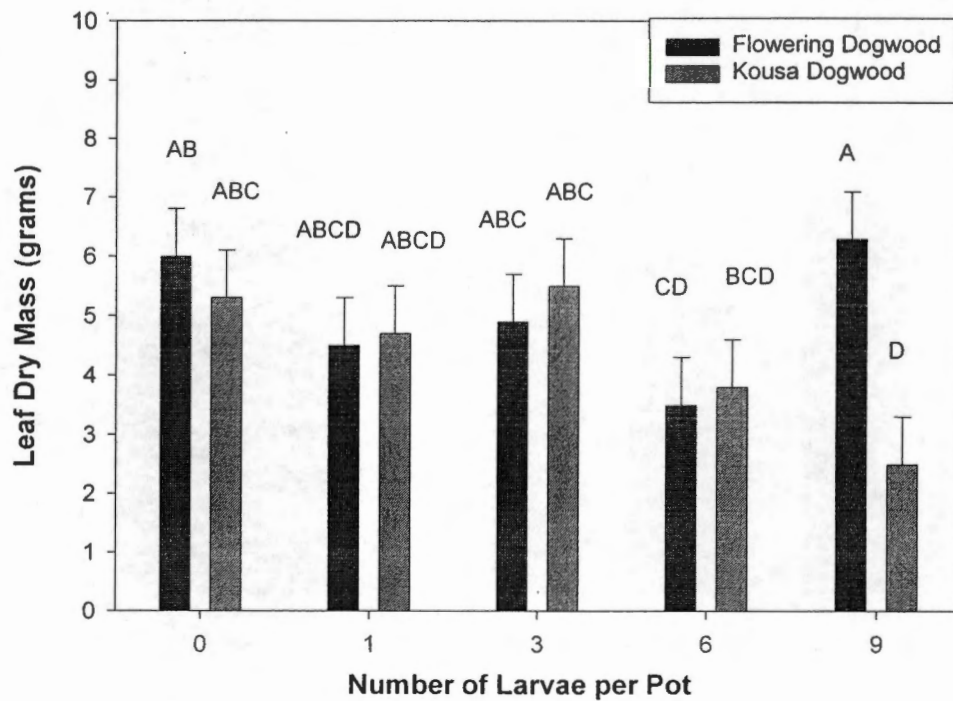


Figure 3.6: Leaf Dry Mass Response of Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

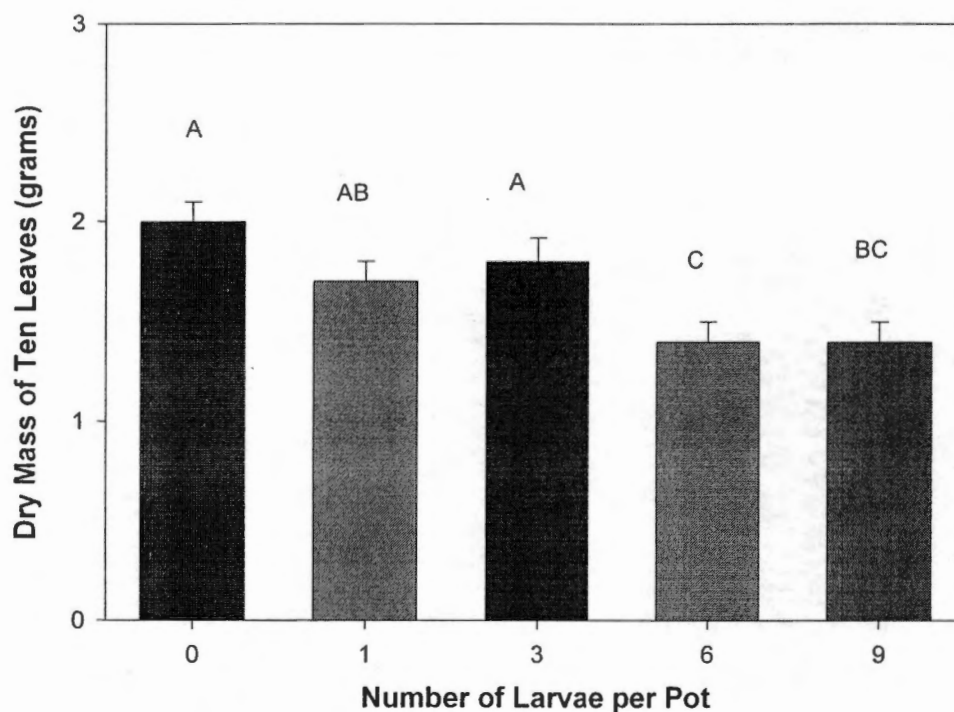


Figure 3.7: Dry Mass of Ten Leaves Response of Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation($\alpha=0.05$).

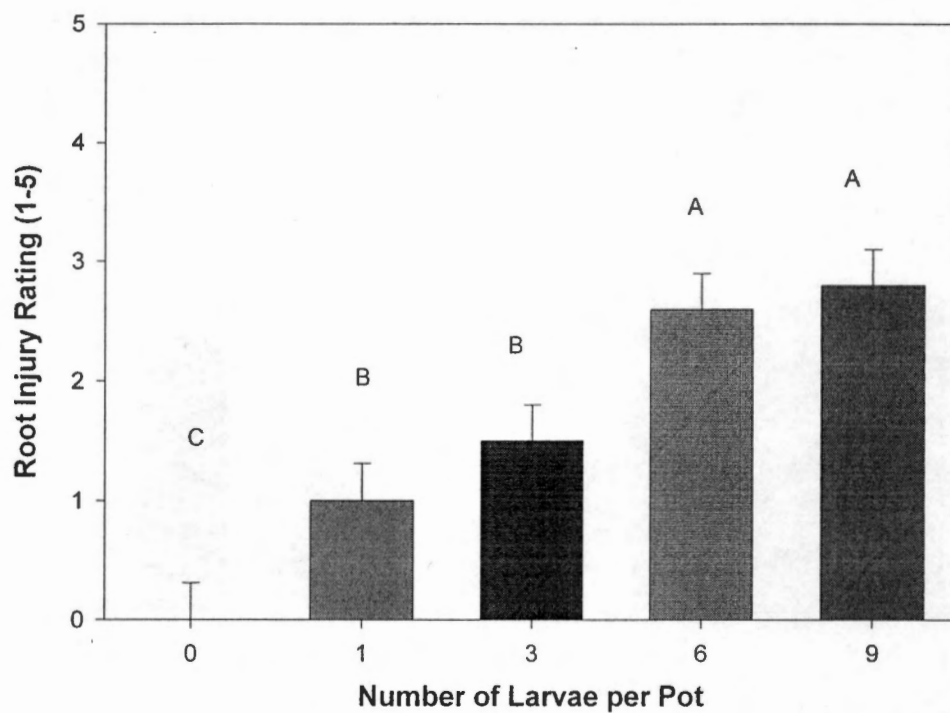


Figure 3.8: Root Injury of Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Root injury rated on a scale of 1-5: 1=10% injury, 2=20% injury, 3=30% injury, 4=40% injury, 5=50% or greater root injury. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

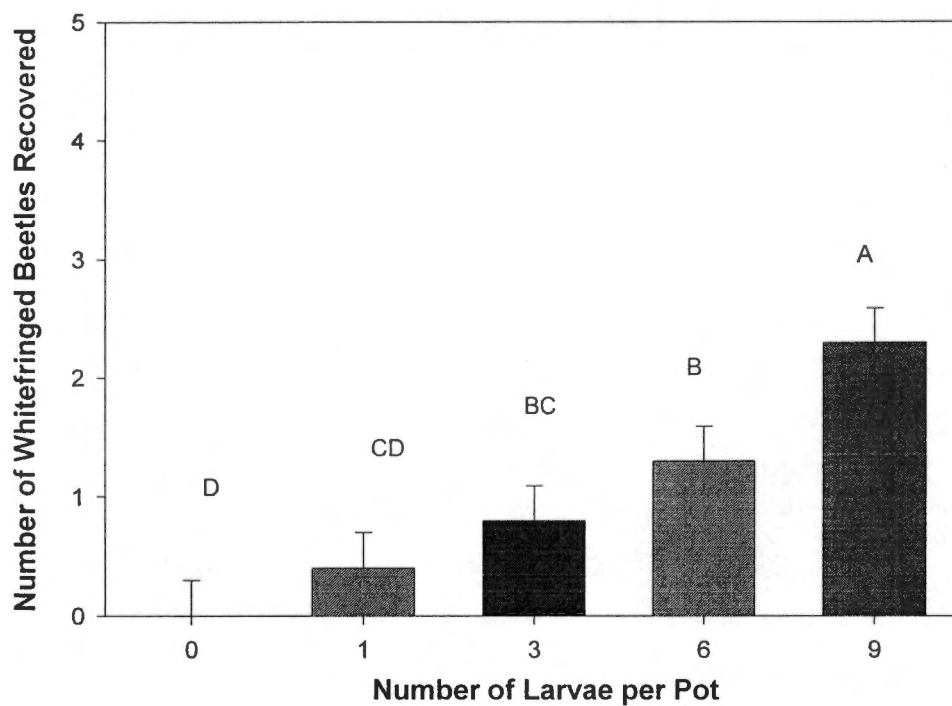


Figure 3.9: Number of Whitefringed Beetles Recovered from Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

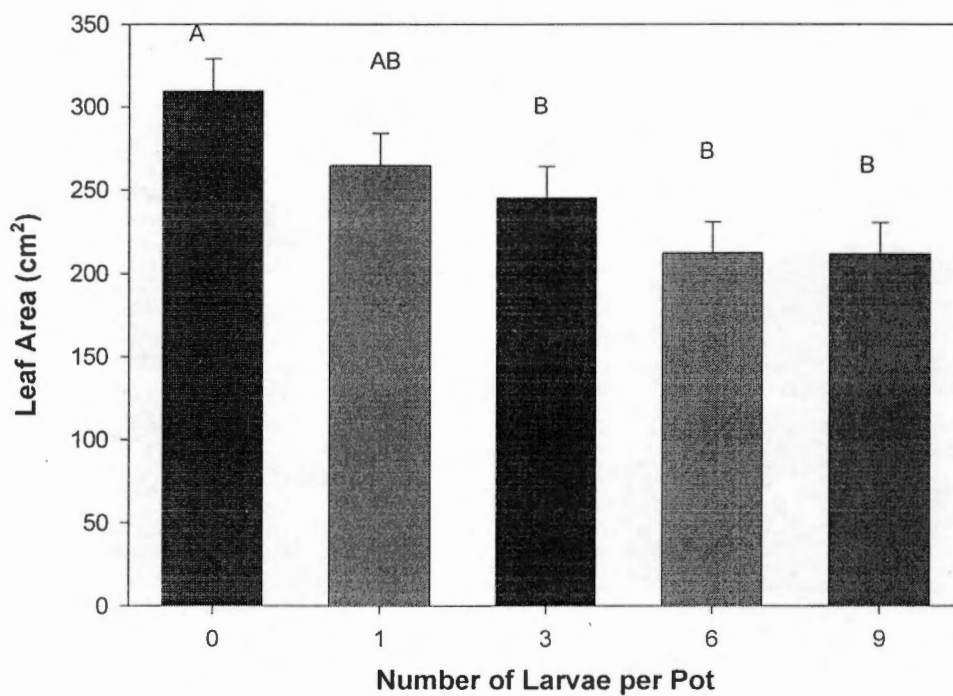


Figure 3.10: Foliar Area (area of ten leaves) Response of Dogwoods Infested with Whitefringed Beetle Larvae in 2002. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

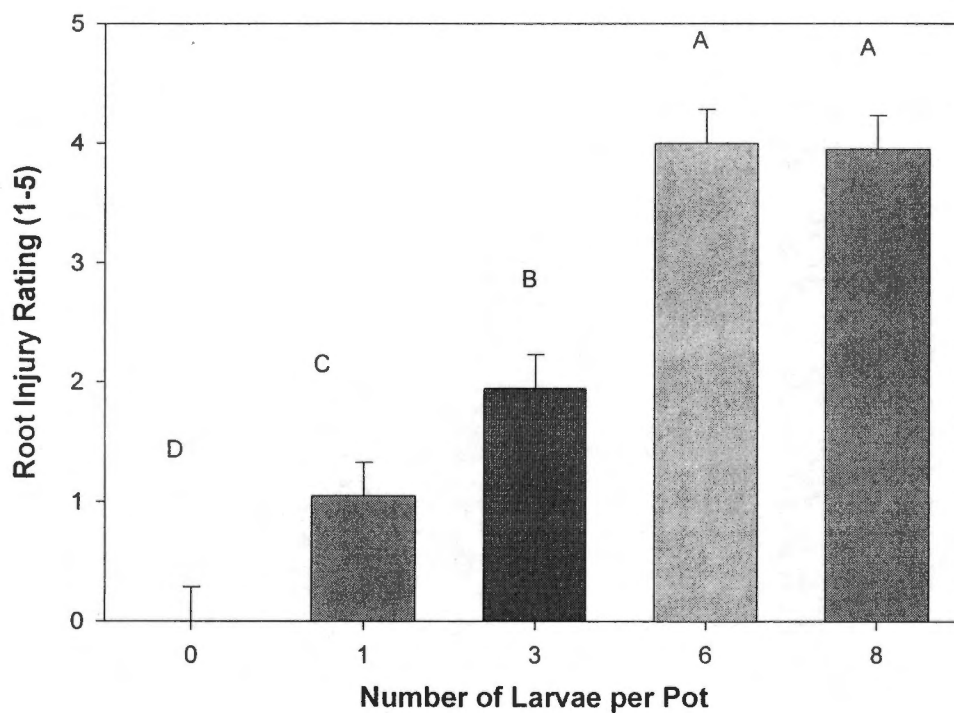


Figure 3.11: Root Injury of Dogwoods Infested with Whitefringed Beetle Larvae in 2003. Root injury rated on a scale of 1-5: 1=10% injury, 2=20% injury, 3=30% injury, 4=40% injury, 5=50% or greater root injury. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

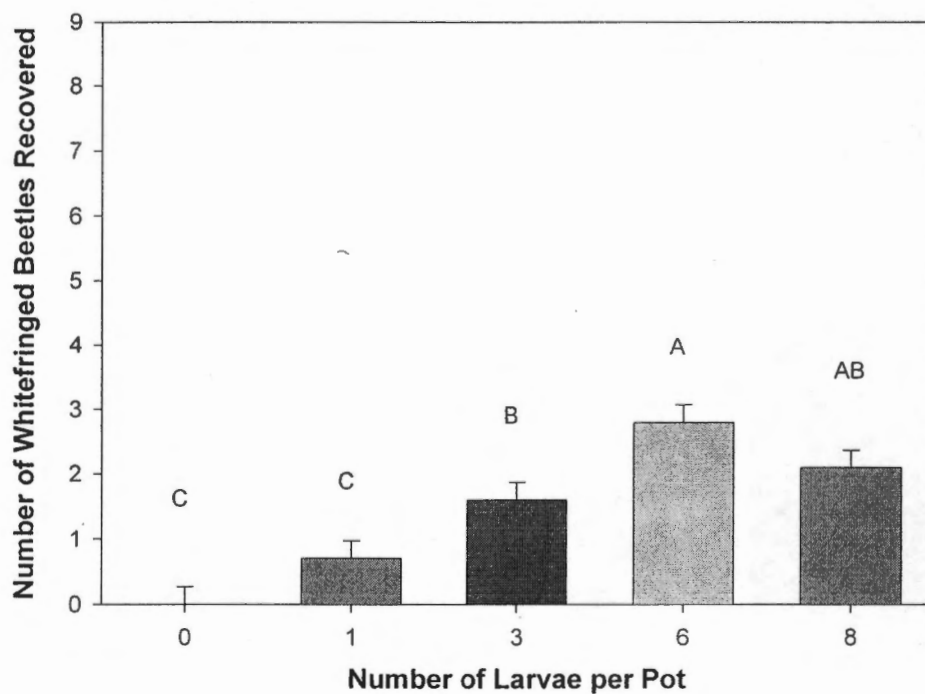


Figure 3.12: Number of Whitefringed Beetles Recovered from Dogwoods Infested with Whitefringed Beetle Larvae in 2003. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).

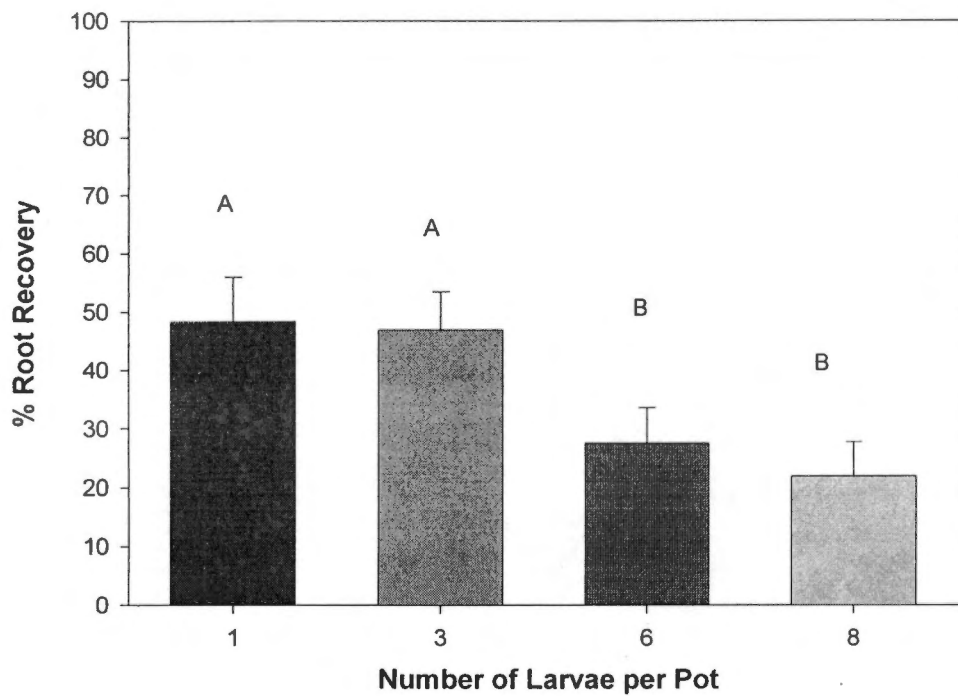


Figure 3.13: Percent Root Recovery of Dogwoods Infested with Whitefringed Beetle Larvae in 2003. Values represent least square mean estimates calculated by the mixed model analysis of variance in SAS. Error bars reflect standard error. Means with no similar letters are different by LSD mean separation ($\alpha=0.05$).



Figure 3.14: Root Injury from Whitefringed Beetle Larval Feeding. A. Example of Dogwood Root Injured by Larval Feeding 2002; B. Example of Root Injured by Larval Feeding 2003.

**Part 4: Leaf Tissue Effects Adult Whitefringed Beetle Longevity and
Fecundity**

Introduction

Since the discovery of the Whitefringed beetle [*Naupactus* (formerly *Graphognathus*) *leucoloma* (Boheman)] in the United States in 1936, research has demonstrated the potential threat to agricultural crops from larval feeding injury (Young et al. 1950; Eggert et al. 1990). The larval stage of this insect gnaws into the roots causing severe injury or girdling. Plants attacked by whitefringed beetle larvae typically become chlorotic, wilt, and will eventually die as a result of feeding activity (Young et al. 1950). Whitefringed beetle adults feed on a diverse array of host plants. Evidence suggests that beetles prefer specific plant resources (Young and App 1939; Young et al. 1950). Importantly, the type of leaf tissue eaten by the adult directly influences the longevity and fecundity of this pest (East 1977; Ottens and Todd 1979; Young et al. 1950). Adult beetles, which were collected as they emerged from the soil, did not lay eggs if they were not fed (East 1977). Peanut [*Arachis hypogaea* (L.)], a leguminous crop has been identified as the host plant that induces highest fecundity when fed to adult whitefringed beetles (Young and App 1939; Young et al. 1950; Ottens and Todd 1979). The relationship of food resources to both fecundity and longevity is important. A host plant that allows high adult fecundity is likely to increase larval populations where these food resources are abundant. In turn, this is expected to yield greater economic damage resulting from higher larval populations.

Publications prepared for growers and the general public have focused on damage to agricultural and forage crops by whitefringed beetles (USDA 1972). As early as 1946, however, inspectors in Georgia identified whitefringed beetle populations in ornamental nurseries (Gross et al. 1972). To a limited extent, the beetles have been recognized as

pests of some ornamental plants (Cherry 1971). Yet to date, research has not explored whitefringed beetle grub damage in ornamental production. Because of the potential for rapid population development and the high probability of establishment once a population is founded, the whitefringed beetle represents a considerable threat to ornamental production in the southeastern U. S.

Recently, nursery growers have observed root damage to flowering dogwood [*Cornus florida* (L.)], kousa dogwood [*Cornus kousa* ((Buerger ex Miq) Hance)], kobus magnolia [*Magnolia kobus* (DC)], yellowwood [*Cladrastis kentukea* ((Dum-Cours.)Rudd)], oakleaf hydrangea [*Hydrangea quercifolia* (Batr.)], common witchhazel [*Hamamelis virginiana* (L.)], and black gum [*Nyssa sylvatica* (Thunb.)] attributed to whitefringed beetle larvae (DRK personal observations). Seedlings and young ornamental liners are particularly susceptible to larval whitefringed beetle damage. Field observations of these crops also reveal adult feeding injury, which suggests that these ornamentals are likely to be preferred adult hosts. While not reported to be suitable hosts for whitefringed beetle adults, red maple [*Acer rubrum* (L.)] and Eastern redbud [*Cercis canadensis* (L.)] are popular ornamental plants and are being considered because of their widespread presence as production liners in the nursery trade. As a leguminous plant, redbud has the potential to be an optional food resource for the whitefringed beetle (East 1977). Japanese honeysuckle [*Lonicera japonica* (Thunb.)] is an invasive and troublesome weed that is abundant in the fields and borders of Tennessee nurseries. Glossy Abelia [*Abelia x grandiflora* ((Andre')Rehd.)] is an increasingly popular flowering ornamental shrub. Glossy Abelia and Japanese honeysuckle have both been reported as hosts for whitefringed beetle adult feeding injury (Jarvis 1968; Senn1969).

The objective of this study was to quantify the influence of these potential ornamental host plant species, which are commonly grown or encountered in Tennessee nurseries, on the longevity and fecundity of adult whitefringed beetles.

Materials and Methods

In June 2002, within a week of emergence from soil pupal cells, approximately 400 newly emerged adults were hand picked from host plants and weeds at a commercial nursery in Middle Tennessee. Adults were transported to Knoxville, Tennessee. Throughout the study, the beetles were kept in a greenhouse in 55% shade. Temperature, relative humidity, and light were monitored and maintained at $25^{\circ}\text{C} \pm 10^{\circ}$ ($75 \pm 18^{\circ}\text{F}$) and $80 \pm 10\%$ RH. Beetles were individually caged in 16 oz. paper containers (Sweetheart, Inc., Chicago, IL). Containers were covered with a 15-cm (6-inch) square of translucent tulle fabric, held in place with a 7.6 cm rubber band. Adults were fed leaf tissue from one of the twelve species of plants tested (Table 4.1)¹. Peanut, which was expected to yield high numbers of eggs, was chosen as the control species (Young and App 1939; Young et al. 1950; Ottens and Todd 1979). Foliage was replaced at three- to five-day intervals, as it was consumed or declined in quality. Leaf petioles were placed in clear, polypropylene, 12 x 75 mm culture test tubes (Baxter Diagnostics, Inc., Mc Graw Park, IL), which were filled with water and plugged with 3.8 cm #2 medium cotton dental wick (Patterson Dental Supply, Inc., Saint Paul, MN) to provide moisture for the leaves as well as a water source for the beetles. Thirty adult beetles were fed tissue from one of each of the twelve species, for a total of 360 adults tested. Each of the 360 adults tested was fed only one type of leaf tissue for the duration of the study. Fir strips 5 cm (2 inches) long

¹ All tables are located in Appendix 4A at the end of this section.

(Forster Craft Sticks, Wilmington, ME) were placed on the bottom of the beetle containers for egg deposition. Fir strips were inspected at leaf change and collected if eggs were attached. Sticks under which eggs had been deposited were removed, dated, labeled with host plant and insect code number, and replaced with a fresh strip. Eggs were taken to the laboratory and counted under a dissection microscope. The experimental unit was the individually caged beetle. Experimental units were arranged in a randomized block design. Data collected consisted of longevity (number of days survived), total eggs laid, oviposition rate (average number of eggs laid per day), number of egg masses, average number of eggs per mass, and average number of masses per day.

Representative samples (2 cups of clean, air dried, lightly packed foliage) were collected from host stock plants. Foliage was submitted to a commercial laboratory for foliar tissue analyses to determine nutrient and mineral content (A&L Laboratories, Memphis, TN). Foliar tissue analysis results were not analyzed statistically because of the limited sample size.

Once all adult beetles tested had died, longevity and fecundity were analyzed using the mixed model analysis of variance and means were separated using the LSMEANS option of PROC MIXED in SAS to determine if there were significant differences between plant species (Littell et al. 1996). Along with the mixed procedure in SAS, diagnostics were run to check for normality and equal variance of data. These included the Shapiro-Wilk test for normality, Extreme Observations, Stem-Leaf Plot, Box Plot, Normal Probability Plot, and a check of equality of standard deviations. The SAS code for these diagnostics was developed by Arnold Saxton (University of Tennessee, Department of Animal Science) and included in analysis of data as a macro program.

Results

Longevity differed among ornamental species for whitefringed beetle adults provided with foliage of a single host plant ($F=7.7$; $df=11, 319$; $P<0.0001$). Beetles fed kobus magnolia lived longer (Least Square Means (LSM) 100.6 ± 13.9 days) than beetles provided other ornamental host plant food resources. Beetles provided glossy abelia leaves had the least longevity (LSM 22.1 ± 2.3) (Figure 4.1)².

Ornamental host plant resources also resulted in different cumulative egg yield from beetles ($F=12.7$; $df=11, 139$; $P<0.0001$). The cumulative total eggs per treatment ranged from 734 eggs, summed among thirty beetles confined with flowering dogwood foliage, to 11,351 total eggs laid by beetles fed peanut leaves (Figure 4.2). Peanut leaf tissue yielded the highest average of 378.4 ± 71.2 eggs per beetle, while beetles fed flowering dogwood, kousa dogwood, and glossy abelia deposited the fewest eggs averaging 24.5 ± 6.3 , 34.0 ± 7.0 , and 29.7 ± 6.9 eggs, respectively (Figure 4.3).

Daily fecundity among host-confined beetles also differed among host plants ($F=6.5$; $df=11, 319$; $P<0.0001$). The greatest fecundity, which averaged 4.2 ± 0.7 eggs per day, was observed for adult beetles fed peanut leaves. Lowest daily fecundity levels were recorded among beetles provided kousa and flowering dogwood, glossy abelia, and Eastern redbud leaf tissue (Figure 4.4).

Each egg mass represented a single period of egg laying activity. The number of masses produced per individual differed among host plant treatments ($F=11.3$; $df=11, 319$; $P<0.0001$). Peanut foliage yielded the greatest cumulative number of masses,

² All figures are found in Appendix 4B located at the end of this section.

averaging 14.3 ± 2.8 . *Kobus magnolia*, which averaged 9.4 ± 1.7 masses per beetle, yielded fewer mean masses than peanut but resulted in the most masses per ornamental host (Figure 4.5). Despite the variation in number of masses produced, the mean number of eggs per mass did not differ among ornamental plant treatments ($F=1.56$; $df=11, 319$; $P>0.1081$) (Table 4.2).

Finally, the number of egg masses produced per day was different among ornamental hosts ($F=7.04$; $df=11, 319$; $P<0.0001$). Beetles fed peanut, red maple, black gum, and yellowwood leaf tissues yielded the highest numbers of egg masses, while flowering dogwood yielded the fewest egg masses per day (Figure 4.6).

Results of the foliar tissue analyses do not suggest the critical role of any particular nutrient in plants for whitefringed beetle longevity or fecundity (Table 4.2). Nitrogen concentrations were low for all plants tested and were critical (Marschner 2002) for several of the treatments (Table 4.3). Red maple and black gum also had high manganese content.

Discussion

Because whitefringed beetle populations are seasonally and geographically patchy in distribution, many nursery producers are unlikely to recognize whitefringed beetles as pests. In several cases, growers recognize whitefringed beetles when shown specimens, but confirm that they have never specifically targeted whitefringed beetles as pests of their nursery crops. One reason that growers do not recognize the beetles as a threat is that, in contrast to root feeding larvae, the more visible adults do not usually do significant damage. Also, larval feeding injury can mistakenly be attributed to other problems or pests. For example, young plants that have roots that have been girdled

appear to be suffering from drought stress. Growers may assume that drought stress is the only problem.

In nursery production fields, growers have reported that roots of witchhazel and both flowering dogwood and kousa dogwood liners are crops on which extensive feeding damage from whitefringed beetles is frequently observed. Yet, fecundity of whitefringed beetles is dependent upon adult, rather than larval food resources (East 1977). Despite regular observations of adult feeding injury to flowering dogwood and kousa dogwood in production fields, survivorship among beetles confined with this food resource was poor.

Adult egg deposition also responds rapidly to changes in diet. For 14 days, 34 adult whitefringed beetles were fed only 'Wairau' Lucerne foliage. Beetles laid an average of 4.1 eggs per day. Seventeen of these adults were then starved, while the remaining seventeen were switched to a 'Grasslands Nui' ryegrass diet. Starved individuals immediately ceased egg laying and lived an average of twelve more days. Adults that were switched to the ryegrass diet survived for an average of sixteen more days, during which they laid 0.3 eggs per day (East 1977).

Ryegrass and other graminaceous plants are poor hosts for whitefringed beetle (East 1977). In contrast, whitefringed beetle longevity and fecundity were increased when leguminous plants were available as a food resource. In a comparison test of twenty eight pasture and forage crop species, sainfoin (*Onobrychis viciifolia* Scop.), a leguminous plant grown for livestock forage, yielded the greatest fecundity (631 eggs per beetle), longevity (87days), and oviposition rate (6.3 average eggs per day). The average fecundity of individual beetles fed legumes was more than twenty times that of individuals fed on grasses and cereals, because of both greater longevity and a higher

oviposition rate (East 1977). Eastern redbud and yellowwood are leguminous ornamental tree species. Peanut, also a legume, was expected to result in the greatest longevity and fecundity among the ornamental plants that were tested. This expectation was based on research, in which adult beetles provided peanut foliage laid more eggs per day and lived much longer than beetles fed on grasses, sorghum, or corn (Ottens and Todd 1979; Young et al. 1950). In this study, adult beetles fed peanut foliage did lay the most eggs. Although longevity of beetles fed peanut was high (67 days), it did not exceed the longevity of beetles fed kobus magnolia leaves (100.6 days). The other two leguminous plants, redbuds and yellowwood, supported only moderate longevity: 45.1 days and 42.9 days, respectively. These results suggest that while some leguminous plants are favorable for whitefringed beetle population development, plants do not have to be legumes to induce high longevity and fecundity numbers in whitefringed beetles. For instance, non-leguminous squash [*Cucurbita pepo* (L.)] induced fecundity similar to peanut and soybeans. In contrast, crotalaria [*Crotalaria* (L.) sp.], a legume, induced a low average fecundity. Fecundity levels of beetles fed squash foliage were second only to peanut (Ottens and Todd 1979). In this trial, although leguminous plants did not necessarily extend longevity in the beetles, they generally led to high or moderate rates of fecundity. Yellowwood yielded an average of 144.9 eggs per beetle or 3.03 eggs per day and beetles fed eastern redbud leaves deposited an average of 92.5 eggs per beetle or 1.3 eggs per day.

Researchers working with forage and agricultural field crops observed much higher fecundity totals than detected in this trial. Young and App (1939) recorded an average of 1,531.7 eggs per beetle fed peanut foliage, with one individual depositing

2,418 eggs. In separate studies, peanut foliage yielded 1,031 eggs per beetle (Ottens and Todd 1979). Egg deposition in this study was similar to that of East (1977) who reported a high treatment average of 631 eggs on adult whitefringed beetles fed sainfoin. East did not report the nutrient contents of the plant tissues that were tested. The low nitrogen content in the leaves used for this study may have been a factor leading to lower egg numbers. The longevity numbers in this trial also match or exceed those reported by East (1977). Beetles fed kobus magnolia lived an average of 100.6 days, while East reported the highest longevity of 87 days for beetles fed sainfoin (East 1977). One possibility is that beetles manipulated daily egg deposition to extend longevity. Still, during their long duration of feeding on kobus magnolia, beetles deposited an average of 215 .1 eggs per beetle.

Although foliar tissue analyses indicated high concentrations of manganese in red maple and black gum, elemental toxicity from manganese varies widely between plant species and environmental conditions (Table 4.3). At high temperatures, the critical threshold in the leaves can be much higher than at low temperatures (Marschner 2002). Manganese toxicity, which appears as brown speckles on foliage or interveinal chlorosis, was not evident among the plants used for this study.

Beetles feeding on Japanese honeysuckle foliage, a weed common in Tennessee production field borders, survived for 48.5 days on average and laid 94.2 eggs per beetle or 1.7 eggs per day. This evidence suggests that honeysuckle could serve as an undetected host to whitefringed beetle populations in the borders of otherwise well-maintained production fields.

Previous research reported that whitefringed beetle adults did most egg laying on sunny afternoons and egg laying would be reduced when the temperature dropped or during cloudy, rainy periods (Cherry 1971). The egg laying data from this experiment has been graphed as well as precipitation data over time and the graphs support the same phenomenon (Figure 4.7). Egg laying peaks opposite precipitation events, suggesting that egg laying peaked on sunny days.

In the field, where adults actively disperse and are exposed to a range of natural mortality factors, longevity and fecundity are probably less than the values recorded in this trial. Oviposition rate, or the average number of eggs laid per day, helps to supplement this information by predicting the relative effects of plant species on whitefringed beetle populations in the field. For example, beetles fed the witchhazel treatment did not exhibit high longevity (25.6 days) and consequently did not produce a high average number of eggs (67.1). Yet, beetles fed witchhazel laid an average of 2.5 eggs per day. Conversely, beetles feeding on kobus magnolia exhibited the highest longevity (100.6 days) and were moderately fecund (215.1 eggs per beetle), but kobus magnolia daily egg yields were among the lowest (1.7). Growers who encounter populations of whitefringed beetles in their production fields, need to consider the longevity, fecundity, and oviposition rate effects of ornamental plant species on whitefringed beetles. Some of the ornamentals tested, like eastern redbud, do not seem to be the preferred hosts of whitefringed beetles, but growers should still be aware of potential effects on beetles, because in absence of a preferred host, the beetles could turn to other nearby plants. Witchhazel and the two dogwood species, which have seen the most root damage in the field, did not lead to high levels of longevity and fecundity.

These plants should not be grown near ornamentals that induce high levels of fecundity like kobus magnolia or yellowwood and they should be kept free of weeds.

Adult whitefringed beetles begin to emerge from pupal cells, found in the upper 7.6 cm (3 in) of the soil, in June and can be detected by scouting for feeding injury, which appears as a characteristic c-shaped excision of the leaf margin. Adults can be detected by looking for feeding injury on leaf margins. In the nursery rows the adults can often be found underneath ornamentals or any preferred weeds near signs of feeding injury. Ragweed, prickly sida, and sickle pod are three weeds that adults are often near. Presence of adult beetles should be monitored and adults should be targeted with insecticidal sprays as soon as they emerge. Since adults emerge throughout the season, continuous monitoring for adults and possible repeat treatments of insecticide will be necessary.

Literature Cited

- Cherry, E. T. 1977. Biology of the whitefringed beetle. M.S. Thesis, University of Tennessee, Knoxville, TN.
- East, R. 1977. Effects of pasture and forage crop species on longevity, fecundity, and oviposition rate of adult white-fringed weevils: *Graphognathus leucoloma* (Boheman). NZ J. Exp. Agric. 5: 177-181.
- Eggert, S. D., R. T. Ervin, and E. Segarra. 1990. Economic analysis of controlling a potential pest threat to Texas: whitefringed beetle. Appl. Agric. Res. 5: 77-81.
- Gross, H. R. Jr., Shaw, Z. A., Mitchell, J. A., and G. R. Padgett. 1972. Crop damage by larvae of the whitefringed beetle as related to time of larval introduction into soil. J. Econ. Entomol. 65: 713-716.
- Jarvis, J. L. 1968. The balanced lattice as an experimental design for testing large numbers of plants for feeding preferences of white-fringed beetles. J. Econ. Entomol. 61: 132-34.
- Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system for mixed models. SAS Institute, Cary, NC.
- Marschner, H. 2002. Mineral Nutrition of Higher Plants, 2nd ed. Boston: Academic Press.
- Ottens, R. J. and J. W. Todd. 1979. Effects of host plant on fecundity, longevity, and oviposition rate of a whitefringed beetle. Ann. Entomol. Soc. Amer. 72: 837-839.
- Senn, L. H., Jr. 1969. Chemicals, host plants, and light as attractants for adult white-fringed beetles, *Graphognathus* sp. (Coleoptera: Curculionidae). Ph.D. Dissertation, University of Georgia, Athens, GA.

- USDA. 1972. Controlling white-fringed beetles. Washington, D. C.
- Young, H. C. and B. A. App. 1939. Biology of the white-fringed beetle (*Naupactus leucoloma* Boh). USDA: Bur. Entomol. Pl. Quar. Washington, D. C.
- Young, H. C., B. A. App, J. B. Gill, and H. S. Hollingsworth. 1950. White-fringed beetles and how to combat them. USDA: Circ. 850.
- Zehnder, G. W., T. H. Briggs, and J. A. Pitts. 1998. Management of whitefringed beetle (Coleoptera: Curculionidae) grub damage to sweet potato with adulticide treatments. J. Econ. Entomol. 91: 708-714.

Appendix 4A: Tables

Table 4.1:^a Ornamental Species Tested For Adult Whitefringed Beetle Longevity and Fecundity.

<u>Species (Authority)</u>	<u>Family</u>	<u>Common Name</u>
<i>Abelia x grandiflora</i> (Andre') Rehd.	Caprifoliaceae	Glossy Abelia
<i>Acer rubrum</i> L.	Aceraceae	Red Maple.
<i>Arachis hypogaea</i> L.	Fabaceae	Peanut
<i>Cercis canadensis</i> L.	Fabaceae	Eastern Redbud
<i>Cladrastis kentukea</i> (Dum.-Cours.) Rudd [<i>C. lutea</i> /Michx.F.) K. Koch.]	Fabaceae	Yellowwood
<i>Cornus florida</i> L.	Cornaceae	Flowering Dogwood
<i>Cornus kousa</i> (Buerger ex. Mia) Hance	Cornaceae	Kousa Dogwood
<i>Hamamelis virginiana</i> L.	Hamamelidaceae	Witchhazel
<i>Hydrangea quercifolia</i> Bartr.	Hydrangeaceae	Oakleaf Hydrangea
<i>Lonicera japonica</i> Thunb.	Caprifoliaceae	Jap. Honeysuckle
<i>Magnolia kobus</i> DC.	Magnoliaceae	Kobus Magnolia
<i>Nyssa sylvatica</i> Thunb.	Nyssaceae	Black Gum

^aThe host trees consist of a mixture of plants donated from Middle Tennessee Nurseries and plants purchased from commercial nursery growers. The honeysuckle leaf tissue was obtained from wild plants growing near the Nursery compound on the University of Tennessee Agricultural Campus. The peanut leaf tissue was collected from peanut plants started from seed and grown in the greenhouse on the University of Tennessee Agricultural Campus.

Table 4.2: Average Number of Eggs Per Mass Produced by Adult Whitefringed Beetles on Selected Ornamental Plants.

<u>Host Plant</u>	<u>Estimate</u>	<u>Host Plant</u>	<u>Estimate</u>
Red Maple	18.1	Glossy Abelia	13.8
Black Gum	17.1	Oakleaf Hydrangea	14.8
Yellowwood	17.7	Jap. Honeysuckle	13.1
Flowering Dogwood	11.8	Redbud	11.8
Kousa Dogwood	22.1	Kobus Magnolia	16.9
Peanut	19.9	Witchhazel	19.7

Estimate is least square mean produced by the mixed model analysis of variance in SAS.

Table 4.3
Longevity, Fecundity, and Oviposition Rate of Whitefringed Beetle Adults on
Selected Ornamental Plants.

Plant Species	Longevity (Days)	Fecundity (Eggs)	Oviposition Rate (Eggs per day)
Red Maple	48.0	146.0	2.94
Black Gum	45.5	122.8	3.06
Yellowwood	42.9	144.9	3.03
Flowering Dogwood	26.0	24.5	0.81
Kousa Dogwood	29.6	34.0	1.33
Peanut	67.1	378.4	4.18
Glossy Abelia	22.1	29.7	1.14
Oakleaf Hydrangea	29.0	63.9	1.50
Japanese Honeysuckle	48.5	94.2	1.69
Redbud	45.1	92.5	1.26
Kobus Magnolia	100.6	215.1	1.68
Witchhazel	25.6	67.1	2.48

Numbers provided are least square mean values produced by the mixed model analysis of variance in SAS.

Table 4.4: Foliar Elemental Analysis of Two Cups of Dry Plant Tissue Used for Whitefringed Beetle Feeding.

Plant Species	N	S	P	K	Mg	Ca	Na	B	Zn	Mn	Fe	Cu	Al
	----- % -----							----- ppm -----					
<i>Abelia x grandiflora</i>	1.42	0.18	0.2	1.58	0.32	1.28	0.02	59	42	498	89	8	59
<i>Acer rubrum</i>	1.79	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Arachis hypogaea</i>	1.89	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Cercis canadensis</i>	2.09	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Cladrastis kentuckea</i>	2.60	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Cornus florida</i>	1.04	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Cornus kousa</i>	0.95	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Hamamelis virginiana</i>	2.02	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Hydrangea quercifolia</i>	1.48	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Lonicera japonica</i>	1.78	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Magnolia kobus</i>	2.66	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
<i>Nyssa sylvatica</i>	1.70	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	30
Normal Ranges	2 - 5	0.1-0.3	0.2-0.5	1.0-5	0.1-0.4	0.1-1		10-100	10-100	20-100	50-300	5-250	NA
Critical Levels	1.79	0.14	0.15	0.78	0.28	1.42	0.01	54	43	1874	98	5	NA
Toxicity Levels	NT	NT	NT	NT	NT	NT	NT	>100	>400	>300	NT	>20	NA

Normal ranges, critical levels, and toxicity levels defined by Marschner (2002). NT=no toxicity.

Table 4.5
Critical Toxicity Contents of Manganese in the Shoots of Various Plant Species.^{abc}

<u>Species</u>	<u>Manganese Content</u> (mg kg ⁻¹ dry wt)
Maize	200
Pigeon pea	300
Soybean	600
Cotton	750
Sweet Potato	1380
Sunflower	5300

^aBased on Edwards and Asher (1982)

^bCritical toxicity contents are associated with a 10% reduction in dry matter production.

^c(Marschner 2002)

Appendix 4B: Figures



100% Cotton

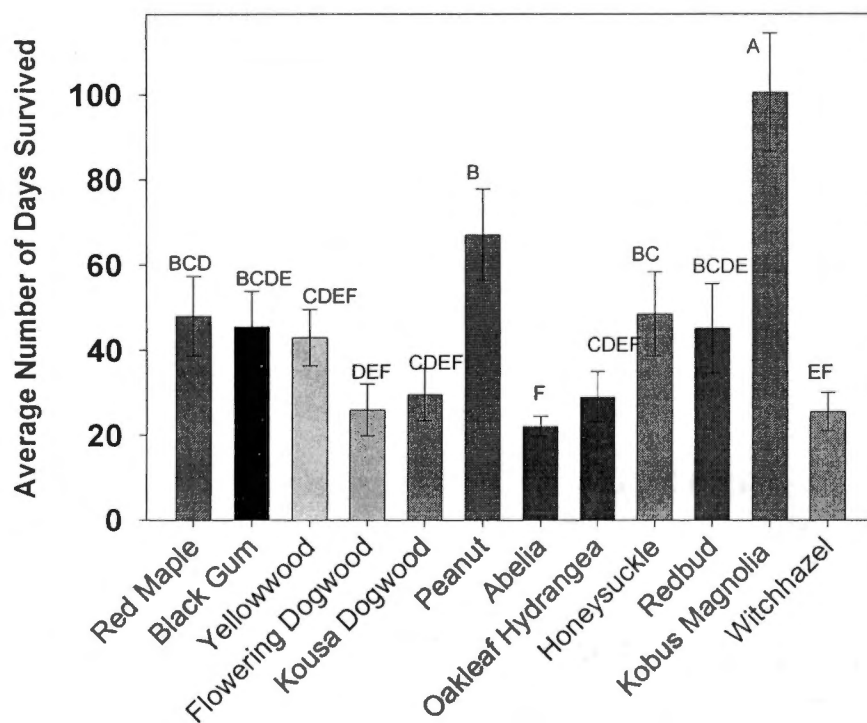


Figure 4.1: Average Number of Days Whitefringed Beetle Adults Survived Feeding on Selected Ornamental Host Plant Leaf Tissue. Numbers shown are least square mean estimates. Error bars represent standard error. Means were separated by LSD mean separation ($\alpha=0.05$). Entries containing no similar letters are different.

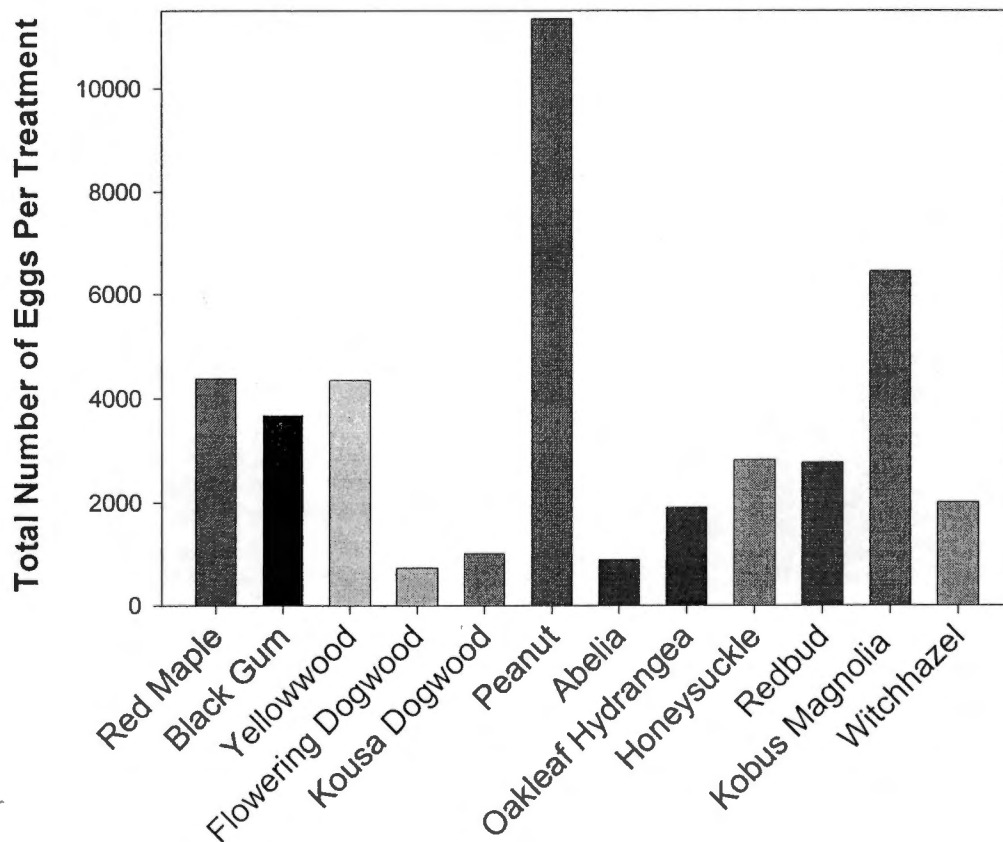


Figure 4.2: Total Number of Eggs Laid by Whitefringed Beetle Adults by Host Plant Consumed. Numbers shown are the total number of eggs produced by all thirty reps of each treatment.

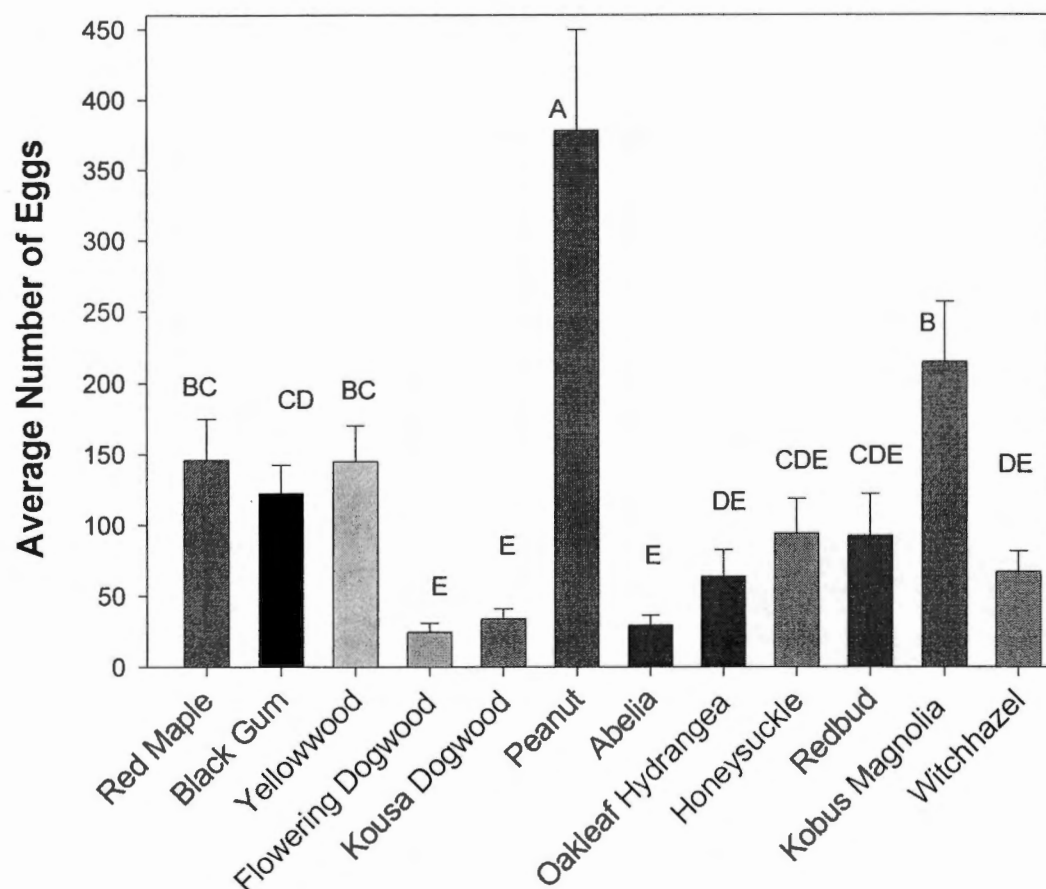


Figure 4.3: Average Number of Eggs Laid by Whitefringed Beetle Adults by Host Plant Consumed. Numbers shown are least square means. Error bars represent the standard error. Means were separated by LSD mean separation ($\alpha=0.05$). Means with no similar letters are different.

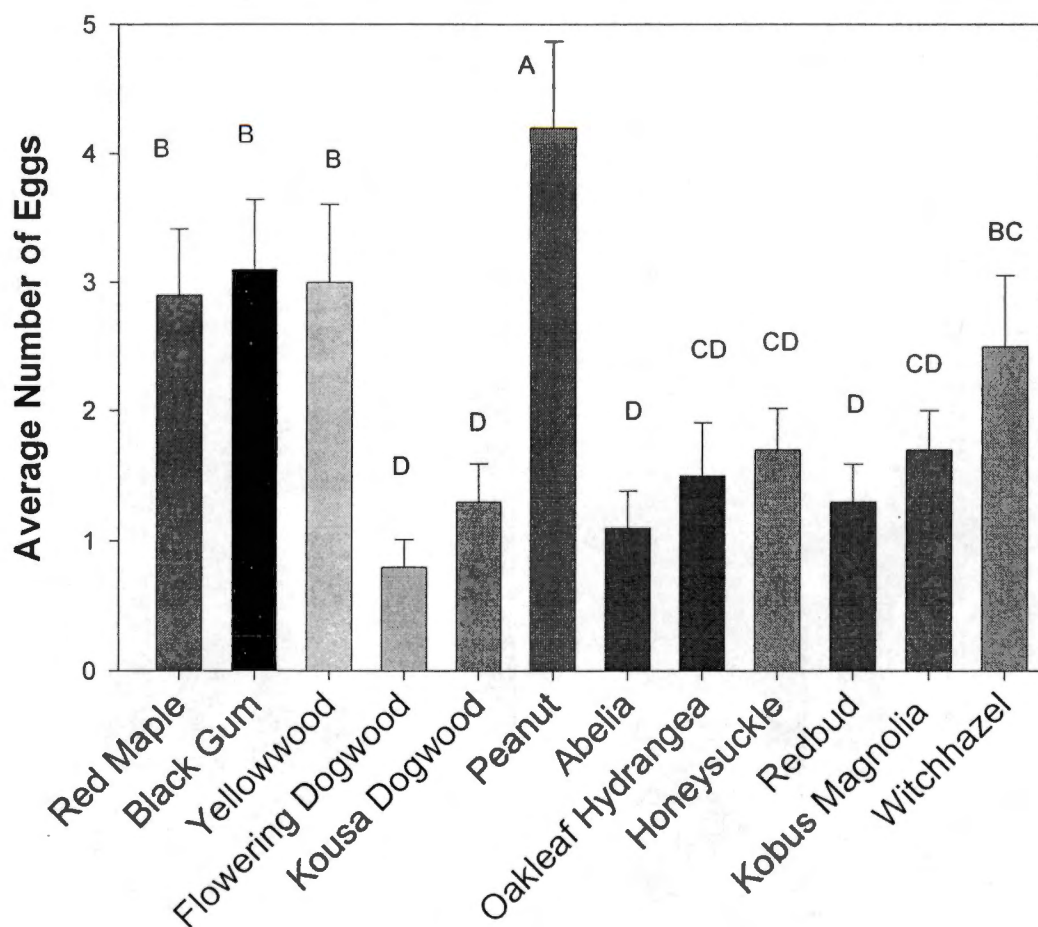


Figure 4.4: Average Number of Eggs Per Day (Oviposition Rate) Laid by Whitefringed Beetles by Host Plant Consumed. Numbers shown are least square mean estimates. Error bars represent the standard error. Means were separated using LSD mean separation ($\alpha=0.05$). Entries with no similar letters are different.

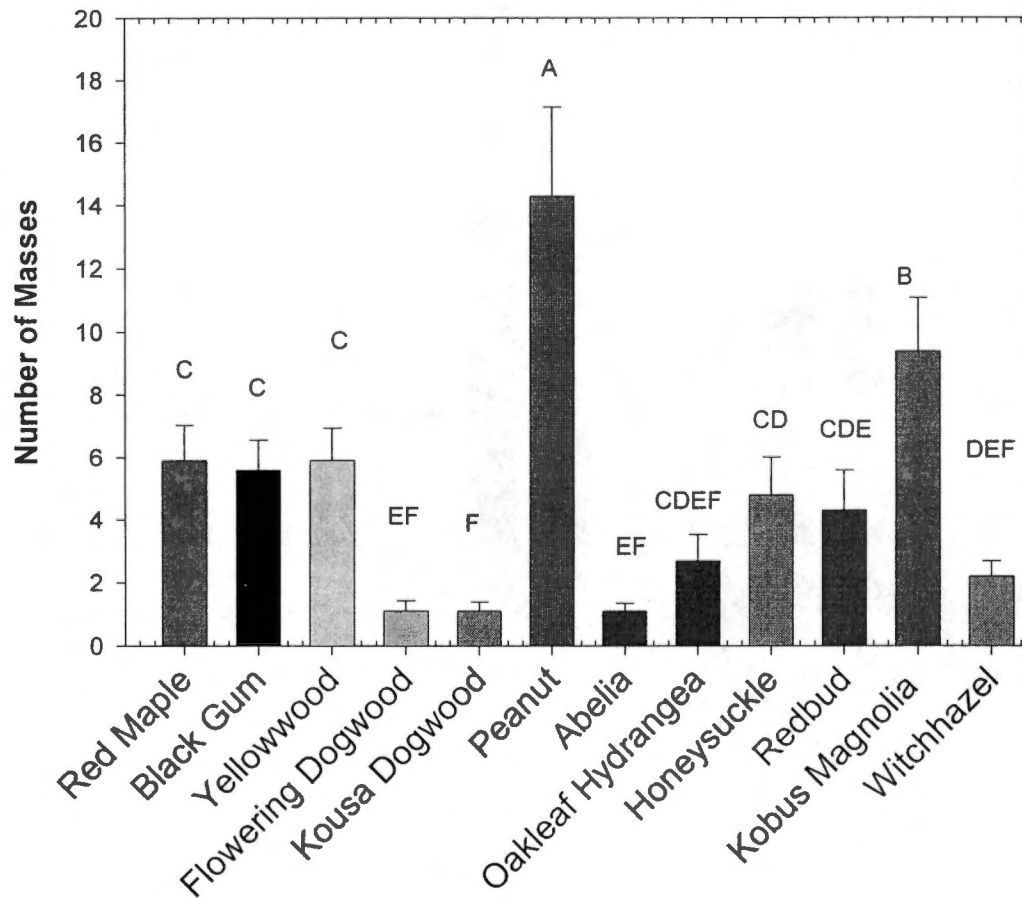


Figure 4.5: Average Number of Egg Masses Deposited by Whitefringed Beetle Adults by Host Plant Consumed. Numbers shown are least square mean estimates. Error bars represent the standard error. Means were separated using LSD mean separation ($\alpha=0.05$). Means with no similar letters are different.

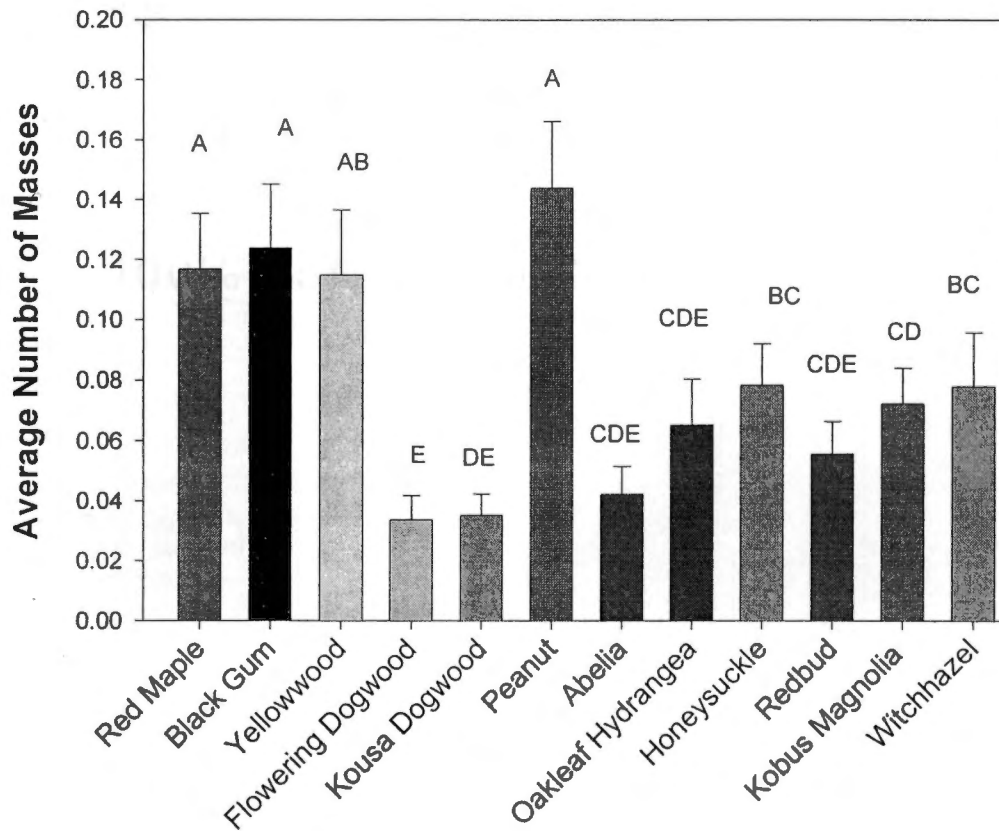


Figure 4.6: Average Number of Egg Masses Deposited per Day by Whitefringed Beetle Adults by Host Plant Consumed. Numbers shown are least square mean estimates. Error bars represent the standard error. Means were separated using LSD mean separation ($\alpha=0.05$). Entries with no common letters are different.

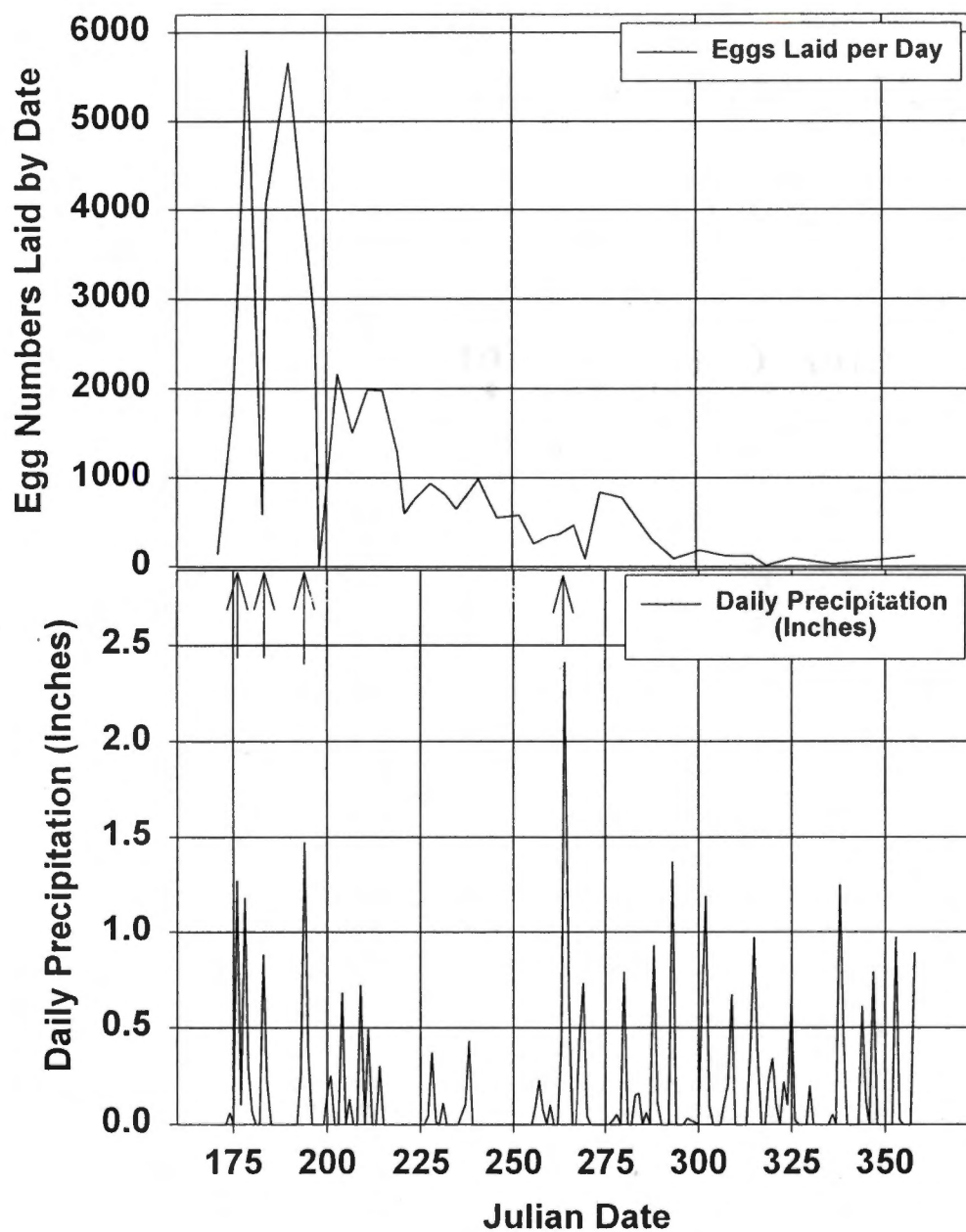
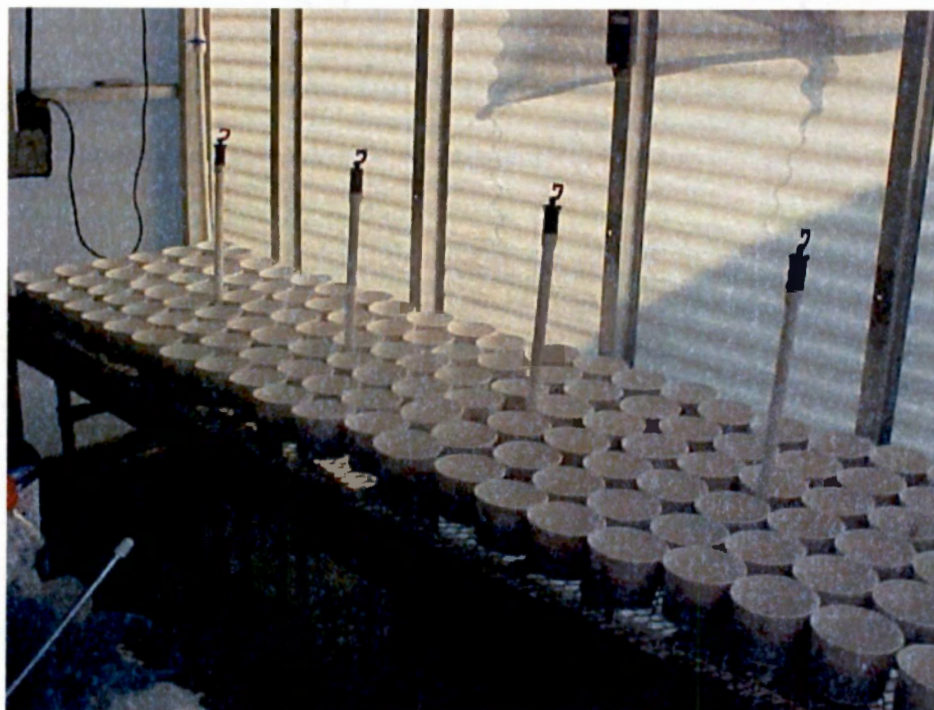


Figure 4.7: Daily Egg Laying of Whitefringed Beetle Adults Graphed by Daily Precipitation Data. Daily precipitation values were taken from the National Weather Service (Morristown, TN) for Knoxville, Tennessee. Arrows indicate drops in egg laying corresponding with peaks in precipitation.



A.

B.



Figure 4.8: Experimental Design. A. Photograph of right side of greenhouse in which individually caged beetles were kept in a randomized block design. B. Photograph of one experimental unit—individually caged beetle with foliage, and oviposition strip.

Because dogwood production is of great importance to the Tennessee nursery industry information that helps solve current production challenges is valuable to growers. Budwood production was not influenced by increasing levels of nitrogen over one season. Growth indices, shoot length, and caliper were affected by fertility treatments. Trees subjected to low levels of fertilizer expressed the most abundant growth. Fertility treatments of 5.3 kg/m^3 (Osmocote 18-6-12) yielded optimal growth for flowering and kousa dogwoods, thus limiting the additional expense and concerns about runoff associated with higher rates of fertilizer.

Growth response to fertility treatment differs by tree species and cultivar as well as by management practices. 'Cherokee Brave' tolerated higher levels of fertility without growth inhibition than did 'Cloud 9.' Trees that were cold-stored well into the growing season (1 May) exhibited limited ability to overcome the stress of being planted late. Kousa trees growing in Knoxville and Decherd demonstrated that plant response to fertility differs according to availability of water. If water was limited fertility treatments in excess of 3.6 kg/m^3 inhibited growth.

Dogwood producers need to consider following management practices that include proper timing of planting and transplanting as well as maintaining optimum availability of water throughout the growing season. Knowledge of fertility requirements specific to dogwood tree species and cultivar will help growers to tailor a management program to the specific needs of that tree, yielding optimal growth.

Although the fertility treatments applied did not impact budwood production during the growing season immediately following fertilizer application, it is possible that the fertilizer treatments applied in 2002 will impact budwood production in the 2003

season. Trees will be evaluated at the conclusion of the 2003 season for delayed fertilization effects. In future, a study of this nature should be conducted on newly budded liners and the trees should be evaluated for three seasons of growth to determine any fertility effects.

Isolated populations of whitefringed beetle larvae do severe economic damage to young seedling liners in Tennessee production fields. Flowering dogwood and kousa dogwood have both been reported to suffer severe feeding injury from larval populations. In an effort to quantify the damage potential of whitefringed beetle larvae, flowering dogwood and kousa dogwood were infested with larvae in quantities of 1, 3, 6, or 9 for two seasons. Results indicate that larvae do have the potential to damage roots of young, seedling liners, resulting in stunted growth or death of the trees. Six larvae per tree induced the maximum amount of injury to roots and caused the most growth inhibition in dogwoods. Pots infested with 9 larvae suffered less damage and growth inhibition, probably as a result of larval competition for food resources (Rogers et al. 2000).

Importantly, the size of the tree and amount of root mass has a major impact on the tree's susceptibility to larval damage. In 2002, bare-rooted liners of both dogwood species had intact primary roots, but fewer lateral and fibrous roots than trees used in the 2003 study. In 2003, it is likely that trees were able to compensate for whitefringed beetle larval feeding, because trees were not growth inhibited by larval feeding. Although more conclusive studies are warranted, the 2002 and 2003 larval trials indicate to growers that whitefringed beetles do quantifiable damage to their nursery liners in as little as a two-month period of time. The next step in determining whitefringed beetle larval impact on dogwoods would be to conduct a similar larval infestation trial in the fall. The addition

of greater numbers of larvae would add to the information gained and provide more insight on larval competition for food resources.

Because of the potential for rapid population development and the high probability of establishment once a population is founded, the whitefringed beetle represents a considerable threat to ornamental production in the southeastern U. S. Importantly, the type of leaf tissue eaten by the adult directly influences the longevity and fecundity of this pest (East 1977; Ottens and Todd 1979; Young et al. 1950). The relationship of food resources to both fecundity and longevity is important. A host plant that allows high adult fecundity is likely to increase larval populations where these food resources are abundant. In turn, this is expected to yield greater economic damage resulting from higher larval populations.

Growers, who encounter populations of whitefringed beetles in their production field, need to consider the longevity, fecundity, and oviposition influence of ornamental plant species on whitefringed beetles. Witchhazel and the two dogwood species, which can experience extensive root damage in the field, did not yield high longevity and fecundity in whitefringed beetles. Still, these plants should not be grown near ornamentals that induce fecundity, like kobus magnolia or yellowwood. Infested fields should also be kept free of weeds and high-risk crops should be rotated within a field on three to four year intervals. Inclusion of a cover crop, like sudax, oats, or a small grain or cereal can alleviate populations of whitefringed beetles, while leguminous cover crops, like red clover, should not be planted (Young et al. 1950). Finally, presence of adult beetles should be monitored and adults should be targeted with insecticidal sprays as

soon as they emerge. Since adults emerge throughout the season, continuous monitoring for adults and possible repeat treatments will be necessary.

Because the dogwood species, which are preferred larval hosts, do not lead to increased longevity and fecundity rates for whitefringed beetle adults, the next logical research step would be to perform a feeding trial using commonly encountered nursery weeds, to ascertain whether weed populations are supporting whitefringed beetle larval infestations in ornamental production fields.

Literature Cited



100% Cotton Fiber

- East, R. 1977. Effects of pasture and forage crop species on longevity, fecundity, and oviposition rate of adult white-fringed weevils: *Graphognathus leucoloma* (Boheman). NZ J. Exp. Agric. 5: 177-181.
- Ottens, R. J. and J. W. Todd. 1979. Effects of host plant on fecundity, longevity, and oviposition rate of a whitefringed beetle. Ann. Entomol. Soc. Amer. 72: 837-839.
- Rogers, S., C. W. Mc Coy, and J. H. Graham. 2000. Larval growth of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) and resulting root injury to three citrus varieties in tow soil types. J. Econ. Entomol. 93: 380-87.
- Young, H. C., B. A. App, J. B. Gill, and H. S. Hollingsworth. 1950. White-fringed beetles and how to combat them. USDA: Circ. 850.

Vita

Deborah Ruth Ketchersid was born in Chattanooga, Tennessee, December 9, 1976. She was raised in Dayton, Tennessee and attended elementary school at Frazier Elementary and Dayton City Schools. Debbie graduated as salutatorian from Rhea County High School in May 1995. From there, she went to Middle Tennessee State University and graduated Summa Cum Laude with a Bachelor of Arts degree in history with minors in secondary education and political science on May 13, 2000. Debbie was the librarian at Frazier and Graysville Elementary Schools for the 2000-01 school year. At this point she began a Master of Science in ornamental horticulture at the University of Tennessee, which she completed in August of 2003. Currently, Debbie plans to pursue a career teaching horticulture at the post-secondary level.

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