Urban Forestry Management Plan

Brownsburg
Hendricks County, Indiana

Prepared For:

Town of Brownsburg
Department of Planning and Building
Department of Parks and Recreation
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TABLE OF CONTENTS

Urban Forestry Management Plan Page

Executive Summary....1

Acknowledgements....2

1.0 Introduction....3
- 1.1 Project Description and Purpose
- 1.2 Municipal Government Coordination
- 1.3 Project Location

2.0 Existing Conditions....3
- 2.1 Tree Inventory
  - 2.1.1 Methodology
  - 2.1.2 Data Analysis
  - 2.1.3 Species Composition
  - 2.1.4 Tree Health
- 2.2 Ecological and Economic Benefits
  - 2.2.1 Ecological Values
  - 2.2.2 Economic Values

3.0 Conclusions and Management Recommendations....9
- 3.1 Urban Reforestation Opportunities and Constraints
  - 3.1.1 Street Trees
  - 3.1.2 Park/Landscape Trees
  - 3.1.3 Forest Trees
- 3.2 Tree Pruning and Removal
- 3.3 Replacement Trees
  - 3.3.1 Deciduous Shade Trees
  - 3.3.2 Evergreens and Conifers
  - 3.3.3 Ornamental Trees and Shrubs
- 3.4 Tree Planting Within New and Redevelopment Areas
- 3.5 Specimen Trees
- 3.6 Invasive Species
- 3.7 Tree Diseases
  - 3.7.1 Dutch Elm Disease
  - 3.7.2 Chestnut Blight
  - 3.7.3 Thousand Cankers Disease
  - 3.7.4 Anthracnose
- 3.8 Tree Pests
  - 3.8.1 Emerald Ash Borer
  - 3.8.2 Gypsy Moth
  - 3.8.3 Bag Worms
  - 3.8.4 Japanese Beetles
- 3.9 Forest Management

References....18

FIGURES

Figure 1 – Brownsburg Incorporated Limits
Figure 2 – Tree Inventory Survey Areas
Figure 3 – Williams Park Subsample Areas
Figure 4 – Specimen Tree Locations
Figure 5 – Planting Opportunities Map

APPENDICES

Appendix A – iTree Streets Analysis Reports
Appendix B – USDA Tree Pruning Guide
Appendix C – Tree Planting Specifications
Appendix D – Invasive Plant Photographs
Appendix E – Reference Materials for Plant Disease Control
Appendix F – Reference Materials for Plant Pest Control

Executive Summary

This Urban Forestry Management Plan has been created for the Town of Brownsburg, Indiana to serve as a guidance document for the preservation of urban forest resources and as a baseline from which a Tree Preservation Ordinance can be developed. The Plan was constructed around a forest inventory conducted by Williams Creek Consulting in May and June 2011. Tree inventory data were analyzed using iTree Streets, a standardized, peer-reviewed data analysis platform which calculates a variety of benefits resulting from the presence of the urban forest. The data analysis indicated the presence of a generally healthy urban forest which provides many ecologically and economically valuable amenities to the Town of Brownsburg.

The Plan identifies common tree diseases, pests, and invasive threats that can adversely affect the health of this resource. A summary of maintenance recommendations such as thinning, crown raising, and sidewalk damage repair is also included. In addition, the plan provides an analysis of opportunities and constraints for expansion of the urban forest within Brownsburg. This opportunities and constraints analysis includes species recommendations for deciduous, coniferous, small, medium and large trees, as well as planting specifications.

Acknowledgements

The Brownsburg Urban Forestry Management Plan was completed with funding from the Put the Trees Back 2010 Grant Program implemented by the Indiana Department of Natural Resources Community and Urban Forestry Program, and from the Town of Brownsburg, Indiana. Williams Creek Consulting, Inc. (WCC) conducted the tree inventory and developed the Urban Forestry Management Plan based upon analysis of the inventory data. Special thanks are due to Todd Barker, Director of Planning and Development; Phil Parnin, Director of Parks and Recreation; Annisa Rainey, Grant Writer and Fundraiser; and Jim Waggoner, Community Development Director. The Urban Forestry Management Plan was authored by Jason Steckel and Chase Kimmel of WCC.

This document provides a snapshot of the present condition of forest resources within the Town of Brownsburg, and a benchmark for the development of informed, ecologically sound management decisions. In addition, it establishes baseline data to allow quantitative and qualitative evaluation of the results of those decisions. This document also provides a starting point for the development of a tree care ordinance. The ultimate objective of this Urban Forestry Management Plan is to create a useful planning tool to facilitate the protection and improvement of the urban forest environment of Brownsburg.

1.0 INTRODUCTION

1.1 Project Description and Purpose

Williams Creek Consulting (WCC), on behalf of the Town of Brownsburg, Indiana has prepared this Urban Forestry Management Plan (Plan) as a technical and planning document for trees and forests located within the public domain of the Town of Brownsburg. As a technical guidance document, the Plan identifies current conditions of trees and forested areas, and provides maintenance and management recommendations. As a planning document, the Plan provides a baseline of information regarding the composition and size of species located within pubic areas of Brownsburg and identifies criteria for tree preservation, removal, and replacement. Ultimately, the purpose of this document is to provide a framework within which the Town of Brownsburg can create an effective Tree Ordinance.

1.2 Municipal Government Coordination

The Brownsburg Planning and Building Department is focused on steering the community toward a sustainable balance of community development, long term economic vitality and job creation, high quality design of the built environment, environmental protection, and a multitude of cultural and recreational opportunities. The consideration of arboricultural issues through the development of a forest management plan and tree ordinance is an integral part of accomplishing this goal.

The mission of the Brownsburg Parks and Recreation Department is to serve citizens by providing quality parks, recreation facilities and programs, thereby ensuring that the Town continues to be a liveable place where all citizens can enjoy a wide range of leisure and recreation activities. The Parks and Recreation Department oversees nearly 200 acres of public land divided among five (5) parks. These areas provide opportunities for hiking, biking, group events, organized and recreational sports, and many designated playgrounds for children. Establishing procedures and protocol for the management of the forest resources under the care of the Parks and Recreation Department is critical to providing a safe and sustainable experience for the citizens of Brownsburg.

Although the Planning and Building, and Parks and Recreation Departments are the primary collaborators for the development of this Plan, its impacts extend throughout the entirety of the municipal government, influencing economic development, emergency response, transportation, and education. For this reason, the Plan was presented to the Brownsburg Town Council, the members of which were provided the opportunity to comment on the Plan. Council member comments and suggestions were incorporated into the final Urban Forestry Management Plan document.

1.3 Project Location

Brownsburg is located in northeastern Hendricks County, in portions of Lincoln, Brown, Middle, and Washington Townships. Currently, the incorporated area of the Town of Brownsburg is approximately 5,400 acres, or 8.5 square miles. The survey area was limited to rights of way of identified main thoroughfare streets within the incorporated limits, five (5) parks, and two (2) additional municipal properties (Figure 2).

2.0 EXISTING CONDITIONS

2.1 Tree Inventory

WCC completed an inventory of trees present within the survey area. Tree Inventory data was collected between May 9 and June 10, 2011.

2.1.1 Methodology

The survey area for the tree inventory consisted of road rights of way and park/municipal parcels. All data was recorded using a TopCon GRS-1 handheld GPS data collector. Information recorded included tree location, species, diameter at breast height (dbh), health status, potential conflicts with overhead lines, and sidewalk damage. Recorded data was compiled within a GIS shapefile associating the recorded characteristics with the geographic location of each tree.

Within street rights of way, and the open portions of parks and municipal parcels, all trees having a dbh of 2 inches or greater were recorded. Within the densely forested portions of Arbuckle Park, Stephens Park, and the Police Training Facility, all trees with a dbh of 5 inches or greater were recorded, due to the relatively high density of trees. In the western, passive use portion of Williams Park, high tree density, and less accessible topography prompted the decision to collect data within randomly distributed subsample areas representative of the tree population of that area. Tree inventory results for this area were calculated by extrapolation of the subsample data over the entire western portion of Williams Park. The overall extent of the survey areas is illustrated in Figure 2 and the subsample areas of Williams Park are illustrated in Figure 3. Tables 1a and 1b summarize the survey areas included in the tree inventory.

Table 1a. Tree Inventory Rights of Way

Street	Length of Survey (feet)
56th Street	5,838
Airport Road	5,328
Grant Street	9,243
Hornaday Road	5,687
Locust Street	2,165
Northfield Drive	25,117
Odell Street	15,583
SR 267	26,688
Tilden Road	7,521
US 136/Main Street	15,229
Whittington Drive	2,256
Wild Ridge Boulevard	7,677
Total	128,330 (24.3 miles)

Table 1b. Tree Inventory Park/Municipal Parcel Areas

Parcel	Area of Survey (acres)
Arbuckle Acres Park	52.8
Cardinal/Delaware Parcel	15
Stephens Park	2.9
Williams Park	79.4
Veterans Memorial Park	0.9
Town Hall	5
Police Training Facility	1.8
Total	157.8

2.1.2 Data Analysis

Tree inventory data were analyzed using i-Tree, a peer-reviewed software suite developed by the U.S. Forest Service, in coordination with several partners. i-Tree provides urban and community forestry analysis tools which help quantify forestry resources and the environmental benefits they provide. Specifically, WCC used the i-Tree Streets tool, employing the selected inventory area as a subsample representing the entirety of Brownsburg's urban forest resources.

Tree inventory data were analyzed to identify patterns and generalizations within the tree population. Analyses were conducted for the entire population in aggregate, as well as for street rights of way and municipal properties individually. Williams Park and Arbuckle Park also contained portions of dense forest, which for some analyses, were considered separately from the open, more manicured portions of the municipal parcels.

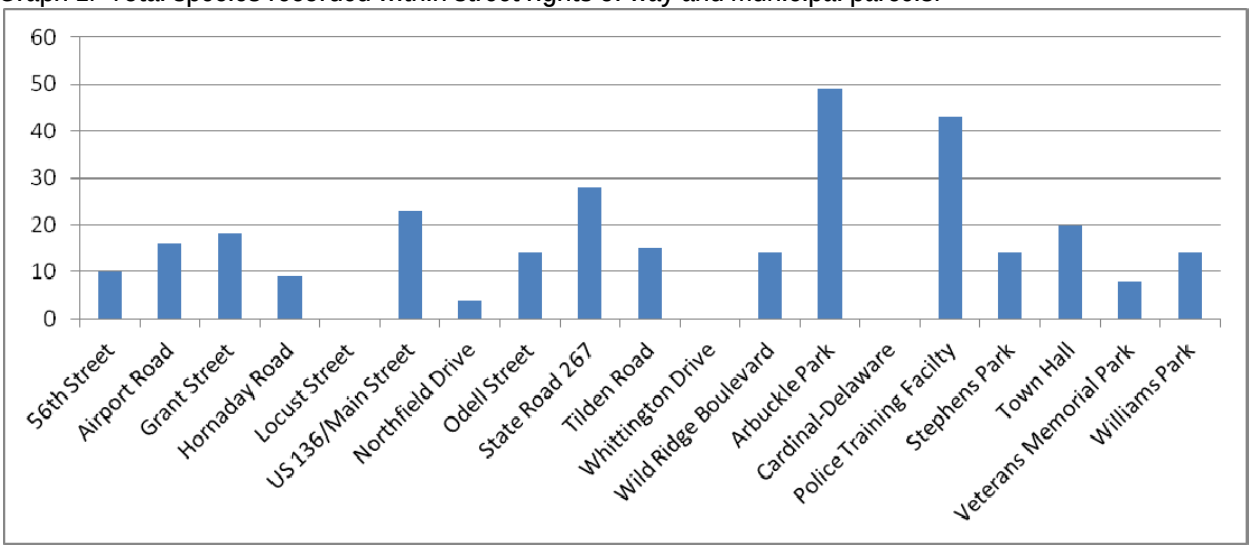
In total, 6,733 individual trees were identified within the survey areas with dbh ranging from 2 inches (the minimum recorded measurement) to 80 inches. Mean dbh for all trees was 10.89 inches. Within street rights of way, mean dbh was 11.45. Hornaday Road had the largest mean dbh at 16.56 inches and Wild Ridge Boulevard had the lowest mean dbh at 6.90 inches. Within municipal parcels, mean dbh was 10.82 inches. The non-forested portion of Arbuckle Park had the largest mean dbh at 18.21 inches and Town Hall had the lowest mean dbh at 2.21 inches.

The largest specimen recorded was a silver maple (*Acer saccharinum*) located in Williams Park having a dbh of 80 inches. Pin oaks (*Quercus palustris*) had the highest mean dbh (26.13 inches).

2.1.3 Species Composition

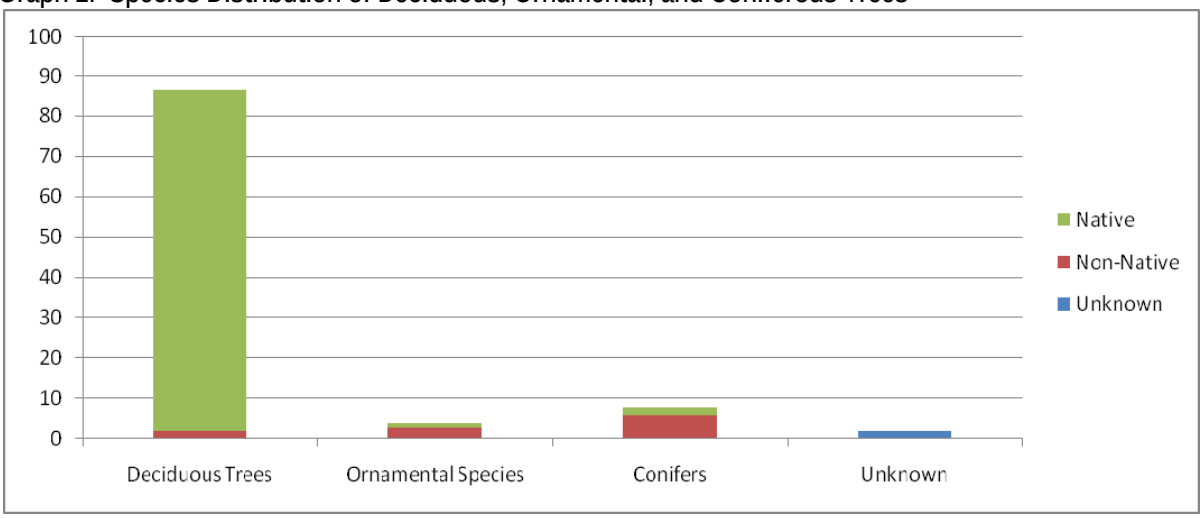
Seventy-two species were identified within 41 genera. Boxelder maple (*Acer negundo*), and green ash (*Fraxinus pennsylvanica*) were the most dominant species, representing 18% and 13% of the total population, respectively. The highest species diversity among street rights of way was observed along SR 267 where 28 species were recorded. The highest species diversity among municipal parcels was observed in Arbuckle Park where 49 species were observed. Graph 1 summarizes species distribution among street rights of way and municipal parcels.

Graph 1. Total species recorded within street rights of way and municipal parcels.



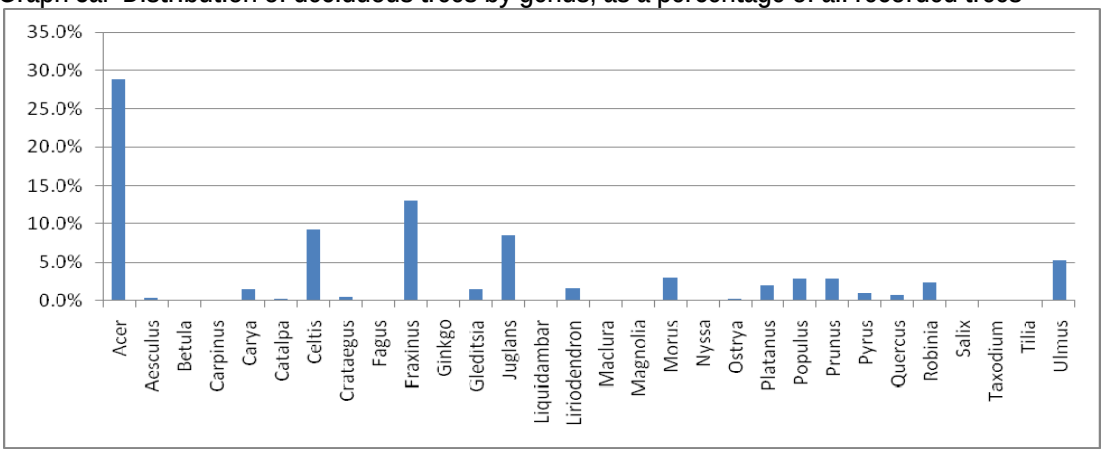
Approximately 71% of the species and 91% of the individual trees observed were native to Indiana. Considered separately, approximately 68% of individual trees recorded within street rights of way and 94% of individual trees recorded within municipal parcels were native to Indiana. This disparity is likely the result of a larger proportion of ornamental species within rights of way. Deciduous trees accounted for the largest proportion of individuals (84.4%) while ornamental species and conifers represented 3.9% and 7.7% of all individuals, respectively. The remainder were species which could not be identified. Species marked as *Unknown* were primarily dead specimens, still standing but unable to be identified due to lack of leaves or bark. Graph 2 summarizes the distribution of species among these divisions.

Graph 2. Species Distribution of Deciduous, Ornamental, and Coniferous Trees

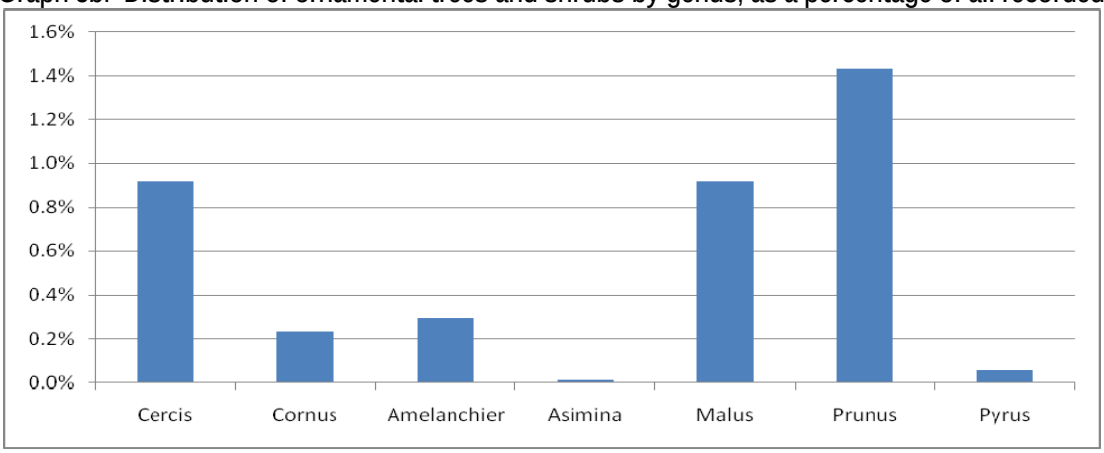


Among the species composing the largest proportion of the population (Deciduous Trees), *Acer* (maple species) and *Fraxinus* (ash species) were the most prevalent genera, accounting for approximately 29% and 13%, respectively, of the total individuals. Graphs 3a, b, and c summarize the distribution of deciduous trees, ornamental species, and conifers, respectively.

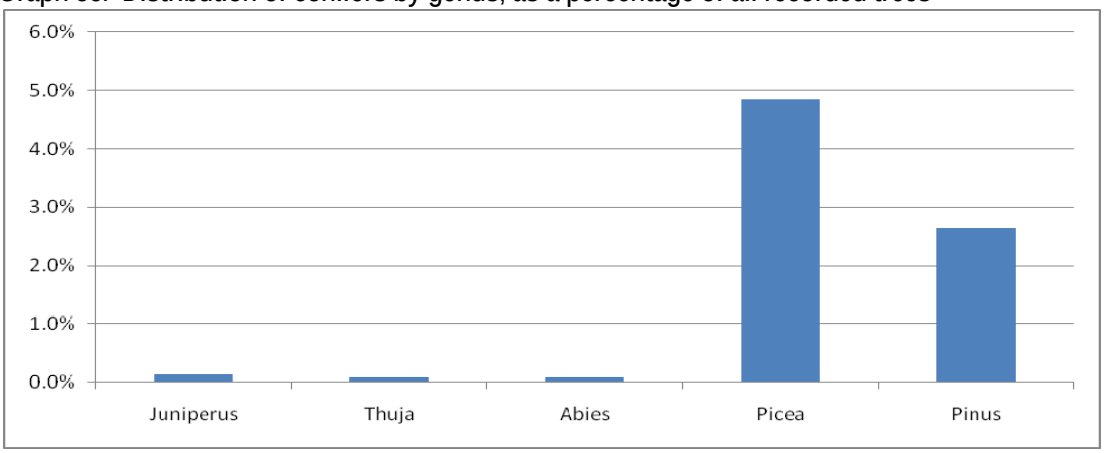
Graph 3a. Distribution of deciduous trees by genus, as a percentage of all recorded trees



Graph 3b. Distribution of ornamental trees and shrubs by genus, as a percentage of all recorded trees



Graph 3c. Distribution of conifers by genus, as a percentage of all recorded trees

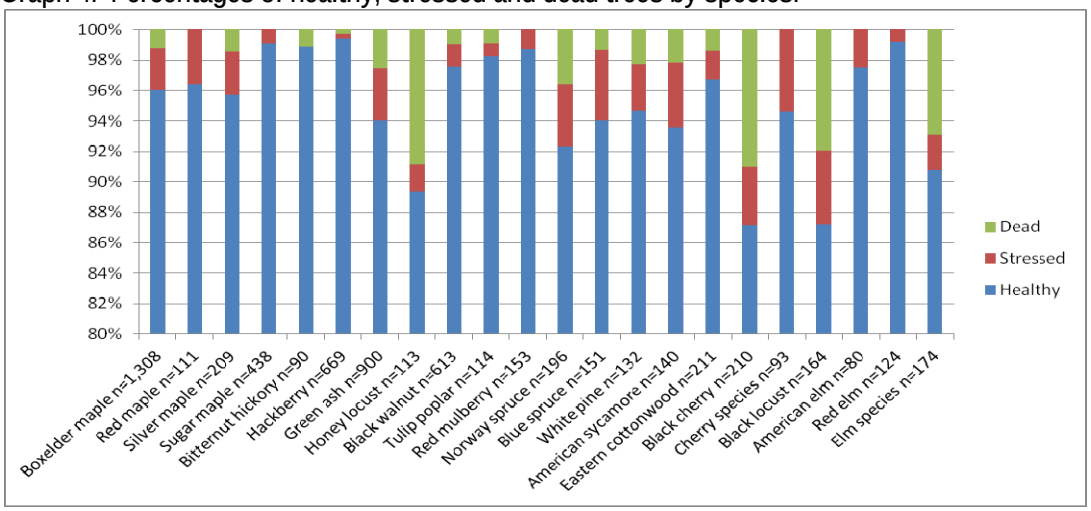


2.1.4 Tree Health

A total of 254 trees (3.8%) were determined to be dead, and 170 trees (2.5%) were identified as stressed. The remainder (93.7%) were categorized as healthy. WCC noted no trees which appeared to pose an immediate threat to public safety or property at the time of the inspection.

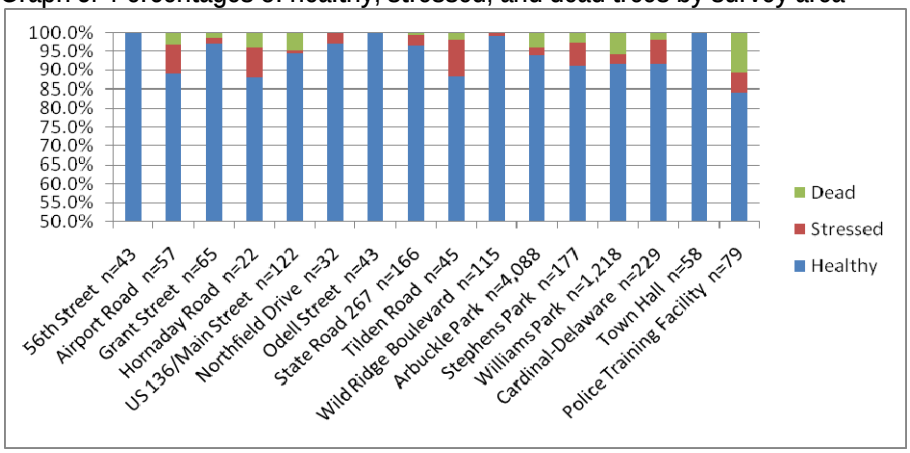
Comparisons of the percentage of healthy, stressed, and dead trees between species has the potential to yield misleading results as the range of individuals recorded within species ranged from 1 to 1,308. Such a broad distribution may indicate in disproportionately high mortality rates in species where comparatively few individuals were recorded. Therefore, only species which represented at least one percent of the total population were used to evaluate percent survival. In this comparison, red elm (*Ulmus rubra*) and sugar maple (*Acer saccharum*) had the highest percentage of healthy individuals at 99.2% and 99.1%, respectively. Conversely, black cherry (*Prunus serotina*) and black locust (*Robinia pseudoacacia*) were observed to have the lowest percentage of healthy individuals at 87.1%, and 87.2% respectively. Graph 4 illustrates the percentages of healthy, stressed, and dead individuals recorded among species which comprise at least 1% of the sample population.

Graph 4. Percentages of healthy, stressed and dead trees by species.



Tree health among survey areas ranged from 100% within the 56th Street right of way to 88% within the Hornaday Road right of way. Incidentally, the Hornaday Road right of way was also noted to have the highest mean dbh among street rights of way, suggesting a potential correlation between larger, older trees and declining tree health. Graph 5 summarizes tree health among survey areas.

Graph 5. Percentages of healthy, stressed, and dead trees by survey area



No trees were observed which exhibited evidence of damage by the invasive emerald ash borer beetle (*Agrilus planipennis)*.

2.2 Ecological and Economic Benefits

i-Tree Streets uses pre-defined values of common ecological and economic benefits associated with tree species and size classes to determine the contribution of the urban forest to the surrounding community. The following sections summarize the results of the analysis of the tree inventory data using this tool.

2.2.1 Ecological Values

Improved air quality, carbon sequestration, and storm water runoff reduction are critical benefits provided by forests. When in the urban environment, these benefits are more directly integrated with the sources of the pollutants.

The iTree analysis evaluated the sample forest population to identify amounts of pollutants removed from the atmosphere city wide. Additionally, iTree determined the economic benefits of this removal. Table 2 provides a summary of the air quality improvements provided by Brownsburg's urban forest resources. A species specific summary of this information is included in Appendix A.

Table 2. Air Quality Improvement Summary

	Ozone	Nitrogen dioxide	Particulate matter ≤ 10 microns	Volatile Organic Compounds	Sulfur dioxide	Economic benefit
Total lbs removed	50,208	9,805	20,621	---	7,560	$80,966
Total lbs avoided	---	22,906	7,339	7,309	86,629	$158,185

Trees play a vital role in the sequestration of carbon dioxide. The carbon storage benefits of Brownsburg's urban forest resources is summarized in Table 3 and Appendix A.

Table 3. Carbon Sequestration Benefits Summary

	Sequestered	Decomposition Release	Maintenance Release	Net Sequestration	Net Economic benefit
Total lbs	21,543,070	3,017,691	800,651	17,724,728	$58,491

Trees increase the available capacity of the soil to absorb storm water by removing water from the soil stratum, and releasing it to the air through transpiration. The ability of the soil to infiltrate additional water during storm events can help alleviate storm water related flooding, reducing flood damage and potentially the need for added sewer infrastructure. Annually, Brownsburg's urban forest resources intercept 327,609,196 gallons of rainfall, providing an economic benefit of $2,031,322. A species specific summary of storm water benefits is provided in Appendix A.

2.2.2 Economic Values

The urban forest environment provides economic benefits to a community both directly and indirectly. Indirect benefits such as improved aesthetics can be an attractive amenity to individuals searching for residential or commercial real estate, ultimately resulting in increased property resale values. The iTree data analysis indicates that the financial benefit from the aesthetic value of trees within the Town of Brownsburg is $5,725,043. A more specific summary of this indirect benefit separated by tree species is provided in Appendix A.

Direct economic benefits consist of reduced heating and cooling costs, which translate into overall lower energy consumption. The shade provided by an urban forest canopy during summer can block a large proportion of direct solar radiation, therefore reducing cooling costs. Similarly, trees planted to insulate buildings from wind can result in reduced heat loss and lower heating costs during winter. In total, the iTree analysis estimates that reductions in electricity and natural gas use result in an annual reduction of $627,539 on energy expenses within the Town of Brownsburg. More detailed summaries of energy use and species values are provided in Appendix A.

3.0 CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

3.1 Urban Reforestation Opportunities and Constraints

Urban forests provide a diverse assortment of benefits ranging from environmental and ecological, to social and economic. While managing existing forests for long term sustainability can help protect the sources of these benefits, re-planting or establishing new trees is an important factor as well.

Examination of the tree inventory data identified existing urban forest resources within the Town of Brownsburg. However, the inventory data also show opportunities for expansion of the urban forest environment. Figure 5 illustrates opportunities and constraints for reforestation within the Town of Brownsburg. These areas are summarized in the following sections:

3.1.1 Street Trees

Areas identified as being suitable for street tree establishment are shown in Figure 5. Criteria for the selection of these areas consisted of a general lack of existing street trees, a planting strip at least 5 feet wide between the front of the street curb and sidewalk, and the absence of other potential conflicts. Maintaining appropriate distances between street trees and items of potential conflict is critical to the success of urban forestry and public safety. Table 4 summarizes common obstacles to street tree planting and minimum recommended setback distances.

Table 4. Street tree minimum setback distances

Potential Conflict	Minimum Setback (feet)
Buried utility lines	5
Driveways	10
Utility poles	15
Street light poles	20
Other trees	20
Street intersections	30

When selecting species for street tree plantings, many factors must be considered. These include, but are not limited to:

- Available space (horizontal and vertical)
- Performance in compacted soil
- Low hanging branches
- Expected life span
- Species with weak wood
- Fruit, nut, or seed production
- Susceptibility to insects or disease

Tables 5, 6, and 7 in Section 3.3 below contain lists of species recommended for new plantings and replacement. Species suitable for use as street trees are noted in these tables.

Figure 5 identifies areas of the tree inventory which were determined to be suitable for street tree establishment. For planning purposes, these areas were identified based on tree inventory data, site observations, and review of aerial photography. In total, the opportunity exists for planting trees within approximately 126,000 linear feet of street right of way within the tree inventory area. Based on average spacing of 30 linear feet between trees, approximately 4,200 trees could be planted within the identified areas.

3.1.2 Park/Landscape Trees

Parks within the Town of Brownsburg provide valuable active and passive recreation opportunities for all residents of the community. Trees within active use areas of parks are generally planted and maintained at a lower density than forested areas. Areas of parks and municipal parcels which were identified as suitable for lower density tree plantings are identified in Figure 5. These consist of areas which are unpaved, without trees, and not currently designated for another use which would conflict with tree plantings such as playgrounds or athletic fields.

Analysis of parks and municipal properties identified opportunities for tree planting within Arbuckle Park, Stephens Park, Williams Park, the Cardinal-Delaware property, and the Police Training Facility property. In total, the opportunity exists for planting trees within approximately 30.9 acres of parks and municipal properties. Portions of Arbuckle and Williams Parks were analyzed to determine the existing density of trees in active use recreation areas. Tree density within these areas was approximately 30 stems per acre, a level which provides shade for users but does not prohibit recreational access. If planted at a density of 30 stems per acre, the 30.9 acres identified provide the opportunity for planting 927 trees within parks and municipal parcels.

3.1.3 Forest Trees

Figure 5 also identifies opportunities for reforestation of densely forested areas. These areas were identified within Arbuckle and Williams Parks and totaled 1.82 acres. Within densely forested areas, an average stem density of 138 trees per acre was observed. Based on this observed density, the opportunity exists for planting approximately 251 trees within densely forested areas of the tree inventory.

3.2 Tree Pruning and Removal

Urban forest management differs from traditional forest management primarily because of the increased interspersion of human interaction within forest resources. Consequently, traditional forest management objectives such as production of marketable timber and provision of large, contiguous tracts of wildlife habitat are unlikely to be feasible in the urban landscape. However, recreation, landscape aesthetics, creating shade, carbon sequestration, and improvements in soil retention and water quality are principal benefits of a well executed urban forestry management plan.

Because of human interaction in the urban forest environment, the safety of people, property, and municipal infrastructure are of particular concern. Unhealthy, damaged, or dead trees can create potential safety hazards and therefore must be addressed. Dead trees and branches should be removed immediately upon inspection to prevent potential injury and property damage. Low-hanging branches in recreational areas may be pruned to improve pedestrian traffic flow. Similarly, trees located under utility lines pose a threat during severe weather, and therefore should be pruned to avoid interference.

Just as pruning is critical to the urban forest environment, appropriate pruning and cutting techniques are critical to preserving the integrity of healthy portions of the tree. The United States Department of Agriculture (USDA) Forest Service has published a guide to tree pruning, included as Appendix B. This publication outlines concepts such as crown raising to improve pedestrian access and crown reduction to prevent damage from or to overhead utility lines. This resource also describes safe and effective cutting techniques. However, it must be noted that tree pruning and cutting should only be attempted by experienced persons using appropriate personal protective equipment (PPE). If an experienced person is not available, consultation with a professional arborist is recommended.

Sustainable disposal of pruned or cut vegetation is also recommended. The Hendricks County Solid Waste Management District operates two yard waste recycling centers which accept yard waste for a minimal fee. The yard waste recycling centers are located at 90 Mardale Drive in Brownsburg, and 7020 South County Road 875 East in Plainfield. Additionally, the Town of Brownsburg owns a chipper which could be used for disposal of branches and other vegetation.

3.3 Replacement Trees

Following removal of a dead tree, it is recommended that a replacement tree be planted. Factors effecting the selection of a replacement tree may include the location of the tree relative to buildings, roads, sidewalks, and utilities, the intended purpose of the tree (screening as opposed to shade), speed of growth, and general aesthetics. Improper pairing of replacement trees and location may result in long term costs to repair damaged infrastructure as a result of root growth, down limbs, etc. The following sections provide recommendations for replacement trees.

3.3.1 Deciduous Shade Trees

Deciduous trees selected to provide shade and aesthetics to a landscape are widely available from a variety of sources. These species include individuals which are suitable across a broad spectrum of soil and wetness conditions. However, as most are considered canopy species, they generally require partial to full sun and grow to be up to 100 feet in height with a crown up to 60 feet in width. While not exhaustive, Table 5 provides recommendations of shade trees suitable for plantings and replacement. Ash species (*Fraxinus spp.*), while excellent native shade trees are excluded due to concerns regarding the spread of the emerald ash borer. Additionally, when replacing deciduous shade trees, a minimum caliper size of 2 inches is recommended. WCC recommends installation of trees native to Indiana due to suitability for seasonal changes and soil conditions. Non-native species may require additional maintenance to ensure success, which would incur additional costs to the Town.

Table 5. Recommended deciduous shade trees

Common Name	Latin Name	Typical height (feet)	Typical Crown Spread (feet)	Wet – Dry Spectrum*	Suitable Street Tree?	Growth Rate
Red Maple	*Acer rubrum*	60-90	40-60	3	Yes	Fast
Sugar Maple	*Acer saccharum*	70-100	50-60	4	Yes	Slow
Black Maple	*Acer nigrum*	80	50-60	3	Yes	Slow
Norway Maple	*Acer platanoides*	60	35-45	3	Yes	Moderate
Silver Maple	*Acer saccharinum*	50-80	40-60	2	No	Fast
Northern Red Oak	*Quercus rubra*	60-90	45-55	4	Yes	Moderate
Pin Oak	*Quercus palustris*	50-90	30-50	2	Yes	Slow
Bur Oak	*Quercus macrocarpa*	50-80	50-60	3	Yes	Slow
White Oak	*Quercus alba*	80-100	40-60	4	Yes	Slow
Swamp White Oak	*Quercus bicolor*	60-70	50-60	2	Yes	Slow
Chestnut Oak	*Quercus prinus*	60-80	45-60	4	Yes	Moderate
Black Walnut	*Juglans nigra*	70-90	35-45	4	No	Fast
Butternut	*Juglans cinerea*	40-70	50-70	4	No	Slow
Pecan	*Carya illinoinensis*	100	40-75	2	No	Moderate
Shagbark Hickory	*Carya ovata*	70-100	40-60	4	No	Moderate
Shellbark Hickory	*Carya laciniosa*	70-100	75-85	2	No	Moderate

Cottonwood	*Populus deltoides*	100	35-50	3	No	Fast
Sycamore	*Platanus occidentalis*	60-100	75-100	2	Yes	Moderate
American Elm	*Ulmus americana*	100	50-65	2	Yes	Moderate
Red/Slippery Elm	*Ulmus rubra*	70	35-60	3	Yes	Moderate
Hackberry	*Celtis occidentalis*	50-90	40-60	3	Yes	Fast
Basswood	*Tilia americana*	60-100	30-50	4	Yes	Moderate
Tulip Poplar	*Liriodendron tulipifera*	80-120	30-50	4	Yes	Moderate
Ohio Buckeye	*Aesculus glabra*	30-70	20-40	3	No	Moderate
Sweet Gum	*Liquidambar styraciflua*	60-100	40-60	2	No	Moderate
Black Gum	*Nyssa sylvatica*	50-100	40-60	3	Yes	Moderate
Black Locust	*Robinia pseudoacacia*	40-80	35-55	4	Yes	Moderate
* 1 = Very wet, 2 = wet, 3 = average wet/dry, 4 = dry, 5 = very dry Source: USDA Plants database						

3.3.2 Evergreens and Conifers

Year-round retention of dense foliage and a wide base as compared to deciduous trees make evergreens a frequent choice for screening. Although less common than deciduous trees in this inventory, evergreens represented approximately 8 percent of the total population, primarily located in landscaped areas. Evergreens, in general, tend to grow well in average to dry conditions. For this reason, they are commonly planted in raised mounds for landscaping purposes, and therefore may become stressed during extended periods of low precipitation.

When possible, native species are preferred for plantings and replacements. However, relatively few native species of evergreens are commonly available as nursery stock. Therefore, the list of recommended evergreens and conifers (Table 6) has been expanded to include commonly available landscape species. For replacement evergreens, a minimum tree height of 5 feet is recommended.

Table 6. Recommended Evergreen and Coniferous Trees

Common Name	Latin Name	Typical height (feet)	Typical Crown Spread (feet)	Wet – Dry Spectrum*	Suitable Street Tree?	Growth Rate
Jack Pine	*Pinus banksiana*	30-70	20-30	4	No	Moderate
Red Pine	*Pinus resinosa*	70-80	25-40	4	No	Moderate
Pitch Pine	*Pinus rigida*	50-60	25-35	4	No	Moderate
Virginia Pine	*Pins virginiana*	30-60	20-30	4	No	Moderate
Blue Spruce	*Picea pungens*	50-70	20-40	4	No	Moderate
Norway Spruce	*Picea abies*	50-80	20-45	4	No	Moderate
Balsam fir	*Abies balsamia*	45-70	20-40	2	No	Moderate
Eastern Redcedar	*Juniperus virginiana*	40-50	8-20	4	No	Moderate
Bald Cypress‡	*Taxodium distichum*	100-120	40-60	2	Yes	Moderate
* 1 = Very wet, 2 = wet, 3 = average wet/dry, 4 = dry, 5 = very dry; ‡ = considered a deciduous conifer; Source: USDA Plants database						

3.3.3 Ornamental Deciduous Trees and Shrubs

For the purposes of this inventory, ornamental deciduous trees and shrubs consist of either a: cultivar species developed specifically for ornamental purposes or b: understory or shrub-form species which occur as native individuals but are primarily used as ornamental species. Examples of these include various cultivars of crabapple (*Malus spp.*) and hawthorn (*Crataegus spp.*) as well as redbud (*Cercis canadensis*). As with evergreens, native species are preferred for plantings and replacements. Table 7 presents a list of commonly available species recommended for ornamental plantings.

Table 7. Recommended Ornamental Deciduous Trees

Common Name	Latin Name	Typical height (feet)	Typical Crown Spread (feet)	Wet – Dry Spectrum*	Suitable Street Tree?	Growth Rate
Pear Hawthorn	*Crataegus calpodendron*	20	15-20	3	Yes	Moderate
Fireberry Hawthorn	*Crataegus chrysocarpa*	20	15-20	3	Yes	Moderate
Sweet Crabapple	*Malus coronaria*	30	15-20	3	No	Moderate
Prairie Crabapple	*Malus ioensis*	10-30	10-20	3	No	Moderate
American Plum	*Prunus americana*	30	10-20	5	No	Moderate
Pincherry	*Prunus pensylvanica*	30	8-15	4	Yes	Moderate
Sandcherry	*Prunus pumila*	30	10-20	3	Yes	Moderate
Chokecherry	*Prunus Virginiana*	20	8-15	3	Yes	Moderate
Redbud	*Cersis canadensis*	40	15-25	4	Yes	Moderate
* 1 = Very wet, 2 = wet, 3 = average wet/dry, 4 = dry, 5 = very dry; Source: USDA Plants database						

3.4 Tree Planting Within New and Redevelopment Areas

Incorporation of trees is highly recommended within new development and redevelopment areas. As a primary measure, developers are encouraged to preserve existing trees when creating site plans, particularly those species listed in Tables 5, 6, and 7. Mature shade trees with dbh of 10 inches or greater are highly recommended for preservation due to the time required for replacement.

When preservation of existing trees is not feasible, or a site is currently devoid of trees, tree plantings should be incorporated into the site landscape design. Although specific designs will vary by location, the following minimum guidelines are recommended:

- Minimum caliper size of newly planted deciduous shade trees will be 2 inches
- Minimum height of newly planted evergreen trees will be 5 feet
- For new commercial developments, a minimum of 3 trees (deciduous or evergreen) per 1,000 square feet of building footprint
- For new single family residential developments, a minimum of 2 trees (deciduous or evergreen) per lot, planted within 30 feet of the street right of way
- For new multi-family residential developments, a minimum of 3 trees (deciduous or evergreen) per 1,000 square feet of building footprint.

The National Arbor Day Foundation provides recommendations and instructional videos for successful planting of bare root, balled and burlapped, and containerized trees. http://www.arborday.org/trees/tips/treePlanting.cfm.

Additional tree planting specifications are included in Appendix C. While specific details may vary between these planting methods, they generally follow these guidelines:

- Dig the hole to the depth of the root ball and at least double the diameter
- Do not disturb the soil at the bottom of the hole
- Place the tree in the center of the hole and begin backfilling with the native soil
- Ensure the tree remains straight
- Backfill only to the root collar
- Use soil to create a basin around the tree to hold water
- Water thoroughly
- Cover the backfilled soil with mulch
- Continue regular water routine during the first growing season

3.5 Specimen Trees

Individual trees with dbh of 20 inches or more (for single stem species) and good health status were identified as specimen trees. The tree inventory identified 662 specimen trees within 32 species. Figure 4 illustrates the locations of specimen trees.

Special conservation efforts are recommended for specimen trees. In the event that a specimen tree dies and must be removed, it is recommended that a replacement of the same species be planted within the general vicinity of the tree that has been removed. In the event that a specimen tree is removed due to development, road, or utility improvements, it is recommended that a replacement of the same species be planted as near to the location of the removed tree as is feasible. It is also recommended that replacements of specimen trees be a minimum caliper size of 4 inches.

3.6 Invasive Species

The USDA defines invasive species as:

introduced species that can thrive in areas beyond their natural range of dispersal. These plants are characteristically adaptable, aggressive, and have a high reproductive capacity. Their vigor combined with a lack of natural enemies often leads to outbreak populations.

The Indiana Department of Natural Resources includes 4 species of woody plants as invasive. Table 8 summarizes these species and example photographs are presented in Appendix D.

Table 8. Summary of IDNR Invasive Woody Species

Common Name	Latin Name	Growth type	Spreads by
Autumn Olive	*Elaeagnus umbellata*	Shrub	Seeds
Bush Honeysuckle	*Lonicera spp.*	Shrub	Seeds
Kudzu	*Pueraria montana*	Vine	Stolon, Rhizome, Seeds
Tree-of-Heaven	*Ailanthus altissima*	Tree	Rhizome, Seeds

Autumn olive (*Elaeagnus umbellata*) is commonly found as a colonist of grasslands and disturbed areas. Bush honeysuckle (*Lonicera spp.*) is commonly found along the perimeter of densely forested areas and tends to spread inward, excluding other understory species. Kudzu (*Pueraria montana*) is a vine which grows at an aggressive rate, often overtaking entire forest canopies, effectively blocking out sunlight from other plants. Tree of heaven (*Ailanthus altissima*) is an introduced species which favors high disturbance environments and produces toxins, released into the soil, which restrict the growth of adjacent plants.

Autumn olive and bush honeysuckle were identified within the forested portions of Williams Park and Arbuckle Park. The southeastern portion of Williams Park, in particular, was characterized by a dense population of bush

honeysuckle. If uncontrolled, these species have the potential to dominate a landscape, resulting in a monoculture. Therefore, it is highly recommended that management actions be taken to prevent the spread of these species and remove them from their current extent.

Effective treatment of woody invasive species typically involves physical removal of above-ground vegetation, followed by application of a Triclopyr-based herbicide (Garlon®). Regular inspection of forested areas following treatment is recommended to ensure control of invasive species.

3.7 Tree Disease

Tree diseases commonly known throughout the U.S. include Chestnut Blight and Dutch Elm Disease. While these historically notable infections remain a concern, additional and less well recognized pathogens are also a threat to the health of forest resources. Below is a summary of tree diseases with the potential to impact central Indiana forests.

3.7.1 Dutch Elm Disease

Dutch Elm Disease is a fungal infection once common among elm trees (*Ulmus spp.*). The disease is transferred from infected to healthy trees via spores carried on the bodies of two species of elm bark beetles. The beetles typically occupy infected trees where they lay their eggs, but travel to healthy trees to feed, transferring the fungal spores. A secondary means of infection is through root grafts. Roots of adjacent elms often make contact, allowing the transfer of the fungus from the vascular tissue of one tree to another (Pecknold, 1996).

Infected trees are characterized by wilting and yellowing leaves, followed by defoliation, and death of infected branches. Brown streaks visible beneath the bark, within vascular tissue is also a common indicator. Treatment of mildly infected trees may be possible by pruning infected branches well below the point of infection. However, if infection is visible in 10%-20% of the tree crown, selective pruning is typically not effective. Additional treatment options include injection of fungicide, control of insects which serve as a vector for the fungus, or complete removal of infected trees. Following removal of trees or infected portions of trees, all wood should be burned or chipped so as to destroy all bark suitable as beetle habitat. Information regarding Dutch Elm Disease is included in Appendix E.

3.7.2 Chestnut Blight

The American chestnut (*Castanea dentata*) is a deciduous shade tree native to the eastern half of North America, including Indiana. The vast majority of the American chestnut population was destroyed in the first half of the 20th century by a disease called Chestnut Blight.

Chestnut Blight is a bark infection of an Asian fungus which spreads via airborne spores. The fungus was introduced into North America from Asiatic chestnut trees and was discovered in the New York Zoological Park in 1904. Following its discovery, the disease was responsible for the near extinction of the American chestnut. Although the primary means of control is the removal of infected trees (similar to Dutch Elm Disease), research is currently underway to develop a hybrid version of the species which have a resistance to the fungal infection.

3.7.3 Thousand Cankers Disease

Thousand Cankers Disease is the result of an interaction of the *Geosmithia morbida* fungus with the walnut twig beetle (*Pityophthorus juglandis*). The walnut twig beetle bores into the bark of a walnut tree and, if carrying the fungus, infects the tree, creating a small, black lesion. In instances where a single tree is infected by thousands of beetles simultaneously, the edges of the lesions blend into each other, resulting in severe damage to the vascular tissue of the tree. Infected trees are characterized by yellowing and wilting leaves and dead branches. Often the entire tree can die within 3-5 years of infection (Marshall and McDonough, 2011).

Currently, thousand cankers disease has not been identified in Indiana. In order to prevent the introduction of the disease, the IDNR has enacted a quarantine on walnut trees. Under the quarantine, certain walnut materials

originating in, or transiting through a quarantined state are prohibited from being brought into Indiana. These materials include:

- All types of hardwood firewood
- Walnut (*Juglans spp.*) nursery stock
- Walnut logs, lumber, chips and mulch
- The *Geosmithia morbida* fungus
- The walnut twig beetle

States currently considered as regulated by the quarantine include:

- Arizona
- California
- Colorado
- Idaho
- Nevada
- New Mexico
- Oregon
- Tennessee
- Utah
- Washington

3.7.4 Anthracnose

Anthracnose is a plant infection most common in years when cool, wet conditions prevail at the time of leaf development. The disease can be caused by any of several different species of fungi which reside in diseased stem and leaf tissue. In early spring, the fungi produce spores which are transferred to newly emerging leaves.

Infected leaves appear similar to those affected by leaf scorch, with the exception that the degradation originates at leaf veins rather than between veins. This can lead to severe leaf damage and eventually defoliation of trees. Varieties most frequently affected by anthracnose include ash, oak (*Quercus spp.*), maple, and sycamore (*Platanus spp.*).

Anthracnose is typically not a terminal disease. Healthy trees will generally develop a new crop of leaves to replace those lost to defoliation. Severely weak or already compromised trees may be more susceptible. Therefore, the most effective treatment for anthracnose is fertilization of trees in spring to provide sufficient nutrients for survival even under stressed conditions. Additionally, removal of infected leaves, twigs, and branches is important as the fungus resides in these materials (Purdue Extension, 2002).

3.8 Pest Control

3.8.1 Emerald Ash Borer

The emerald ash borer is a non-native, wood boring insect pest of North American ash trees. The species was first identified in southeastern Michigan in 2002 and is thought to have been introduced to North America via wood packing material originating in Asia. As of 2009 the emerald ash borer was identified in 13 states (Indiana, Illinois, Kentucky, Maryland, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Virginia, West Virginia, and Wisconsin) and parts of Canada (USDA, 2009).

Because the range of the species can be extended rapidly by physical movement of infested wood, the IDNR has enacted a firewood quarantine on selected counties in southern Indiana. Hendricks County is not currently included in this quarantine, nor are any adjoining counties. However, transfer of firewood between counties is strongly discouraged, in an attempt to prevent further spread of this pest.

Beyond the quarantine, current methods for controlling the spread of the emerald ash borer are generally restricted to pesticide application. Ongoing research conducted by the USDA Animal and Plant Health Inspection Service (APHIS) is attempting to identify a biological control mechanism for the emerald ash borer. Appendix F contains resources regarding the quarantine, pesticide use, and efforts for the development of a biological control.

3.8.2 Gypsy Moth

The gypsy moth (*Lymantria dispar*), is a European species introduced to Massachusetts in 1869. Since that time it has spread westward and was identified in Indiana in 1973. Currently, populations are known to exist in the northeastern portion of the state (Purdue Extension, 2004).

Gypsy moths damage trees by consuming living foliage, oak leaves being their preferred food. While leaves will re-grow, repeated defoliation by moths can kill trees.

Pesticide application can kill the larval form of the insect, preventing leaf damage. However, more effective control can be realized by conservation of natural predators of the moth. Additional information on the available control mechanisms of gypsy moths is included in Appendix F.

3.8.3 Bag Worms

Bag Worms (*Thyridopteryx ephemeraeformis*) are a species of moth, whose larval form occupies primarily evergreen trees. Upon emerging from a bag-like cocoon structure, the larvae eat the foliage of the host tree. This can result in severe damage to evergreens and eventually death (Gibb and Sadof, 2009).

Prevention of tree damage from bag worms can be as simple as removing the larval bags and soaking in soapy water, prior to June, when eggs typically hatch. After eggs have hatched, control of the larvae can be achieved via pesticide application. Additional information regarding control options of bag worms is included in Appendix F.

3.8.4 Japanese Beetles

Japanese Beetles (*Popillia japonica*) were introduced to North America in 1916 and have become a notable and devastating pest to urban landscape plants. In larval form, the species lives underground and primarily consumes the roots of turf grasses. Adults prefer plant and tree foliage and are known to consume leaves of more than 300 species of plants, including many common deciduous and ornamental trees.

Many pesticides are effective in controlling Japanese beetles, although the type and delivery mechanism varies with the life cycle stage. Recent developments have incorporated lawn grub (larval) protection into some lawn fertilizers. Appendix F contains additional information regarding this species.

3.9 Forest Management

Passively used forested areas typically require less intensive management than high traffic urban forest resources. However, management efforts within densely forested areas such as portions of Arbuckle and Williams Parks should include semi-annual inspections to identify potential management concerns. Items to be noted include, but are not limited to the following:

- Dead trees in danger of falling on or near recreational trails
- Wind or lightning damaged trees
- Evidence of pest infestation
- Evidence of tree disease
- Selective cutting of lower quality species to encourage species diversity

In the event that inspections identify problems, action should be taken to rectify the issue as soon as is reasonably possible.

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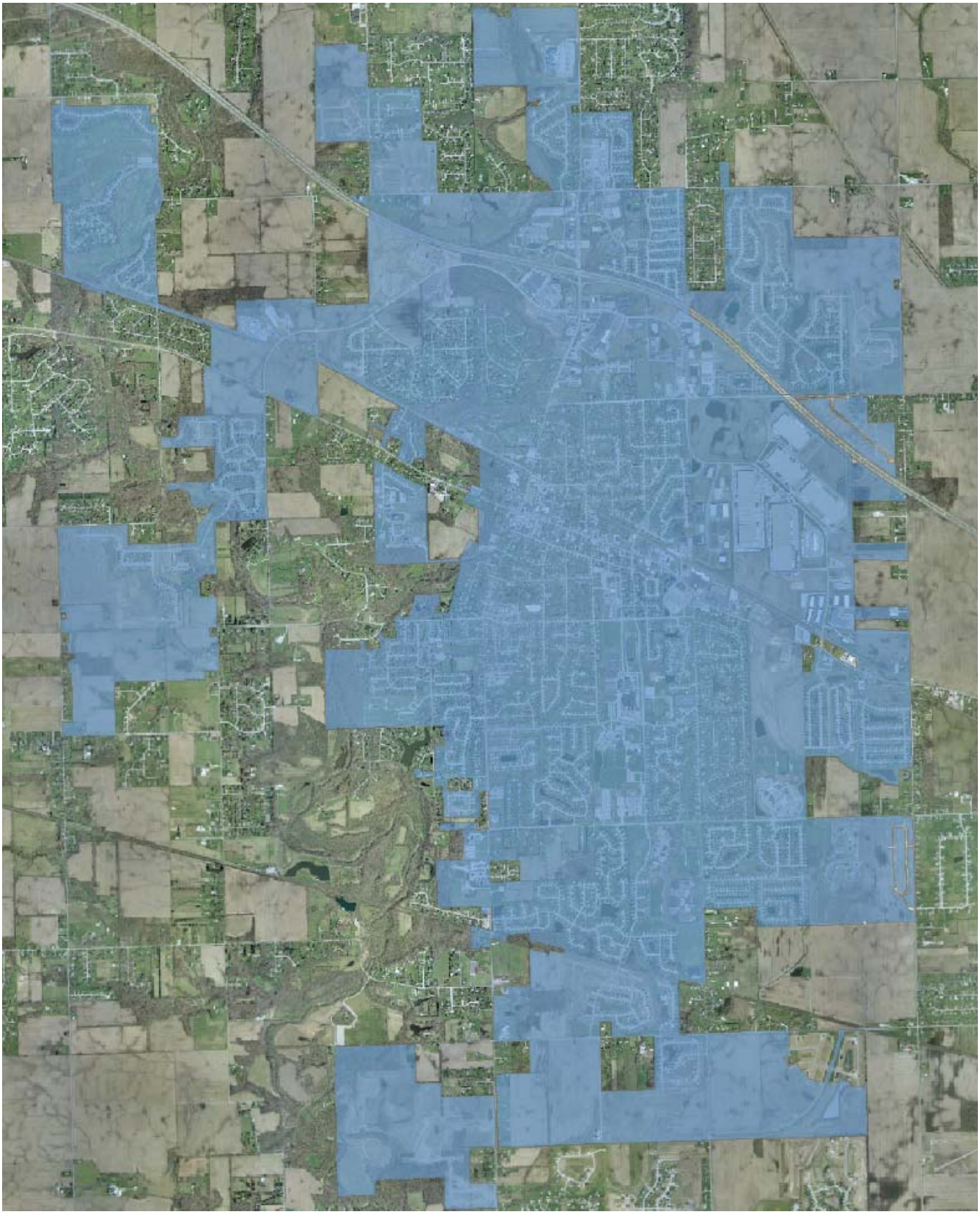
FIGURES



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Indianapolis, IN 46202
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Fax: 317-423-0696

N

1"≈,2,700

FIGURE 1
Brownsburg Incorporated Limits
(Indiana University Spatial Data Portal)

Urban Forestry Management Plan
Brownsburg, Hendricks County, Indiana

Prepared for:
Town of Brownsburg, Indiana

Project No.
01.0416.A.4

Date:
December 2011

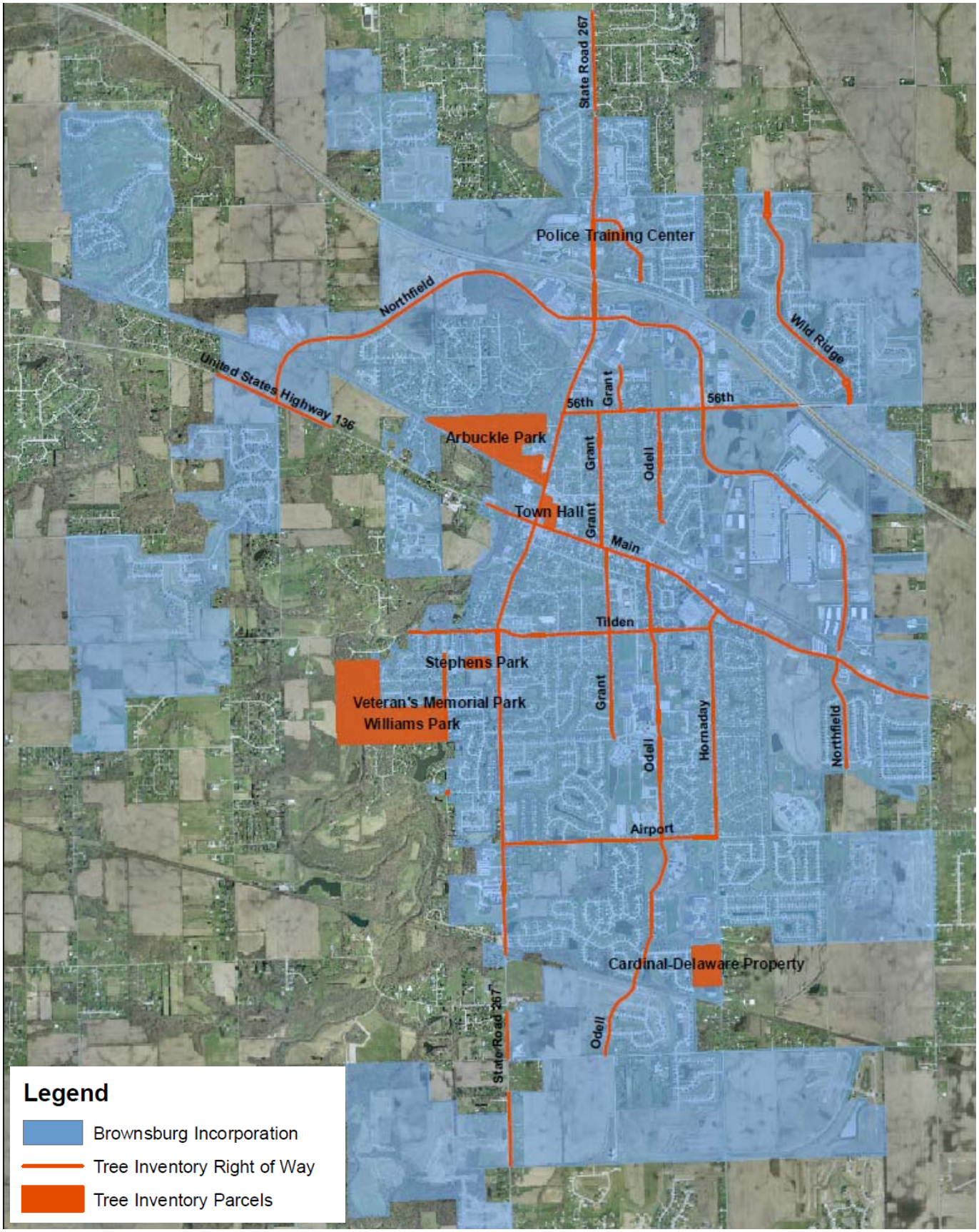

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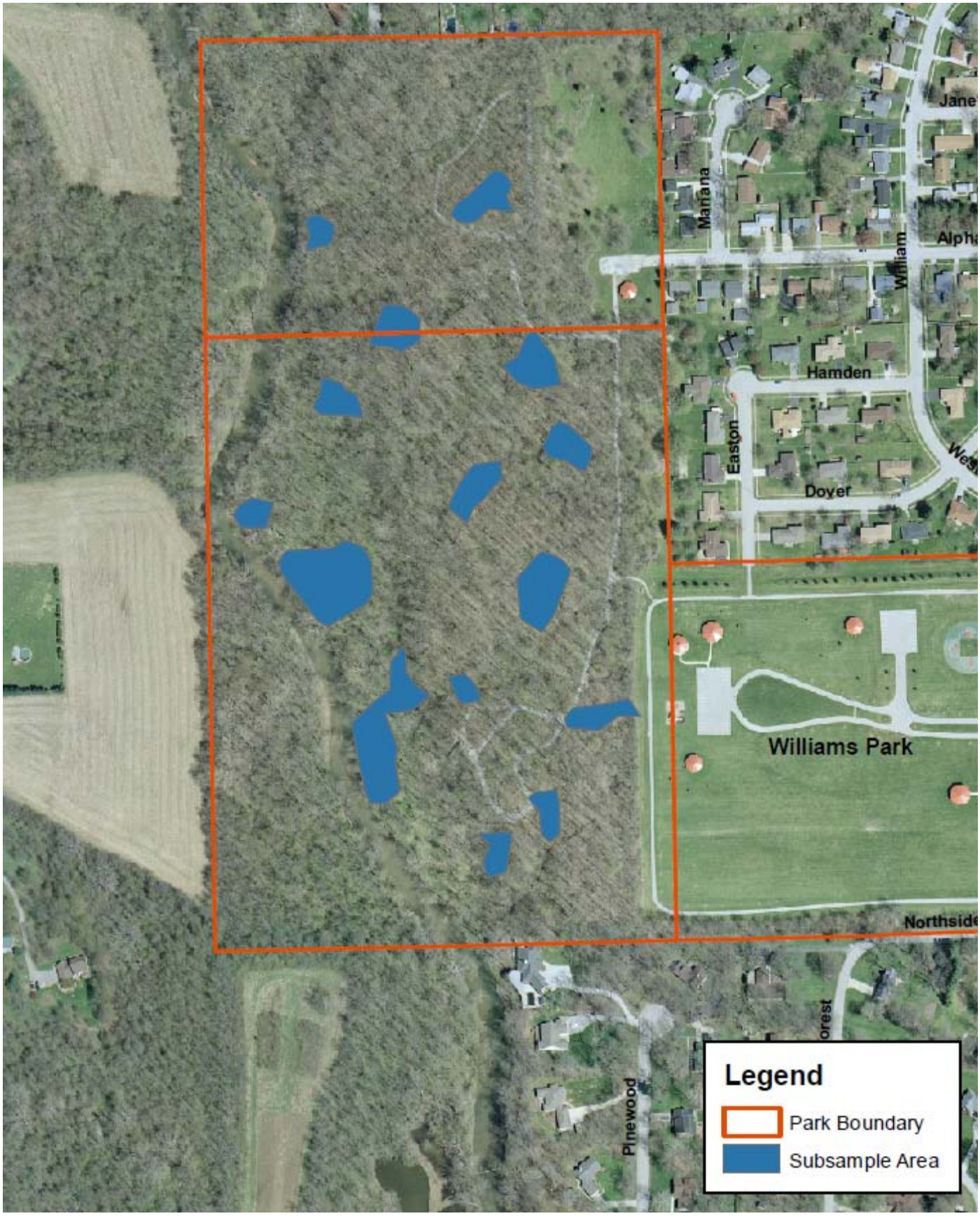
FIGURE 2
Tree Inventory Survey Areas
(Indiana University Spatial Data Portal)

Urban Forestry Management Plan
Brownsburg, Hendricks County, Indiana

Prepared for:
Town of Brownsburg, Indiana

Project No.
01.0416.A.4

Date:
December 2011



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1"≈ 300'

FIGURE 3
Williams Park Subsample Areas
(Indiana University Spatial Data Portal)

Urban Forestry Management Plan
Brownsburg, Hendricks County, Indiana

Prepared for:
Town of Brownsburg, Indiana

Project No.
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Date:
December 2011

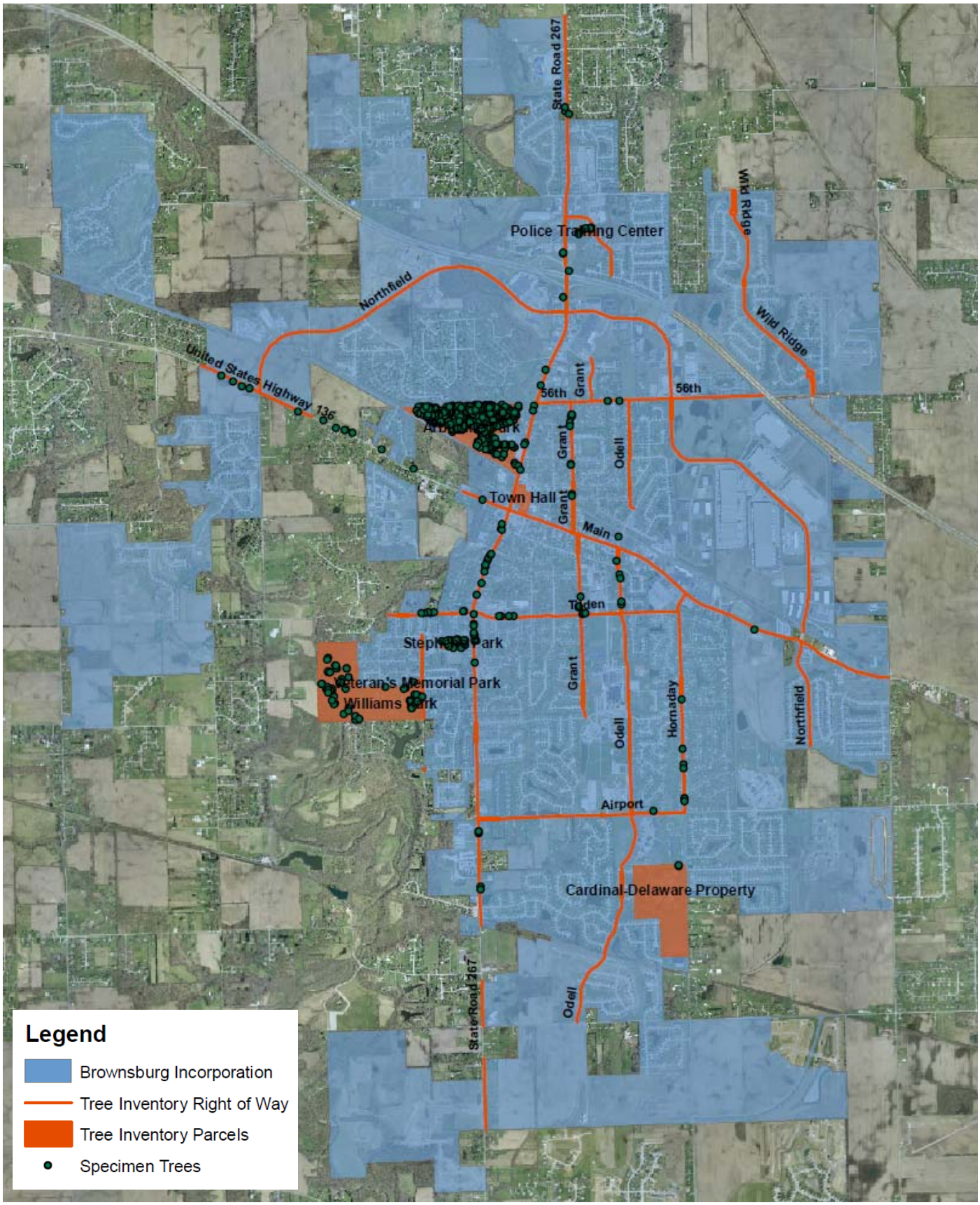

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FIGURE 4
Specimen Tree Locations
(Indiana University Spatial Data Portal)

Urban Forestry Management Plan
Brownsburg, Hendricks County, Indiana

Prepared for:
Town of Brownsburg, Indiana

Project No.
01.0416.A.4

Date:
December 2011

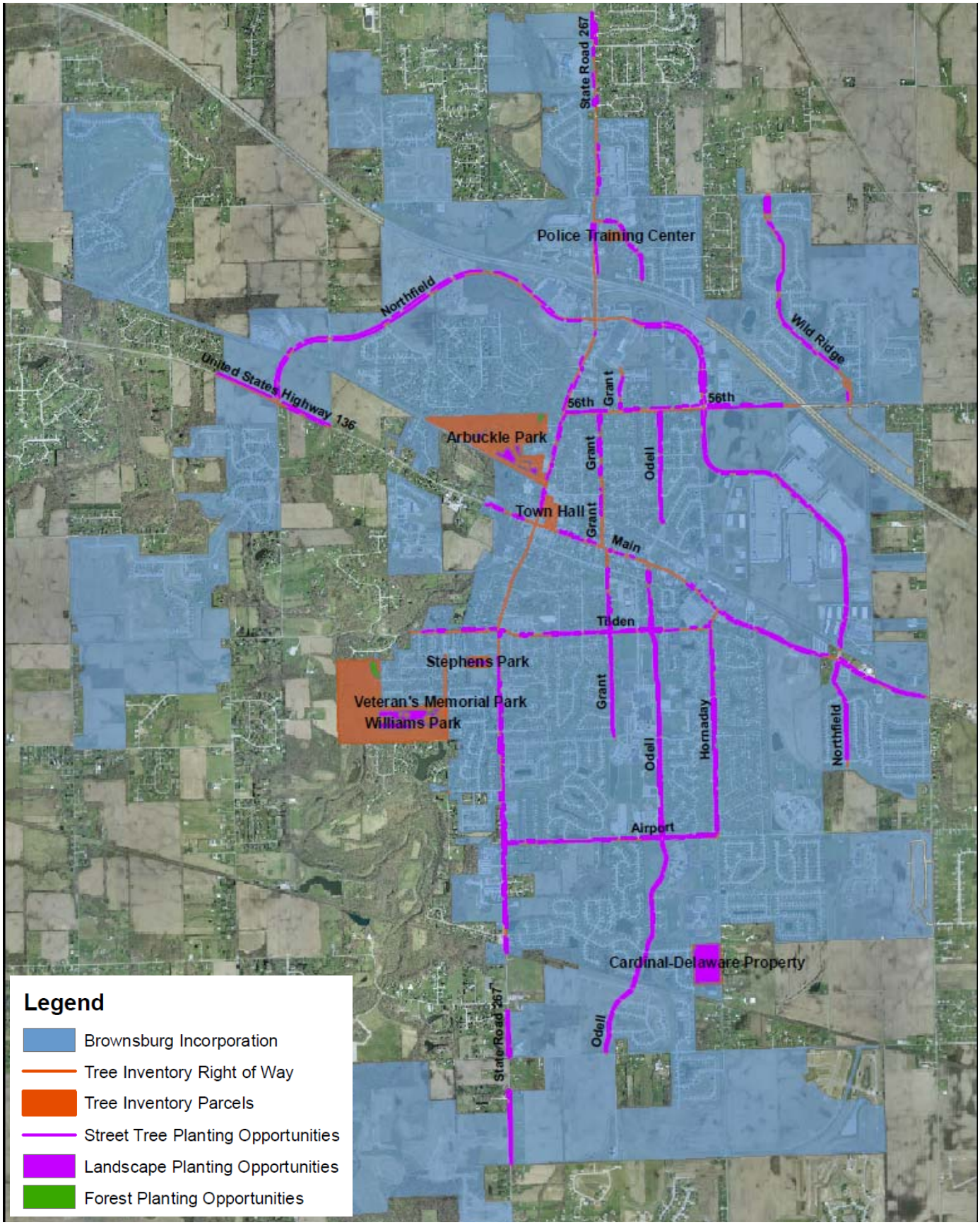

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FIGURE 5
Reforestation Opportunities
(Indiana University Spatial Data Portal)

Urban Forestry Management Plan
Brownsburg, Hendricks County, Indiana

Prepared for:
Town of Brownsburg, Indiana

Project No.
01.0416.A.4

Date:
December 2011

Appendix A

iTree Streets Analysis Reports

Brownsburg

Annual Air Quality Benefits of Public Trees by Species

11/11/2011

Species	Deposition (lb)				Total Depos. ($)	Avoided (lb)				Total Avoided ($)	BVOC Emissions (lb)	BVOC Emissions ($)	Total (lb)	Total ($)	Standard Error	% of Total Trees	Avg. $/tree
	O_3	NO_2	PM_{10}	SO_2		NO_2	PM_{10}	VOC	SO_2								
Boxelder	6,387.3	1,311.8	2,722.4	1,013.4	10,529	3,122.0	966.5	959.8	11,291.8	20,743	-2,583.3	-775	25,191.7	30,496	(±26,827)	18.2	1.05
Green ash	7,963.1	1,474.2	3,066.9	1,099.3	12,424	3,761.4	1,180.4	1,173.5	13,847.3	25,376	0.0	0	33,566.0	37,800	(±24,073)	12.5	1.89
Northern hackberry	4,624.4	949.8	1,971.0	733.7	7,623	2,055.5	663.1	660.7	7,842.4	14,304	0.0	0	19,500.6	21,926	(±16,115)	9.3	1.47
Black walnut	5,192.3	773.8	1,802.7	619.1	7,605	2,525.3	882.1	884.3	10,665.6	19,208	-1,233.0	-370	22,112.1	26,443	(±20,546)	8.5	1.94
Sugar maple	2,289.5	470.2	975.8	363.2	3,774	1,086.7	336.7	334.4	3,935.4	7,228	-2,255.5	-677	7,536.5	10,325	(±6,310)	6.1	1.06
Eastern cottonwood	3,323.2	682.5	1,416.4	527.2	5,478	1,463.9	451.8	448.6	5,273.8	9,693	-15,436.1	-4,631	-1,848.6	10,540	(±9,042)	2.9	2.25
Black cherry	1,782.9	330.1	686.7	246.1	2,782	838.6	263.3	261.7	3,088.9	5,660	0.0	0	7,498.3	8,442	(±4,752)	2.9	1.81
Silver maple	3,287.2	675.1	1,401.1	521.5	5,418	1,423.7	443.7	440.9	5,194.2	9,530	-1,473.8	-442	11,913.5	14,506	(±5,409)	2.9	3.12
Norway spruce	628.6	158.1	346.9	134.7	1,191	219.5	78.1	78.4	948.9	1,704	-1,130.5	-339	1,462.8	2,556	(±1,093)	2.7	0.59
Elm	670.2	137.6	285.7	106.3	1,105	288.3	97.9	97.9	1,174.2	2,124	0.0	0	2,858.1	3,229	(±2,445)	2.4	0.83
Black locust	1,256.3	232.6	483.8	173.4	1,960	605.2	190.5	189.5	2,237.2	4,097	0.0	0	5,368.4	6,057	(±4,525)	2.4	1.60
Red mulberry	1,154.8	237.2	492.2	183.2	1,903	522.1	163.8	162.9	1,921.7	3,522	-387.5	-116	4,450.3	5,309	(±2,098)	2.1	1.56
Blue spruce	391.5	98.5	216.1	83.9	742	134.3	47.6	47.8	577.5	1,038	-700.5	-210	896.7	1,569	(±545)	2.1	0.47
American sycamore	2,008.9	371.9	773.7	277.3	3,134	903.6	281.8	280.0	3,299.9	6,054	0.0	0	8,197.1	9,188	(±6,628)	1.9	2.95
Unknown	557.8	114.6	237.7	88.5	919	254.2	81.2	80.9	958.0	1,750	-217.2	-65	2,155.6	2,604	(±1,798)	1.9	0.84
Eastern white pine	612.9	154.2	338.3	131.4	1,161	208.9	76.8	77.2	940.0	1,681	-811.3	-243	1,728.5	2,598	(±1,483)	1.8	0.88
Slippery elm	437.9	89.9	186.6	69.5	722	188.3	64.3	64.3	772.5	1,396	0.0	0	1,873.4	2,118	(±1,862)	1.7	0.77
Tulip tree	1,020.4	188.9	393.0	140.9	1,592	493.9	155.1	154.2	1,820.5	3,336	0.0	0	4,367.0	4,928	(±4,126)	1.6	1.94
Red maple	568.8	116.8	242.4	90.2	938	260.5	80.4	79.8	938.4	1,725	-261.2	-78	2,116.3	2,584	(±1,158)	1.5	1.05
Honeylocust	1,273.7	261.6	542.9	202.1	2,100	485.4	165.8	165.9	1,992.2	3,600	-577.2	-173	4,512.4	5,527	(±2,185)	1.5	2.32
Plum	238.6	49.0	101.7	37.9	393	91.8	31.3	31.3	375.5	679	0.0	0	957.0	1,072	(±546)	1.3	0.51
Bitternut hickory	579.2	107.2	223.1	80.0	904	283.5	89.5	89.0	1,051.7	1,925	0.0	0	2,503.1	2,829	(±2,666)	1.2	1.41
American elm	397.4	81.6	169.4	63.1	655	166.8	55.7	55.7	665.4	1,207	0.0	0	1,655.1	1,862	(±1,197)	1.1	1.05
OTHER STREET TREES	3,561.0	737.3	1,544.4	575.0	5,916	1,522.8	491.6	489.9	5,816.2	10,607	-1,974.3	-592	12,763.8	15,930	(±4,978)	9.3	1.07
Citywide total	50,208.0	9,804.6	20,620.7	7,560.9	80,966	22,906.2	7,338.9	7,308.6	86,629.3	158,185	-29,041.5	-8,712	183,335.8	230,439	(±134,162)	100.0	1.44

Brownsburg

Annual CO_2 Benefits of Public Trees by Species

11/11/2011

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Boxelder	1,920,235	6,337	-171,780	-105,347	-915	2,065,116	6,815	3,708,224	12,237	(±10,765)	18.2	11.1	0.42
Green ash	4,017,188	13,257	-563,180	-117,168	-2,245	2,532,550	8,357	5,869,391	19,369	(±12,336)	12.5	17.5	0.97
Northern hackberry	2,559,366	8,446	-220,966	-70,242	-961	1,434,391	4,733	3,702,549	12,218	(±8,980)	9.3	11.0	0.82
Black walnut	2,322,844	7,665	-361,888	-90,612	-1,493	1,951,041	6,438	3,821,385	12,611	(±9,798)	8.5	11.4	0.92
Sugar maple	1,016,391	3,354	-115,370	-36,228	-500	719,726	2,375	1,584,520	5,229	(±3,195)	6.1	4.7	0.54
Eastern cottonwood	755,289	2,492	-222,279	-53,243	-909	964,506	3,183	1,444,272	4,766	(±4,089)	2.9	4.3	1.02
Black cherry	881,802	2,910	-127,629	-26,674	-509	564,938	1,864	1,292,437	4,265	(±2,401)	2.9	3.9	0.91
Silver maple	1,622,297	5,354	-372,880	-52,537	-1,404	949,965	3,135	2,146,845	7,085	(±2,642)	2.9	6.4	1.52
Norway spruce	130,611	431	-18,847	-21,374	-133	173,592	573	263,982	871	(±373)	2.7	0.8	0.20
Elm	687,584	2,269	-38,176	-13,596	-171	214,779	709	850,591	2,807	(±2,126)	2.4	2.5	0.73
Black locust	691,429	2,282	-73,307	-19,245	-305	409,164	1,350	1,008,041	3,327	(±2,485)	2.4	3.0	0.88
Red mulberry	216,104	713	-30,807	-16,177	-155	351,458	1,160	520,577	1,718	(±679)	2.1	1.6	0.50
Blue spruce	76,908	254	-11,210	-13,596	-82	105,652	349	157,753	521	(±181)	2.1	0.5	0.15
American sycamore	777,089	2,564	-198,547	-27,462	-746	603,517	1,992	1,154,597	3,810	(±2,748)	1.9	3.4	1.22
Unknown	156,483	516	-14,062	-12,171	-87	175,215	578	305,466	1,008	(±696)	1.9	0.9	0.33
Eastern white pine	56,822	188	-6,527	-11,165	-58	171,976	568	211,106	697	(±398)	1.8	0.6	0.24
Slippery elm	485,853	1,603	-24,171	-9,254	-110	141,309	466	593,737	1,959	(±1,723)	1.7	1.8	0.71
Tulip tree	545,141	1,799	-61,653	-15,038	-253	332,955	1,099	801,406	2,645	(±2,215)	1.6	2.4	1.04
Red maple	120,801	399	-26,272	-9,287	-117	171,627	566	256,869	848	(±380)	1.5	0.8	0.34
Honeylocust	438,367	1,447	-66,828	-12,976	-263	364,423	1,203	722,986	2,386	(±943)	1.5	2.2	1.00
Plum	37,996	125	-3,685	-1,576	-17	68,683	227	101,418	335	(±170)	1.3	0.3	0.16
Bitternut hickory	333,301	1,100	-28,345	-9,287	-124	192,347	635	488,015	1,610	(±1,518)	1.3	1.5	0.80
American elm	312,233	1,030	-24,826	-7,058	-105	121,718	402	402,068	1,327	(±853)	1.1	1.2	0.75
OTHER STREET TREI	1,380,939	4,557	-234,458	-49,339	-937	1,063,798	3,511	2,160,940	7,131	(±2,229)	9.3	6.4	0.48
Citywide total	21,543,070	71,092	-3,017,691	-800,651	-12,601	5,844,447	52,287	33,569,175	110,778	(±64,496)	100.0	100.0	0.69

Brownsburg

Annual Stormwater Benefits of Public Trees by Species

11/14/2011

Species	Total rainfall interception (Gal)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Boxelder	38,817,903	240,688	(±211,734)	18.2	11.9	8.27
Green ash	45,341,193	281,135	(±179,046)	12.5	13.8	14.04
Northern hackberry	33,478,864	207,583	(±152,562)	9.3	10.2	13.95
Black walnut	33,311,324	206,545	(±160,486)	8.5	10.2	15.14
Sugar maple	15,677,038	97,204	(±59,403)	6.1	4.8	9.97
Eastern cottonwood	25,971,245	161,033	(±138,152)	2.9	7.9	34.30
Black cherry	10,117,374	62,732	(±35,314)	2.9	3.1	13.43
Silver maple	24,037,228	149,041	(±55,573)	2.9	7.3	32.05
Norway spruce	5,856,615	36,314	(±15,533)	2.7	1.8	8.33
Elm	5,227,017	32,410	(±24,544)	2.4	1.6	8.37
Black locust	7,082,324	43,913	(±32,807)	2.4	2.2	11.61
Red mulberry	9,033,797	56,013	(±22,134)	2.1	2.8	16.45
Blue spruce	3,633,130	22,527	(±7,825)	2.1	1.1	6.70
American sycamore	11,699,279	72,541	(±52,327)	1.9	3.6	23.29
Unknown	3,191,281	19,787	(±13,664)	1.9	1.0	6.40
Eastern white pine	5,043,341	31,271	(±17,851)	1.8	1.5	10.65
Slippery elm	3,460,123	21,454	(±18,862)	1.7	1.1	7.78
Tulip tree	5,778,785	35,831	(±30,005)	1.6	1.8	14.13
Red maple	3,674,121	22,781	(±10,212)	1.5	1.1	9.22
Honeylocust	6,812,197	42,239	(±16,696)	1.5	2.1	17.74
Plum	1,318,462	8,175	(±4,162)	1.3	0.4	3.91
Bitternut hickory	3,203,401	19,862	(±18,716)	1.3	1.0	9.92
American elm	2,958,638	18,345	(±11,798)	1.1	0.9	10.31
OTHER STREET TREES	22,885,196	141,898	(±44,345)	9.3	7.0	9.50
Citywide total	327,609,876	2,031,322	(±1,182,644	100.0	100.0	12.67

Brownsburg

Annual Energy Benefits of Public Trees By Species

11/11/2011

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Boxelder	943.5	64,157	31,512.9	30,662	94,819	(±83,413)	18.2	15.1	3.26
Green ash	1,157.0	78,679	32,041.9	31,177	109,856	(±69,964)	12.5	17.5	5.49
Northern hackberry	655.3	44,562	10,806.3	10,515	55,077	(±40,478)	9.3	8.8	3.70
Black walnut	891.4	60,613	-11,839.8	-11,520	49,093	(±38,145)	8.5	7.8	3.60
Sugar maple	328.8	22,360	10,846.2	10,553	32,913	(±20,114)	6.1	5.2	3.38
Eastern cottonwood	440.7	29,964	15,279.6	14,867	44,831	(±38,461)	2.9	7.1	9.55
Black cherry	258.1	17,551	7,100.0	6,908	24,459	(±13,769)	2.9	3.9	5.23
Silver maple	434.0	29,513	13,269.9	12,912	42,424	(±15,819)	2.9	6.8	9.12
Norway spruce	79.3	5,393	-1,559.2	-1,517	3,876	(±1,658)	2.7	0.6	0.89
Elm	98.1	6,673	-288.7	-281	6,392	(±4,840)	2.4	1.0	1.65
Black locust	186.9	12,712	4,928.8	4,796	17,507	(±13,079)	2.4	2.8	4.63
Red mulberry	160.6	10,919	4,461.5	4,341	15,260	(±6,030)	2.1	2.4	4.48
Blue spruce	48.3	3,282	-877.4	-854	2,429	(±844)	2.1	0.4	0.72
American sycamore	275.7	18,749	8,343.4	8,118	26,868	(±19,381)	1.9	4.3	8.63
Unknown	80.1	5,443	1,620.9	1,577	7,021	(±4,848)	1.9	1.1	2.27
Eastern white pine	78.6	5,343	-2,386.0	-2,322	3,021	(±1,725)	1.8	0.5	1.03
Slippery elm	64.6	4,390	-325.5	-317	4,073	(±3,581)	1.7	0.7	1.48
Tulip tree	152.1	10,344	4,157.1	4,045	14,389	(±12,049)	1.6	2.3	5.67
Red maple	78.4	5,332	2,721.1	2,648	7,980	(±3,577)	1.5	1.3	3.23
Honeylocust	166.5	11,322	-870.6	-847	10,474	(±4,140)	1.5	1.7	4.40
Plum	31.4	2,134	-133.7	-130	2,004	(±1,020)	1.3	0.3	0.96
Bitternut hickory	87.9	5,976	2,218.6	2,159	8,134	(±7,665)	1.3	1.3	4.06
American elm	55.6	3,781	171.6	167	3,948	(±2,539)	1.1	0.6	2.22
OTHER STREET TREES	486.0	33,049	7,854.7	7,643	40,692	(±12,717)	9.3	6.5	2.73
Citywide total	7,238.8	492,240	139,053.4	135,299	627,539	(±365,356)	100.0	100.0	3.92

Brownsburg

Replacement Value for Public Trees by Species

11/11/2011

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error	% of Total
Boxelder	439,442	4,812,704	6,246,609	2,492,303	647,027	184,392	0	384,028	0	15,206,505	(±13,377,201)	11.33
Green ash	140,576	1,554,250	3,670,696	5,739,374	3,377,018	2,381,883	840,959	384,028	296,255	18,385,038	(±11,708,865)	13.70
Northern hackberry	132,221	2,053,952	4,303,034	3,296,339	1,914,902	1,373,237	667,257	183,734	0	13,924,677	(±10,233,830)	10.38
Black walnut	49,400	533,426	2,949,437	7,132,278	4,139,361	1,540,398	349,751	161,735	187,340	17,043,127	(±13,242,548)	12.70
Sugar maple	191,449	2,152,338	2,340,601	1,273,717	810,512	491,316	143,159	0	0	7,403,092	(±4,524,159)	5.52
Eastern cottonwood	19,429	71,251	142,062	804,799	2,204,052	3,284,832	2,522,877	2,157,332	461,809	11,668,443	(±10,010,502)	8.70
Black cherry	32,178	367,885	791,022	686,807	763,812	137,428	206,243	93,440	215,620	3,294,435	(±1,854,528)	2.46
Silver maple	59,676	39,199	209,870	682,252	1,684,303	1,396,945	1,924,930	1,308,158	1,385,676	8,691,010	(±3,240,609)	6.48
Norway spruce	127,136	401,030	336,630	909,675	750,399	233,669	0	0	0	2,758,541	(±1,179,986)	2.06
Elm	0	687,754	614,893	183,344	26,770	0	0	0	0	1,512,762	(±1,145,599)	1.13
Black locust	33,539	333,577	527,571	739,339	351,165	0	0	0	0	1,985,192	(±1,483,102)	1.48
Red mulberry	169,090	366,972	659,172	523,366	389,509	160,104	151,631	102,753	0	2,522,598	(±996,806)	1.88
Blue spruce	185,572	297,406	252,079	287,429	635,704	0	68,414	0	0	1,726,603	(±599,793)	1.29
American sycamore	17,733	155,534	227,145	741,645	915,107	1,240,829	393,543	775,072	255,938	4,722,546	(±3,406,581)	3.52
Unknown	3,321	125,512	203,991	190,707	18,262	0	0	0	0	541,793	(±374,132)	0.40
Eastern white pine	81,919	249,148	551,477	237,835	92,105	0	0	0	0	1,212,484	(±692,164)	0.90
Slippery elm	6,862	472,794	483,837	23,910	0	0	0	0	0	987,403	(±868,082)	0.74
Tulip tree	0	136,772	543,647	1,284,981	279,146	145,726	0	0	0	2,390,272	(±2,001,616)	1.78
Red maple	210,453	401,431	266,570	79,802	136,370	352,990	306,074	139,737	161,684	2,055,111	(±921,228)	1.53
Honeylocust	25,906	207,699	384,470	731,180	176,128	144,472	93,440	0	0	1,763,296	(±696,987)	1.31
Plum	186,834	306,554	213,454	50,680	26,770	0	0	0	0	784,294	(±399,246)	0.58
Bitternut hickory	0	198,851	536,680	510,325	41,586	0	0	0	0	1,287,442	(±1,213,145)	0.96
American elm	32,382	299,673	317,573	145,807	207,929	0	93,440	0	0	1,096,805	(±705,378)	0.82
Callery pear	7,155	191,989	575,230	133,003	0	0	0	0	0	907,377	(±394,152)	0.68
Eastern redbud	74,963	142,908	375,728	368,680	115,526	98,263	0	0	0	1,176,069	(±534,941)	0.88
Apple	194,089	203,708	244,942	96,128	0	0	0	0	0	738,867	(±347,538)	0.55
Mulberry	0	235,833	322,152	106,480	0	53,368	0	0	0	717,833	(±637,339)	0.54
Pine	0	24,486	360,692	132,603	0	41,476	59,435	0	0	618,692	(±375,399)	0.46
Ash	0	44,043	218,307	531,125	0	0	0	0	0	793,475	(±375,105)	0.59
Hawthorn	90,786	140,187	71,730	0	0	0	0	0	0	302,703	(±170,879)	0.23
Ohio buckeye	0	146,821	101,344	134,906	0	0	0	0	0	383,071	(±249,716)	0.29
Northern red oak	15,472	98,145	97,977	96,128	0	0	126,323	0	0	434,046	(±155,201)	0.32
Eastern serviceberry	25,906	79,168	89,447	0	0	0	0	0	0	194,520	(±132,452)	0.14
Northern catalpa	6,708	0	83,684	67,574	0	39,940	56,401	76,155	0	330,462	(±214,545)	0.25
Shagbark hickory	32,382	47,501	63,890	0	0	0	0	0	0	143,773	(±131,217)	0.11
Pin oak	0	9,700	16,329	64,086	166,838	261,118	505,291	0	401,794	1,425,157	(±816,580)	1.06

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error	% of Total
White oak	22,893	47,927	34,904	0	0	98,263	143,159	394,066	0	741,211	(±373,104)	0.55
Eastern hophornbeam	0	69,130	87,259	0	0	0	0	0	0	156,390	(±152,835)	0.12
American basswood	7,057	44,452	15,078	29,743	51,742	81,074	0	0	0	229,146	(±158,059)	0.17
Flowering dogwood	23,209	45,649	16,329	0	0	0	0	0	0	85,187	(±41,274)	0.06
Eastern red cedar	5,050	22,819	14,665	13,152	0	31,484	0	0	0	87,170	(±44,488)	0.06
Sweetgum	0	0	25,556	72,904	83,172	64,632	93,440	0	0	339,704	(±197,393)	0.25
Osage orange	0	15,576	34,107	0	146,590	0	0	0	0	196,273	(±130,274)	0.15
White mulberry	8,052	64,220	12,962	0	0	0	0	0	0	85,234	(±83,297)	0.06
Cherry plum	22,893	39,503	34,904	0	0	0	0	0	0	97,300	(±95,088)	0.07
Dogwood	46,417	19,401	0	0	0	0	0	0	0	65,818	(±56,125)	0.05
Willow	0	33,401	11,621	0	0	46,504	0	89,140	0	180,666	(±101,747)	0.13
Fir	4,408	18,645	9,750	15,465	0	0	0	0	0	48,268	(±31,802)	0.04
Northern white cedar	29,121	0	0	0	0	0	0	0	0	29,121	(±28,459)	0.02
River birch	0	7,917	38,334	0	41,586	0	0	0	0	87,837	(±69,255)	0.07
Pear	15,683	9,525	15,207	28,676	0	0	0	0	0	69,091	(±54,475)	0.05
Norway maple	7,155	7,443	28,060	0	0	0	0	0	0	42,659	(±23,516)	0.03
American beech	0	18,108	16,125	32,886	0	0	0	0	0	67,119	(±50,422)	0.05
Black willow	0	0	30,155	29,743	0	81,074	0	0	0	140,972	(±77,711)	0.11
Baldcypress	22,577	10,051	0	0	0	0	0	0	0	32,629	(±31,887)	0.02
Paper birch	6,708	15,062	0	0	0	0	0	0	0	21,770	(±21,275)	0.02
Ponderosa pine	0	0	0	56,850	0	0	0	0	0	56,850	(±39,876)	0.04
Black maple	0	0	32,659	0	0	0	0	0	0	32,659	(±31,917)	0.02
Hickory species	0	9,174	12,962	0	0	0	0	0	0	22,137	(±14,585)	0.02
Black tupelo	6,959	9,054	0	0	0	0	0	0	0	16,013	(±15,649)	0.01
Spruce	0	12,430	0	0	0	0	0	0	0	12,430	(±12,147)	0.01
Pawpaw	6,631	0	0	0	0	0	0	0	0	6,631	(±6,480)	0.00
American hornbeam	0	7,788	0	0	0	0	0	0	0	7,788	(±7,611)	0.01
Ginkgo	7,526	0	0	0	0	0	0	0	0	7,526	(±7,355)	0.01
Pyramid magnolia	0	0	15,078	0	0	0	0	0	0	15,078	(±14,735)	0.01
Bur oak	0	10,051	0	0	0	0	0	0	0	10,051	(±9,823)	0.01
Chinkapin oak	0	0	0	35,410	0	0	0	0	0	35,410	(±34,605)	0.03
Citywide total	2,834,922	18,127,531	29,879,688	30,793,438	20,193,394	13,965,418	8,745,766	6,249,377	3,366,116	134,155,650	(±78,105,952)	100.00

Brownsburg

Annual Aesthetic/Other Benefits of Public Trees by Species

11/11/2011

Species	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Boxelder	985,470	(±866,920)	18.2	17.2	33.86
Green ash	689,332	(±439,015)	12.5	12.0	34.42
Northern hackberry	876,464	(±644,150)	9.3	15.3	58.88
Black walnut	457,964	(±355,839)	8.5	8.0	33.58
Sugar maple	352,780	(±215,590)	6.1	6.2	36.20
Eastern cottonwood	223,484	(±191,729)	2.9	3.9	47.60
Black cherry	157,842	(±88,854)	2.9	2.8	33.78
Silver maple	142,143	(±53,001)	2.9	2.5	30.57
Norway spruce	71,176	(±30,446)	2.7	1.2	16.32
Elm	235,360	(±178,236)	2.4	4.1	60.79
Black locust	131,985	(±98,604)	2.4	2.3	34.89
Red mulberry	150,063	(±59,297)	2.1	2.6	44.08
Blue spruce	57,303	(±19,906)	2.1	1.0	17.06
American sycamore	94,814	(±68,394)	1.9	1.7	30.44
Unknown	58,905	(±40,676)	1.9	1.0	19.05
Eastern white pine	58,776	(±33,553)	1.8	1.0	20.01
Slippery elm	168,645	(±148,265)	1.7	3.0	61.13
Tulip tree	95,810	(±80,232)	1.6	1.7	37.77
Red maple	66,102	(±29,631)	1.5	1.2	26.76
Honeylocust	87,185	(±34,462)	1.5	1.5	36.62
Plum	31,725	(±16,150)	1.3	0.6	15.17
Bitternut hickory	71,157	(±67,051)	1.3	1.2	35.53
American elm	105,329	(±67,739)	1.1	1.8	59.17
OTHER STREET TREES	355,229	(±111,013)	9.3	6.2	23.79
Citywide total	5,725,043	(±3,333,143)	100.0	100.0	35.72

Appendix B

USDA Tree Pruning Guide

NA-FR-01-95

USDA Forest Service

Northeastern Area State and Private Forestry

HOW to Prune Trees

Peter J. Bedker, Joseph G. O'Brien, and Manfred M. Mielke
Illustrations by Julie Martinez, Afton, MN

Introduction

The objective of pruning is to produce strong, healthy, attractive plants. By understanding how, when and why to prune, and by following a few simple principles, this objective can be achieved.

Why Prune

The main reasons for pruning ornamental and shade trees include safety, health, and aesthetics. In addition, pruning can be used to stimulate fruit production and increase the value of timber. Pruning for *safety* (Fig. 1A) involves removing branches that could fall and cause injury or property damage, trimming branches that interfere with lines of sight on streets or driveways, and removing branches that grow into utility lines. Safety pruning can be largely avoided by carefully choosing species that will not grow beyond the space available to them, and have strength and form characteristics that are suited to the site.

Pruning for *health* (Fig. 1B) involves removing diseased or insect-infested wood, thinning the crown to increase airflow and reduce some pest problems, and removing

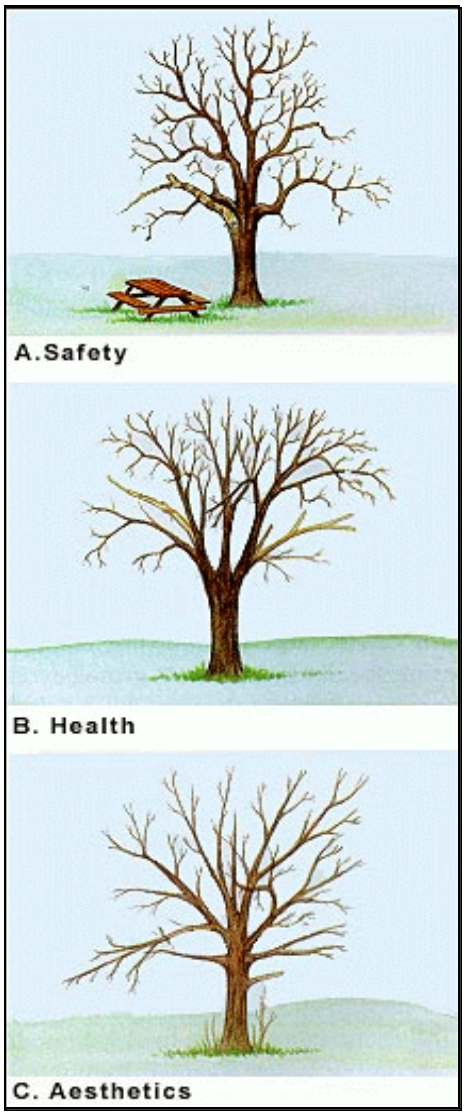


Figure 1. Reasons for pruning.

crossing and rubbing branches. Pruning can best be used to encourage trees to develop a strong structure and reduce the likelihood of damage during severe weather. Removing broken or damaged limbs encourage wound closure.

Pruning for *aesthetics* (Fig. 1C) involves enhancing the natural form and character of trees or stimulating flower production. Pruning for form can be especially important on open-grown trees that do very little self-pruning.

All woody plants shed branches in response to shading and competition. Branches that do not produce enough carbohydrates from photosynthesis to sustain themselves die and are eventually shed; the resulting wounds are sealed by **woundwood** (callus). Branches that are poorly attached may be broken off by wind and accumulation of snow and ice. Branches removed by such natural forces often result in large, ragged wounds that rarely seal. Pruning as a cultural practice can be used to supplement or replace these natural processes and increase the strength and longevity of plants.

Trees have many forms, but the most common types are pyramidal **(excurrent)** or spherical (**decurrent)**. Trees with pyramidal crowns, e.g., most conifers, have a strong central stem and lateral branches that are more or less horizontal and do not compete with the central stem for dominance. Trees with spherical crowns, e.g., most hardwoods, have many lateral branches that may compete for dominance.

To reduce the need for pruning it is best to consider a tree's natural form. It is very difficult to impose an unnatural form on a tree without a commitment to constant maintenance.

Pollarding and **topiary** are extreme examples of pruning to create a desired, unnatural effect. Pollarding is the practice of pruning trees annually to remove all new growth. The following year, a profusion of new branches is produced at the ends of the branches. Topiary involves pruning trees and shrubs into geometric or animal shapes. Both pollarding and topiary are specialized applications that involve pruning to change the natural form of trees. As topiary demonstrates, given enough care and attention plants can be pruned into nearly any form. Yet just as proper pruning can enhance the form or character of plants, improper pruning can destroy it.

Pruning Approaches

Producing strong structure should be the emphasis when pruning young trees. As trees mature, the aim of pruning will shift to maintaining tree structure, form, health and appearance.

Proper pruning cuts are made at a node, the point at which one branch or twig attaches to another. In the spring of the year growth begins at buds, and twigs grow until a new node is formed. The length of a branch between nodes is called an internode.

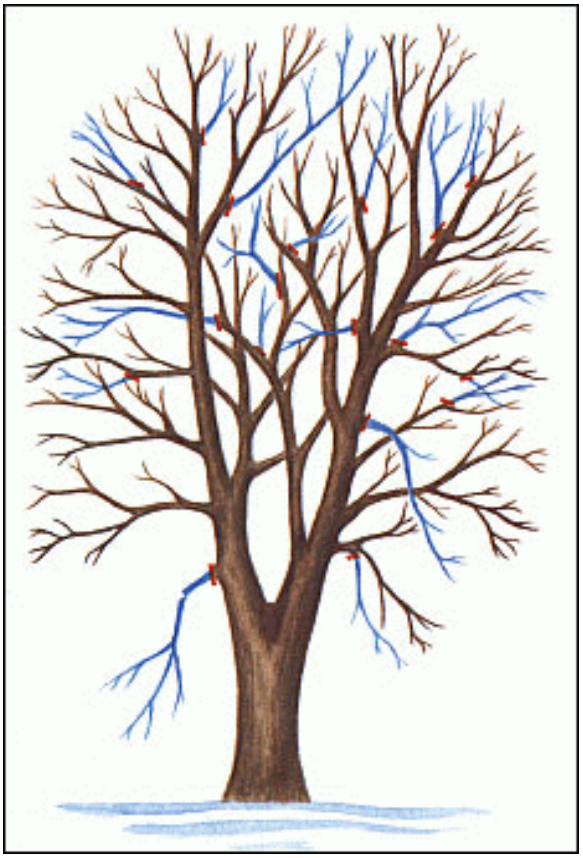


Figure 2. Crown thinning - branches to be removed are shaded in blue; pruning cuts should be made at the red lines. No more than one-fourth of the living branches should be removed at one time.

The most common types of pruning are:

1. *Crown Thinning* (Fig. 2)

Crown thinning, primarily for hardwoods, is the selective removal of branches to increase light penetration and air movement throughout the crown of a tree. The intent is to maintain or develop a tree's structure and form. To avoid unnecessary stress and prevent excessive production of epicormic sprouts, no more than one-quarter of the living crown should be removed at a time. If it is necessary to remove more, it should be done over successive years.

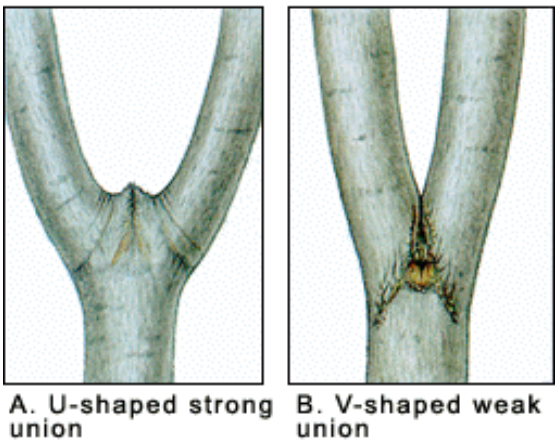


Figure 3. Types of branch unions.

Branches with strong U-shaped angles of attachment should be retained (Fig 3A). Branches with narrow, V-shaped angles of attachment often form **included bark** and should be removed (Fig. 3B). Included bark forms when two branches grow at sharply acute angles to one another, producing a wedge of inward-rolled bark between them. Included bark prevents strong attachment of branches, often causing a crack at the point below where the branches meet. Codominant stems that are approximately the same size and arise from the same position often form included bark. Removing some of the lateral branches from a codominant stem can reduce its growth enough to allow the other stem to become dominant.

Lateral branches should be no more than one-half to three-quarters of the diameter of the stem at the point of attachment. Avoid producing "lion's tails," tufts of branches and foliage at the ends of branches, caused by removing all inner lateral branches and foliage. Lion's tails can result in sunscalding, abundant **epicormic sprouts**, and weak branch structure and breakage. Branches that rub or cross

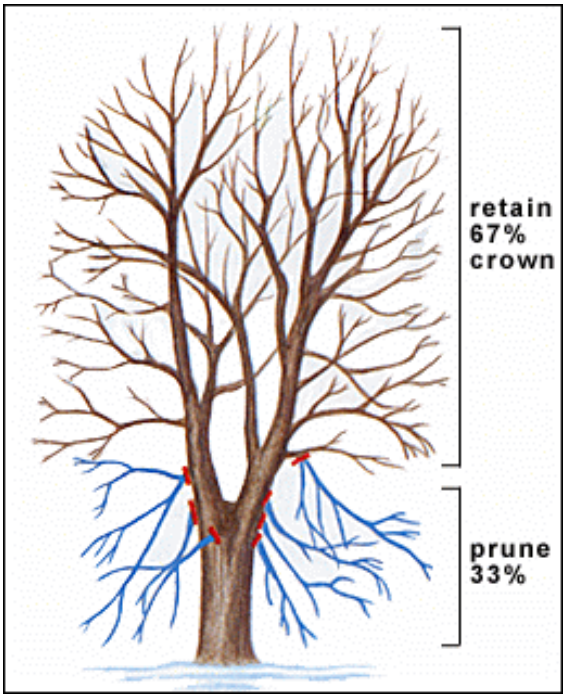


Figure 4. Crown raising - branches to be removed are shaded in blue; pruning cuts should be made where indicated with red lines. The ratio of live crown to total tree height should be at least two-thirds.

another branch should be removed.

Conifers that have branches in whorls and pyramidal crowns rarely need crown thinning except to restore a dominant leader. Occasionally, the leader of a tree may be damaged and multiple branches may become codominant. Select the strongest leader and remove competing branches to prevent the development of codominant stems.

2. *Crown Raising* (Fig. 4)

Crown raising is the practice of removing branches from the bottom of the crown of a tree to provide clearance for pedestrians, vehicles, buildings, lines of site, or to develop a clear stem for timber production. Also, removing lower branches on white pines can prevent blister rust. For street trees the minimum clearance is often specified by municipal ordinance. After pruning, the ratio of the living crown to total tree height should be at least two-thirds (e.g., a 12 m tree should have living branches on at least the upper 8 m).

On young trees "temporary" branches may be retained along the stem to encourage taper and protect trees from vandalism and sun scald. Less vigorous shoots should be selected as temporary branches and should be about 10 to 15 cm apart along the stem. They should be pruned annually to slow their growth and should be removed eventually.

3. *Crown Reduction* (Fig. 5)

Crown reduction pruning is most often used when a tree has grown too large for its permitted space. This method, sometimes called **drop crotch pruning**, is preferred to topping because it results in a more natural appearance, increases the time before pruning is needed again, and minimizes stress (see drop crotch cuts in the next section).

Crown reduction pruning, a method of last resort, often results in large pruning wounds to stems that may lead to decay. This method should never be used on a tree with a pyramidal growth form. A better long term solution is to remove the tree and replace it

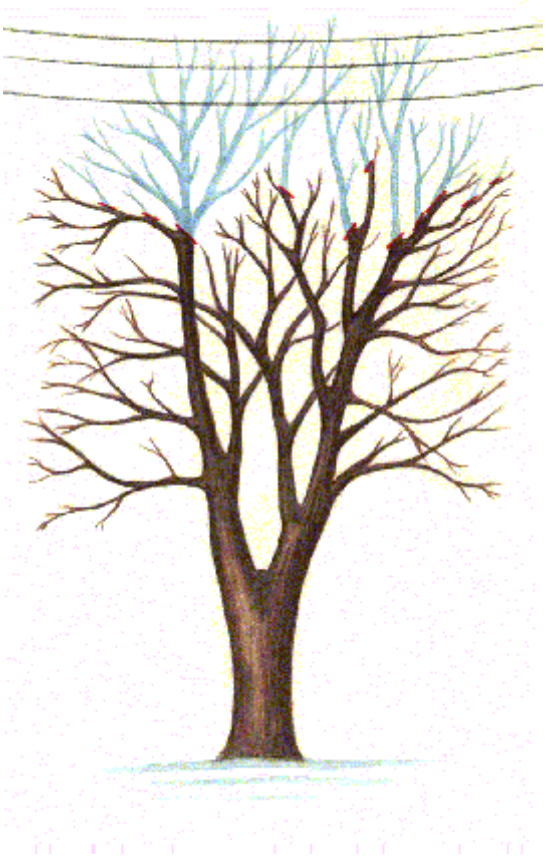


Figure 5. Crown reduction - branches to be removed are shaded in blue; pruning cuts should be made where indicated with red lines. To prevent branch dieback, cuts should be made at lateral branches that are at least one-third the diameter of the stem at their union.

with a tree that will not grow beyond the available space.

Pruning Cuts

Pruning cuts should be made so that only branch tissue is removed and stem tissue is not damaged. At the point where the branch attaches to the stem, branch and stem tissues remain separate, but are contiguous. If only branch tissues are cut when pruning, the stem tissues of the tree will probably not become decayed, and the wound will seal more effectively.

1. *Pruning living branches* (Fig. 6)

To find the proper place to cut a branch, look for the **branch collar** that grows from the stem tissue at the underside of the base of the branch (Fig. 6A). On the upper surface, there is usually a **branch bark ridge** that runs (more or less) parallel to the branch angle, along the stem of the tree. A proper pruning cut does not damage either the branch bark ridge or the branch collar.

A proper cut begins just outside the branch bark ridge and angles down away from the stem of the tree, avoiding injury to the branch collar (Fig. 6B). Make the cut as close as possible to the stem in the **branch axil**, but outside the branch bark ridge, so that stem tissue is not injured and the wound can seal in the shortest time possible. If the cut is too far from the stem, leaving a branch stub, the branch tissue usually dies and woundwood forms from the stem tissue. Wound closure is delayed because the woundwood must seal over the stub that was left.

The quality of pruning cuts can be evaluated by examining pruning wounds after one growing season. A concentric ring of woundwood will form from proper pruning cuts (Fig. 6B).
Flush cuts made inside the branch bark ridge or branch collar, result in pronounced development of woundwood on the sides of the pruning wounds with very little woundwood forming on the top or bottom (Fig. 7D). As described above, stub cuts result in the death of the remaining branch and woundwood forms around the base from stem tissues.
When pruning small branches with hand pruners, make sure the tools are sharp enough

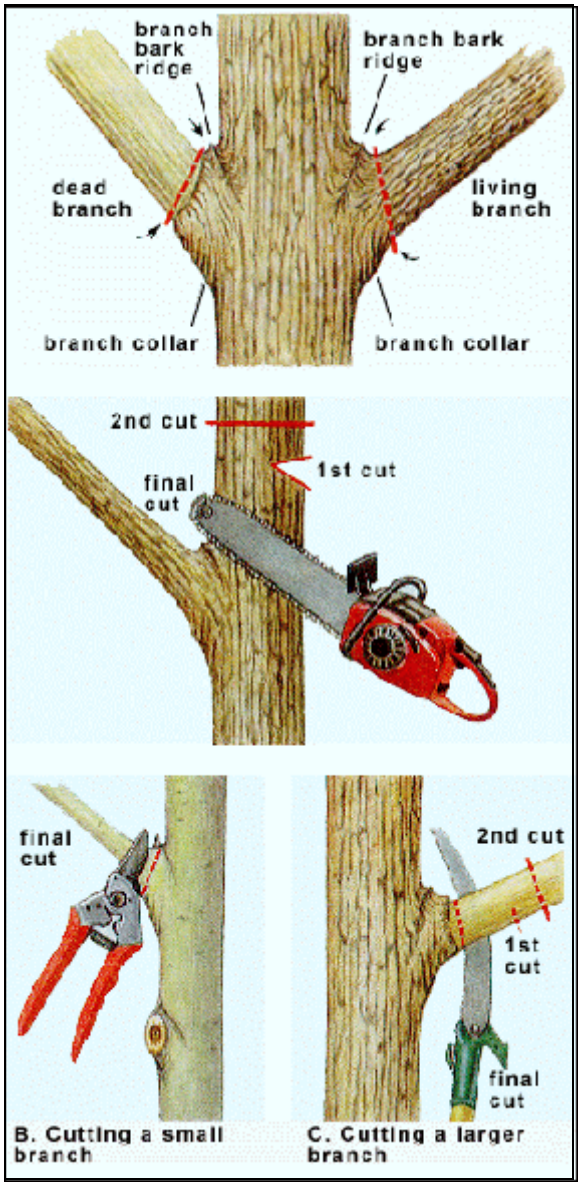


Figure 6. Pruning cuts

to cut the branches cleanly without tearing. Branches large enough to require saws should be supported with one hand while the cuts are made. If the branch is too large to support, make a three-step pruning cut to prevent bark ripping (Fig. 6C).

1. The first cut is a shallow notch made on the underside of the branch, outside the branch collar. This cut will prevent a falling branch from tearing the stem tissue as it pulls away from the tree.
2. The second cut should be outside the first cut, all the way through the branch, leaving a short stub.
3. The stub is then cut just outside the branch bark ridge/branch collar, completing the operation.

2. *Pruning dead branches* (Fig. 6)

Prune dead branches in much the same way as live branches. Making the correct cut is usually easy because the branch collar and the branch bark ridge, can be distinguished from the dead branch, because they continue to grow (Fig. 6A). Make the pruning cut just outside of the ring of woundwood tissue that has formed, being careful not to cause unnecessary injury (Fig. 6C). Large dead branches should be supported with one hand or cut with the three-step method, just as live branches. Cutting large living branches with the three step method is more critical because of the greater likelihood of bark ripping.

3. *Drop Crotch Cuts* (Fig. 6D)

A proper cut begins just above the branch bark ridge and extends through the stem parallel to the branch bark ridge. Usually, the stem being removed is too large to be supported with one hand, so the three cut method should be used.

1. With the first cut, make a notch on the side of the stem away from the branch to be retained, well above the branch crotch.

2. Begin the second cut inside the branch crotch, staying well above the branch bark ridge, and cut through the stem above the notch.
3. Cut the remaining stub just inside the branch bark ridge through the stem parallel to the branch bark ridge.

To prevent the abundant growth of epicormic sprouts on the stem below the cut, or dieback of the stem to a lower lateral branch, make the cut at a lateral branch that is at least one-third of the diameter of the stem at their union.

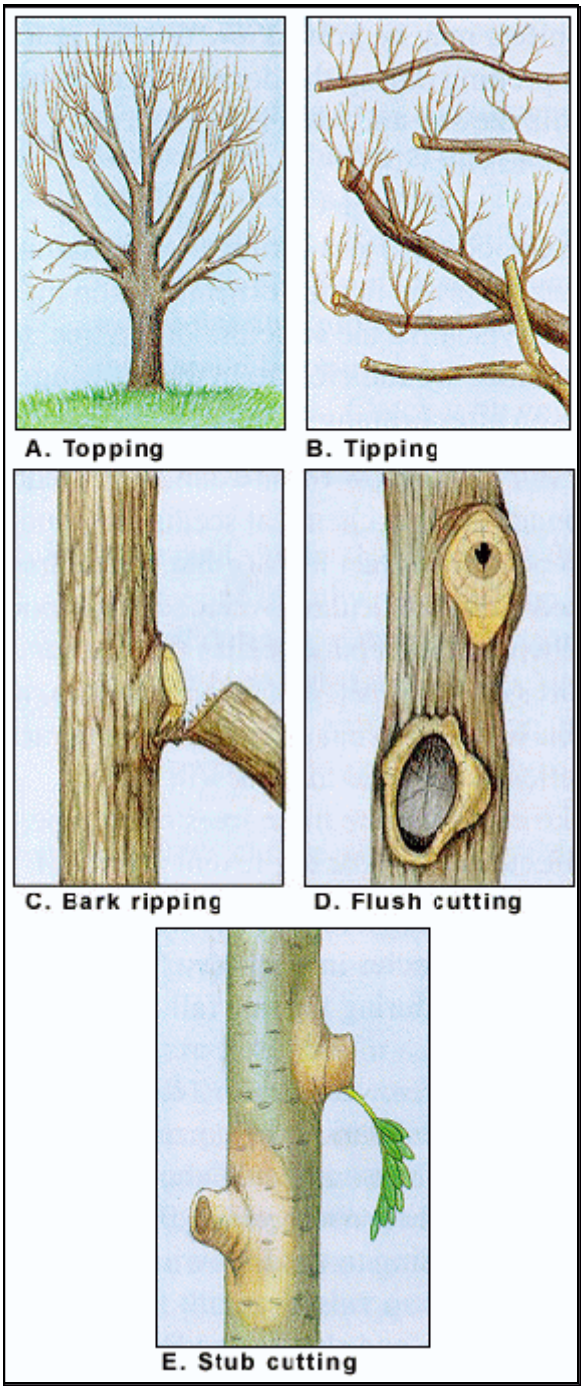
Pruning Practices That Harm Trees

Topping and **tipping** (Fig. 7A, 7B) are pruning practices that harm trees and should not be used. Crown reduction pruning is the preferred method to reduce the size or height of the crown of a tree, but is rarely needed and should be used infrequently.

Topping, the pruning of large upright branches between nodes, is sometimes done to reduce the height of a tree (Fig. 7A). Tipping is a practice of cutting lateral branches between nodes (Fig. 7B) to reduce crown width.

These practices invariably result in the development of epicormic sprouts, or in the death of the cut branch back to the next lateral branch below. These epicormic sprouts are weakly attached to the stem and eventually will be supported by a decaying branch.

Improper pruning cuts cause unnecessary injury and bark ripping (Fig. 7C). Flush cuts injure stem tissues and can result in decay (Fig. 7D). **Stub cuts** delay wound closure and can provide entry to canker fungi that kill the cambium, delaying or preventing woundwood formation (Fig. 7E).



When to Prune

Conifers may be pruned any time of year, but pruning during the dormant season may minimize sap and resin flow from cut branches.

Hardwood trees and shrubs *without showy flowers*: prune in the dormant season to easily visualize the structure of the tree, to maximize wound closure in the growing season after pruning, to reduce the chance of transmitting disease, and to discourage excessive sap flow from wounds. Recent wounds and the chemical scents they emit can actually attract insects that spread tree disease. In particular, wounded elm wood is known to attract bark beetles that harbor spores of the Dutch elm disease fungus, and open wounds on oaks are known to attract beetles that spread the oak wilt fungus. Take care to prune these trees during the correct time of year to prevent spread of these fatal diseases. Contact your local tree disease specialist to find out when to prune these tree species in your area. Usually, the best time is during the late fall and winter.

Flowering trees and shrubs: these should also be pruned during the dormant season for the same reasons stated above; however, to preserve the current year's flower crop, prune according to the following schedule:

- Trees and shrubs that flower in early spring (redbud, dogwood, etc.) should be pruned immediately after flowering (flower buds arise the year before they flush, and will form on the new growth).
- Many flowering trees are susceptible to fireblight, a bacterial disease that can be spread by pruning. These trees, including many varieties of crabapple, hawthorn, pear, mountain ash, flowering quince and pyracantha, should be pruned during the dormant season. Check with your county extension agent or a horticulturist for additional information.
- Trees and shrubs that flower in the summer or fall always should be pruned during the dormant season (flower buds will form on new twigs during the next growing season, and the flowers will flush normally).

Dead branches: can be removed any time of the year.

Pruning Tools

Proper tools are essential for satisfactory pruning (Fig.6). The choice of which tool to use depends largely on the size of branches to be pruned and the amount of pruning to be done. If possible, test a tool before you buy it to ensure it suits your specific needs. As with most things, higher quality often equates to higher cost.

Generally speaking, the smaller a branch is when pruned, the sooner the wound created will seal. Hand pruners are used to prune small branches (under 2.5 cm diameter) and many different kinds are available. Hand pruners can be grouped into by-pass or anvil styles based on the blade configuration. Anvil style pruners have a straight blade that cuts the branch against a small anvil or block as the handles are squeezed. By-pass pruners use a curved cutting blade that slides past a broader lower blade, much like a scissors. To prevent unnecessary tearing or crushing of tissues, it is best to use a

by-pass style pruner. Left- or right-handed types can be purchased.

Slightly larger branches that cannot be cut with a hand pruner may be cut with small pruning saws (up to 10 cm) or lopping shears (up to 7 cm diameter) with larger cutting surfaces and greater leverage. Lopping shears are also available in by-pass and anvil styles.

For branches too large to be cut with a hand pruner or lopping shears, pruning saws must be used. Pruning saws differ greatly in handle styles, the length and shape of the blade, and the layout and type of teeth. Most have tempered metal blades that retain their sharpness for many pruning cuts. Unlike most other saws, pruning saws are often designed to cut on the "pull-stroke."

Chain saws are preferred when pruning branches larger than about 10 cm. Chainsaws should be used only by qualified individuals. To avoid the need to cut branches greater than 10 cm diameter, prune when branches are small.

Pole pruners must be used to cut branches beyond reach. Generally, pruning heads can cut branches up to 4.4 cm diameter and are available in the by-pass and anvil styles. Once again, the by-pass type is preferred. For cutting larger branches, saw blades can be fastened directly to the pruning head, or a separate saw head can be purchased. Because of the danger of electrocution, pole pruners should not be used near utility lines except by qualified utility line clearance personnel.

To ensure that satisfactory cuts are made and to reduce fatigue, keep your pruning tools sharp and in good working condition. Hand pruners, lopping shears, and pole pruners should be periodically sharpened with a sharpening stone. Replacement blades are available for many styles. Pruning saws should be professionally sharpened or periodically replaced. To reduce cost, many styles have replaceable blades.

Tools should be clean and sanitized as well as sharp. Although sanitizing tools may be inconvenient and seldom practiced, doing so may prevent the spread of disease from infected to healthy trees on contaminated tools. Tools become contaminated when they come into contact with fungi, bacteria, viruses and other microorganisms that cause disease in trees. Most pathogens need some way of entering the tree to cause disease, and fresh wounds are perfect places for infections to begin. Microorganisms on tool surfaces are easily introduced into susceptible trees when subsequent cuts are made. The need for sanitizing tools can be greatly reduced by pruning during the dormant season.

If sanitizing is necessary it should be practiced as follows: Before each branch is cut, sanitize pruning tools with either 70% denatured alcohol, or with liquid household bleach diluted 1 to 9 with water (1 part bleach, 9 parts water). Tools should be immersed in the solution, preferably for 1-2 minutes, and wood particles should be wiped from all cutting surfaces. Bleach is corrosive to metal surfaces, so tools should be thoroughly cleaned with soap and water after each use.

Treating wounds

Tree sap, gums, and resins are the natural means by which trees combat invasion by pathogens. Although unsightly, sap flow from pruning wounds is not generally harmful; however, excessive "bleeding" can weaken trees.

When oaks or elms are wounded during a critical time of year (usually spring for oaks, or throughout the growing season for elms) -- either from storms, other unforeseen mechanical wounds, or from necessary branch removals -- some type of wound dressing should be applied to the wound. Do this immediately after the wound is created. In most other instances, wound dressings are unnecessary, and may even be detrimental. Wound dressings will not stop decay or cure infectious diseases. They may actually interfere with the protective benefits of tree gums and resins, and prevent wound surfaces from closing as quickly as they might under natural conditions. The only benefit of wound dressings is to prevent introduction of pathogens in the specific cases of Dutch elm disease and oak wilt.

Pruning Guidelines

To encourage the development of a strong, healthy tree, consider the following guidelines when pruning.

General

- ? Prune first for safety, next for health, and finally for aesthetics.
- ? Never prune trees that are touching or near utility lines; instead consult your local utility company.
- ? Avoid pruning trees when you might increase susceptibility to important pests (e.g. in areas where oak wilt exists, avoid pruning oaks in the spring and early summer; prune trees susceptible to fireblight only during the dormant season).
- ? Use the following decision guide for size of branches to be removed: 1) under 5 cm diameter - go ahead, 2) between 5 and 10 cm diameter - think twice, and 3) greater than 10 cm diameter - have a good reason.

Crown Thinning

- ? Assess how a tree will be pruned from the top down.
- ? Favor branches with strong, U-shaped angles of attachment. Remove branches with weak, V-shaped angles of attachment and/or included bark.
- ? Ideally, lateral branches should be evenly spaced on the main stem of young trees.
- ? Remove any branches that rub or cross another branch.
- ? Make sure that lateral branches are no more than one-half to three-quarters of the diameter of the stem to discourage the development of co-dominant stems.

? Do not remove more than one-quarter of the living crown of a tree at one time. If it is necessary to remove more, do it over successive years.

Crown Raising

? Always maintain live branches on at least two-thirds of a tree's total height. Removing too many lower branches will hinder the development of a strong stem.

? Remove basal sprouts and vigorous epicormic sprouts.

Crown Reduction

? Use crown reduction pruning only when absolutely necessary. Make the pruning cut at a lateral branch that is at least one-third the diameter of the stem to be removed.

? If it is necessary to remove more than half of the foliage from a branch, remove the entire branch.

Glossary

Branch Axil: the angle formed where a branch joins another branch or stem of a woody plant.

Branch Bark Ridge: a ridge of bark that forms in a branch crotch and partially around the stem resulting from the growth of the stem and branch tissues against one another.

Branch Collar: a "shoulder" or bulge formed at the base of a branch by the annual production of overlapping layers of branch and stem tissues.

Crown Raising: a method of pruning to provide clearance for pedestrians, vehicles, buildings, lines of sight, and vistas by removing lower branches.

Crown Reduction Pruning: a method of pruning used to reduce the height of a tree. Branches are cut back to laterals that are at least one-third the diameter of the limb being removed.

Crown Thinning: a method of pruning to increase light penetration and air movement through the crown of a tree by selective removal of branches.

Callus: see woundwood.

Decurrent: a major tree form resulting from weak apical control. Trees with this form have several to many lateral branches that compete with the central stem for dominance resulting in a spherical or globose crown. Most hardwood trees have decurrent forms.

Epicormic Sprout: a shoot that arises from latent or adventitious buds; also know as water sprouts that occur for on stems and branches and suckers that are produced from the base of trees. In older wood, epicormic shoots often result from severe defoliation or radical pruning.

Excurrent: a major tree form resulting from strong apical control. Trees with this form have a strong central stem and pyramidal shape. Lateral branches rarely compete for dominance. Most conifers and a few hardwoods, such as sweetgum and tuliptree, have excurrent forms.

Flush Cuts: pruning cuts that originate inside the branch bark ridge or the branch collar, causing unnecessary injury to stem tissues.

Included Bark: bark enclosed between

branches with narrow angles of attachment, forming a wedge between the branches.

Pollarding: the annual removal of all of the previous year's growth, resulting in a flush of slender shoots and branches each spring.
Stub Cuts: pruning cuts made too far outside the branch bark ridge or branch collar, that leave branch tissue attached to the stem.

Tipping: a poor maintenance practice used to control the size of tree crowns; involves the cutting of branches at right angles leaving long stubs.

Topping: a poor maintenance practice often used to control the size of trees; involves the indiscriminate cutting of branches and stems at right angles leaving long stubs. Synonyms include rounding-over, heading-back, dehorning, capping and hat-racking. Topping is often improperly referred to as pollarding.

Topiary: the pruning and training of a plant into a desired geometric or animal shape.

Woundwood: lignified, differentiated tissues produced on woody plants as a response to wounding (also known as callus tissue).

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"How to Prune Trees" was written to help people properly prune the trees they care about. If you doubt your ability to safely prune large trees, please hire a professional arborist. Information in this publication can be used to interview and hire a competent arborist.

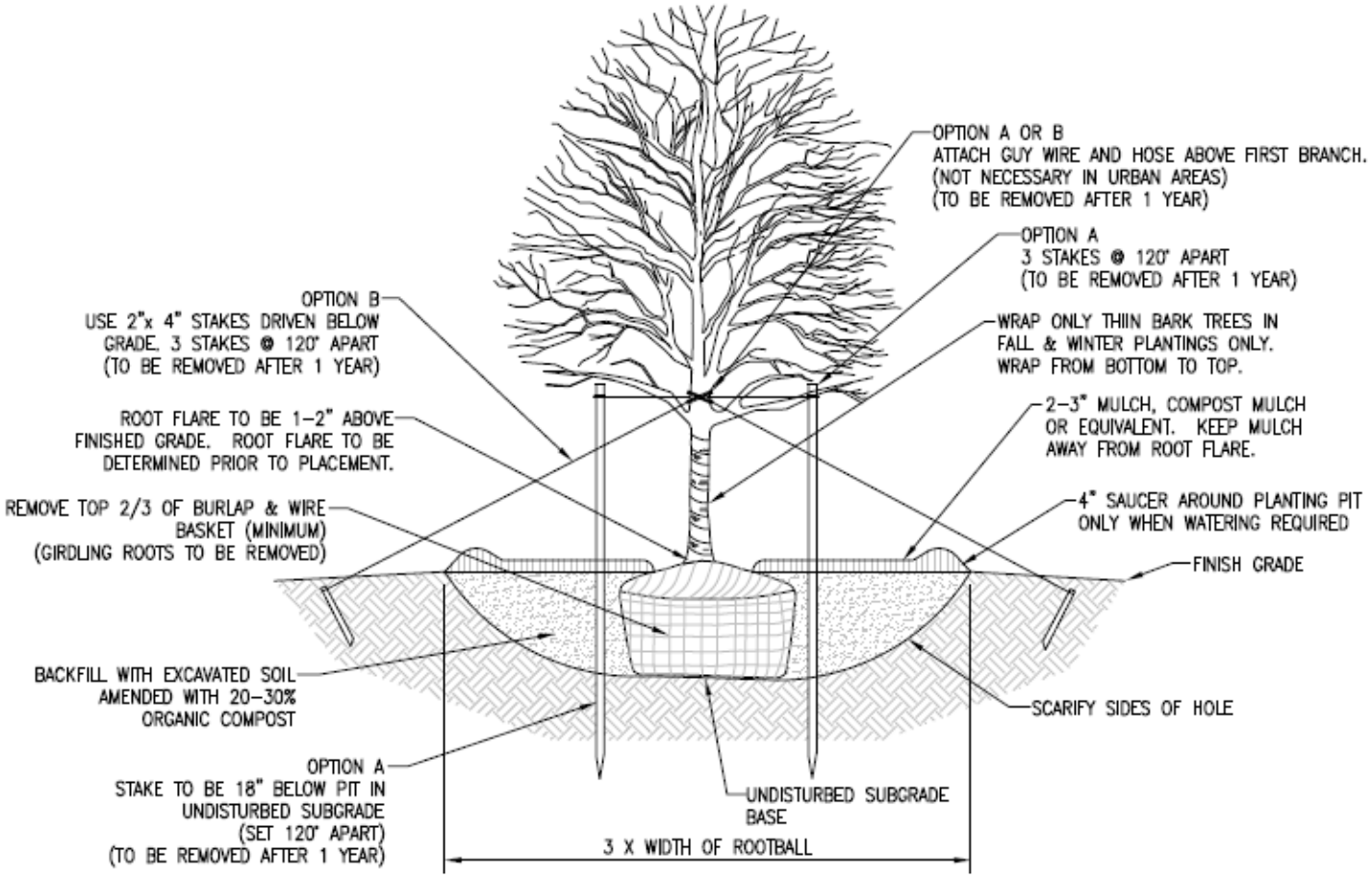
Appendix C

Tree Planting Specifications

TREE AND SHRUB INSTALLATION GUIDELINES

TREES AND SHRUBS (AS SPECIFIED)

A. Dig hole width at least twice the diameter of the root ball and depth only as deep as the root ball. The root flare should be visible above the root ball soil. Root ball should be placed on undisturbed soil only to prevent settling of the ball.
B. Remove containers/wire baskets and place plant in center of hole and level. Loosen pot bound roots and remove or cut any circling roots.
C. Backfill hole with native soil and tamp gently to remove air pockets. Avoid soil compaction by large vehicles or tools.
D. Water all trees and shrubs deeply and thoroughly upon installation and as needed to maintain health during the first year of establishment.
E. Avoid fertilizing trees for two years, until roots are established.
F. Stake tree in southwesterly direction. Ties should be loose fitting and allow for natural sway. Remove after one year.
G. Minimize pruning to dead or broken branches.
H. Place 4" perforated corrugated plastic pipe (CPP) around tree for protection from deer. Cut length to height of tree from root flare to first branch and slice lengthwise.



SHADE TREE PLANTING DETAIL

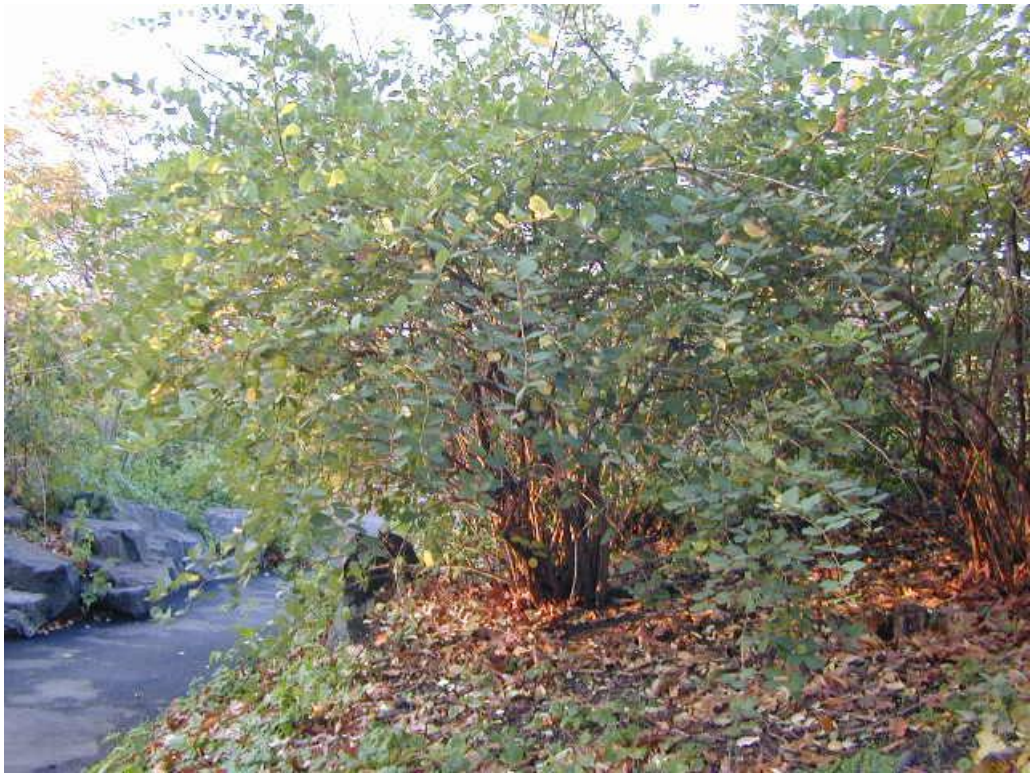
NOT TO SCALE

Appendix D

Invasive Tree Photographs

Autumn Olive

Bush Honeysuckle



Kudzu

Tree-of-Heaven

Appendix E

Reference Materials for Plant Disease Control

DEPARTMENT OF
B·O·T·A·N·Y
PLANT·PATHOLOGY
PURDUE UNIVERSITY • WEST LAFAYETTE IN

Dutch Elm Disease

Paul C. Pecknold, Extension Plant Pathologist

Despite the destructiveness of Dutch elm disease (DED) many American elms continue to survive, adding grace and beauty to the Indiana landscape. Knowledge of the disease and proper management practices will hopefully enable you to save your elm for another season, or possibly, even another generation.

Cause

DED is caused by a fungus (*Ophiostoma ulmi*) that is carried from diseased trees to healthy trees via two species of elm bark beetles: the smaller European elm bark beetle and the native elm bark beetle. Spores of the fungus are produced in the wood and bark of dead or dying trees; the beetles also inhabit dead or dying elm trees. When the beetles emerge from DED-infested trees, they carry spores of the fungus on their bodies and migrate to vigorous elms to feed. After feeding in healthy trees, the beetles then move to dying or dead elms where the females lay their eggs; thus, the disease is perpetuated through this linking of fungus and insect.

A second way the fungus can be spread is by root grafts. Roots of adjacent elms often make contact and grow together, thus allowing the fungus to travel from an infected tree to a healthy adjacent tree.

Symptoms

The disease results in wilting and yellowing of the foliage, followed by leaf death, defoliation and death of the affected branches. Wilting and yellowing of the leaves usually becomes visible about mid June and are most evident during July and August. Brown streaks develop under the bark in the sapwood of infected branches. This may be seen as a ring of discoloration when a diseased branch is cut or as dark streaks when the bark is peeled back from the infected branch (Figure 2).

Figure 1. Remove and dispose of all diseased trees, regardless of cause.

Ornamental Diseases

Purdue University
Cooperative Extension Service

Management

The most important step in control of DED is good sanitation. If proper sanitation practices are not followed, other control measures are of little use.

(1) Sanitation. Remove and dispose of all diseased elms and all elms killed or seriously weakened regardless of cause. Elm wood may be chipped so none remains with sufficient bark to serve as brood wood for beetles. If chipping is not possible, diseased elm should be burned (where permitted) or buried in a landfill. It is also important to keep elm trees pruned so that large dead or weakened branches in otherwise healthy trees do not become beetle brood wood sites. Prune in the winter while trees are dormant. *Do not stockpile diseased wood for firewood!*

(2) Insect Control. The insecticide Methoxychlor is used to control the beetles that spread DED. Proper application and timing are essential to effectively reduce the population of elm bark beetles. Methoxychlor can be applied in early spring (March or April) when temperatures reach 40 degrees F or higher. Apply as close to bud swell as possible to insure residual protection through peak beetle activity. Note: Spraying alone, without a good sanitation program is of little value.

(3) Preventing Spread through Roots. Spread of DED through root grafts can be prevented by chemical soil fumigation with Vapam *(a restricted use chemical)*, or by mechanical separation (cutting of roots by digging a narrow trench 18 to 24 inches deep between diseased and healthy elms). Simply removing infected trees promptly does not necessarily prevent spread of the disease to adjacent trees through connecting roots.

(4) Eradicant Pruning. Removing diseased branches, well below the point where sapwood discoloration is evident, may help rid the tree of infection. Such eradicant pruning must be done early. For trees that are showing 10-20% of the crown infected it is too late for such pruning. Prune back at least 10 feet into healthy wood, usually to a major limb. If further streaking is noticed in the pruned wood, cut back another 10 feet. Such pruning may seem rather drastic; however, many American elms have been saved by this pruning method. Carefully watch the tree for any signs of further wilting.

(5) Injection of Systemic Fungicides. The injection of systemic fungicides can be done on a preventative basis for selected high-value trees located in high disease risk areas, or they can be applied to help cure infected elms showing early stages of disease development (less than 5-10% of crown showing symptoms). Alamo and Arbotect 20-S are trade names of two systemic fungicides registered for control of DED. These fungicides are generally effective for 2 to 3 years, however trees should be evaluated for possible retreatment 12 months after treatment. Repeated injections are discouraged due to the physical damage (woodstain and decay) that results from the injection process. The pesticide labels recommend that the fungicides "be administered by trained arborists or others trained in injection techniques and in the identification of DED".

Systemic fungicides are most effective when used in conjunction with other management practices.

Figure 2. Brown discoloration just beneath the bark is typical of internal symptoms of Dutch elm disease.

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DNR
Indiana Department of Natural Resources

The Indiana Quarantine for Thousand Cankers Disease (TCD) Of Black Walnut Trees

PURDUE UNIVERSITY

Philip Marshall and Marcus McDonough, Indiana DNR
Dr. Matthew Ginzel and Jodie Ellis, Purdue University

The Indiana Department of Natural Resources issued a quarantine order on August 30, 2010, to prevent the introduction of Thousand Cankers Disease (TCD) of walnut trees into Indiana.

Walnut Trees in Indiana Landscapes

Walnut trees are among Indiana's most valuable timber trees; they are important in the state's urban landscapes and native ecosystems. Indiana ranks third in production of walnut timber in the United States. ***As of March 2011, TCD has not been found in Indiana***; the TCD quarantine will help keep this destructive disease out of the state.

Basic Information about TCD

A TCD canker on black walnut

Thousand cankers disease results when an insect and a fungal pathogen interact. The spores of the **fungus** *Geosmithia morbida* are carried on the **walnut twig beetle** (*Pityophthorus juglandis*). As the beetle burrows into a branch on a walnut tree to feed, it infects the tree tissue with the pathogen.

The fungal infection causes small, black lesions called **cankers** to form where the beetle entered the tree. Thousands of beetles at a time may feed in a single tree, which delivers an enormous dose of the pathogen.

Eventually the edges of the cankers blend into each other, preventing the flow of vital nutrients throughout the tree. Trees infected with TCD exhibit symptoms of **general decline** such as of the presence of **yellowing, wilted leaves** and **dieback of branches** in the crown. The tree often succumbs to TCD within 3-5 years after symptoms first appear. Identifying TCD before signs of tree decline appear is difficult.

Walnut Twig Beetle

The **walnut twig beetle**, native to the southeastern United States, is a tiny yellowish-brown beetle about the size of a mustard seed (1-2 mm long). All species of walnut trees (*Juglans*) are susceptible to TCD with black walnut (*J. nigra*) appearing to be the most susceptible.

How Does the TCD Quarantine Work?

Under the TCD quarantine, regulated walnut materials originating in, or transiting through, a quarantined state are prohibited from being brought into Indiana.

Regulated articles include:

- *All types* of hardwood firewood
- Walnut nursery stock, budwood, and scion wood
- Walnut logs, lumber, chips, and mulch
- The fungus *Geosmithia morbida*
- The walnut twig beetle, *Pityophthorus juglandis*

Firewood

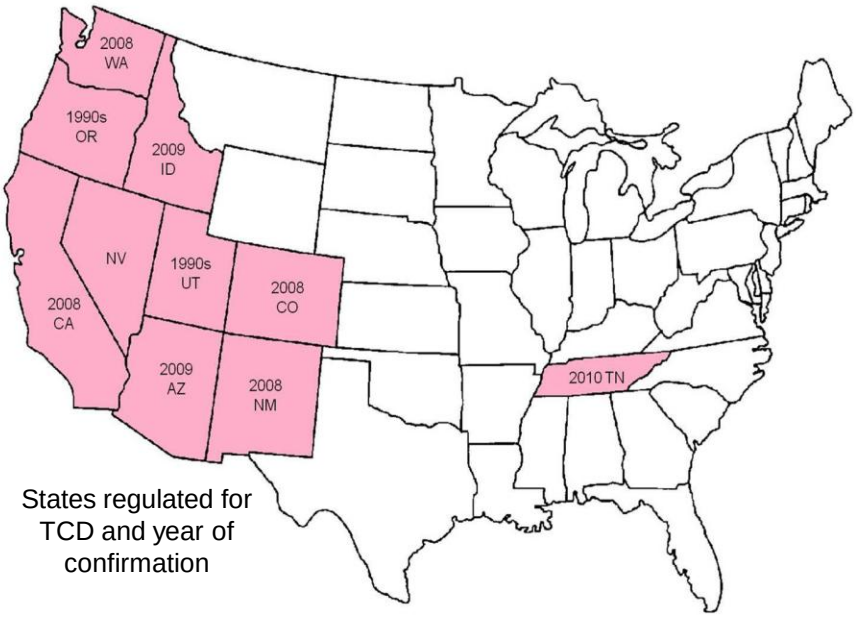
Continued on back page

(TCD Quarantine continued)

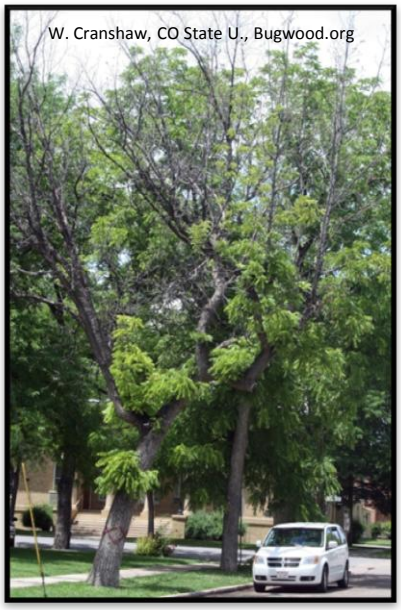
Walnut items *exempt* from the quarantine include:

- Nuts, nut meat, and hulls
- Kiln dried lumber that has 100 % squared edges and is 100% bark free
- Finished wood products without bark attached such as furniture, instruments, and gun stocks

Regulated articles may be brought into Indiana if the state of origin provides a **state-issued phytosanitary certificate** indicating the county of origin of the article and the items are free of TCD. Notification must be given at least 24 hours before the item(s) are transported into Indiana. In addition, the importer must have a **compliance agreement issued by the Indiana DNR**. The shipment must also be re-inspected by the DNR once it arrives in Indiana .



States regulated for TCD and year of confirmation



Black walnut trees exhibiting symptoms of decline from TCD.

How to Report a Suspected Find of TCD in Indiana

If you wish to report a suspected find of TCD in Indiana, notify the Indiana Department of Natural Resources, Division of Entomology and Plant Pathology, by calling **1-866- NO EXOTIC (1-866-663-9684)** or by sending an email to **depp@dnr.on.gov**. Please include your contact information, a description of the symptoms you have observed, and the location of the suspect tree.

Updates on Indiana's Thousand Cankers Disease Quarantine

To read the entire quarantine document and for updated information on TCD in Indiana, visit: **http://www.in.gov/dnr/entomolo/6249.htm**

More information on TCD

More information about TCD is located at the following websites:

- Indiana Department of Natural Resources: **http://www.in.gov/dnr/entomolo/6249.htm**
- Purdue Plant Pathology: **http://www.ppdl.purdue.edu/ppdl/hot10/8-23.html**
- USDA Thousand Cankers Disease Pest Alert: **http://na.fs.fed.us/pubs/palerts/cankers_disease/thousand_cankers_disease_low_res.pdf**
- The Walnut Council: **http://www.walnutcouncil.org/**

Prepared by Indiana Department of Natural Resources, Division of Entomology and Plant Pathology and Purdue University's Department of Entomology
February 2011

Anthracnose of Shade Trees

One of the most common and unsightly shade tree diseases to greet Indiana homeowners in spring is anthracnose. A fungus-caused plant disease, anthracnose becomes severe when cool, wet spring weather persists as leaves are first emerging. In Indiana, those trees most commonly affected are ash, oak (white), maple, and sycamore. Dogwood, birch, catalpa, elm, walnut, butternut, hickory, and linden may also be affected.

Symptoms

Anthracnose is most noticeable in the lower branches. Often the very top portions of the tree escape infection and appear quite healthy in comparison to the lower sections of the tree (see Figure 1).

A common leaf symptom is the killing of tissue on or adjacent to leaf veins (see Figure 2). This is opposite from leaf scorch symptoms which tend to be located between leaf veins rather than on the veins. Refer to pages 4 and 5 for causes of leaf scorch.

• Ash, both green and white, are generally the first to show infection from anthracnose. Green ash is especially apt to show extreme leaf drop in mid to late April. Symptoms start as irregular necrotic areas near the midvein and expand outward to the leaf margin.

• Sugar maples are often the second to show anthracnose infection. Infected leafs will curl and turn black; severe infection can result in extensive leaf defoliation in the lower branch canopy (see Figure 3).

• Sycamore anthracnose is the most serious of the anthracnose diseases in Indiana. In those years when infection is severe, sycamores will appear more dead than alive through the early spring months. Newly emerged leaf tissue will suddenly wilt and turn brown. This stage, commonly referred to as "twig blight" is often confused with late freeze injury. The cause of twig blight is the numerous stem cankers (localized, injured areas) that occur throughout the tree canopy. The leaf blight phase of sycamore anthracnose often follows twig blight. Brown, dead areas, develop along the leaf veins (see Figure 2). Frequently the infected area will expand outward to the leaf margin, causing a distortion of the leaf. Injury is again most noticeable in the lower branches.

• Of the oaks, white oak is most susceptible to anthracnose. Leaf symptoms appear along the midribs and veins to the leaf edges. The disease is most common on the lower branches. Red oak seldom show infection but do commonly show symptoms of blister leaf, another fungal-caused leaf disease.

Fig. 1 - Anthracnose caused defoliation of this sycamore. Note that the very top of the tree escaped infection.

Cause

Anthracnose results from infection by any of several different fungi. During winter these fungi reside in diseased leaf and/or stem tissue. In early spring, infectious spores are produced and then carried by rain and wind to newly emerging leaves. Anthracnose is most severe in those years when cool, wet conditions prevail at the time new leaves are emerging.

"It is important to understand that the fungi that cause anthracnose are very "host specific." Therefore the fungus that causes sycamore anthracnose WILL NOT attack dogwood; likewise, the fungus that attacks dogwood will not attack sycamore."

Fig. 2 - Leaf blighting of sycamore caused by anthracnose is most noticeable along leaf veins.

In the case of sycamore anthracnose, cankers are formed when the fungus grows from leaf tissue down the petiole and into stem tissue. The fungus will overwinter within cankers and cause a girdling of stem tissue the following spring, resulting in twig blight. Additional spores are produced from recently infected leaf and stem tissue, which allows further spread of the disease.

Remedies for Anthracnose

Cultural Practices: Anthracnose does not result in tree death. Most trees are able to withstand infection and push out a new crop of leaves by mid-June. Healthy, vigorous trees will quickly recover from anthracnose with little if any permanent injury. Therefore, the primary control for anthracnose is to maintain good tree health. In the spring, after leaf emergence, fertilize trees suffering from severe defoliation; also be sure to deep-water affected trees during drought periods.

Sanitation is also important in helping to minimize the severity of anthracnose the following year. Since the fungi that cause anthracnose overwinter within fallen leaves and/or twigs, it is best to rake and dispose of all fallen leaves and twigs before they become brittle and break into fragments that are difficult, if not impossible, to rake. Unfortunately, such sanitation does little good for sycamore anthracnose since so much of the fungus resides in cankers within the tree canopy. Prune out all dead and dying branches as they occur.

Fungicide Applications: In most cases, spraying with fungicides is unnecessary because the disease usually does not affect the long-term health of trees. An important exception to this is dogwood anthracnose; this is a very aggressive disease that can cause permanent damage and even tree death. For information on dogwood anthracnose and recommended fungicides, refer to BP- 48 (Dogwood Anthracnose).

When a specimen tree must be protected, fungicides can be applied. Thorough coverage and proper timing of the sprays are critical for adequate control. Spray applications must be made in early spring, before infection has occurred. Sprays applied after symptoms appear are of little benefit since infection has already occurred. Apply the first spray when buds first start to open. Two additional sprays should be made at about 10-day intervals. Chlorothalonil (sold as Daconil 2787, Fung-onil, etc.) and various copper containing fungicides are labeled for certain anthracnose diseases. Before applying any pesticide, check the label to make sure the plant type is listed. Fungicides vary in their formulation and percent active ingredient. Follow all label directions regarding amounts of pesticide to use, methods of application, and safety warnings.

Once symptoms develop, it is too late to apply fungicides to control anthracnose.

Fig. 3 - Maple anthracnose often results in leaf distortion and defoliation.

The first and most important step before managing a tree disease is to accurately diagnose the problem. With an inaccurate diagnosis, more harm than good could be done, not to mention the wasting of both time and money.

This publication is just one of several available online from Purdue Extension that addresses diseases found on landscape trees in Indiana. If your tree does not have symptoms similar to those described in this publication, please check the others.

Also, for more detailed photographs of disease symptoms, consider purchasing Common Tree Diseases of Indiana (BP-63). It presents information about the six most common tree diseases seen in Indiana. It is available from the Purdue Extension Media Distribution Center. The publication is $5 and can be ordered by calling 1-888-EXT-INFO.

If you are still in doubt as to the cause of the problem, consult a professional such as the Extension Educators at your local Purdue University Cooperative Extension Service office or Purdue University's Plant Pest and Diagnostic Laboratory (P&PDL).

To submit a plant sample to the P&PDL for diagnosis, obtain a sample submission form from your local Purdue Extension office, from the P&PDL office (1-888-EXT-INFO), or from the P&PDL Web page www.ppdl.purdue.edu/. Detailed instructions for submitting most types of samples are included on the back of the forms.

Submit a sample that is representative of the problem and shows the varying degrees of symptoms. Send several branches (even large ones) showing the symptoms and a detailed description of the problem and other useful information about the site, the age of the tree or shrub, and the date of planting. Photographs are very helpful.

Send the sample and submission form by first-class or overnight mail early in the week to:

Plant & Pest Diagnostic Laboratory
Purdue University
1155 LSPS
West Lafayette, IN 47907-1155

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Appendix F

Reference Materials for Plant Pest Control

United States Department of Agriculture

Emerald Ash Borer Biological Control Program

5-Year Implementation Strategy (FY2010-2014)

October 2009

PEST STATUS and PROGRAM BACKGROUND

The Emerald Ash Borer (EAB) *Agrilus planipennis* (Fairmaire) (Coleoptera: Buprestidae) is a non-native wood-boring pest of North American ash (*Fraxinus* spp.)[1]. This devastating pest was first found in 2002 in southeastern Michigan and adjacent areas of Windsor, Ontario, Canada. It is thought to have been introduced in the 1990's on solid wood packing material originating from Asia. As of September 2009, EAB has been discovered in 13 states (Indiana, Illinois, Kentucky, Maryland, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Virginia, West Virginia and Wisconsin) and parts of Canada.

This destructive beetle represents an enormous threat to North America's ash resources and forested ecosystems. Unlike many other wood boring beetles, EAB aggressively kills healthy as well as stressed trees. Larvae bore through the bark and into the cambium where they feed on the phloem. As the larvae feed they create serpentine-like galleries that disrupt the flow of nutrients, usually causing tree death after four to five years of infestation. Currently, there are no effective natural enemies attacking EAB in North America. If no new management strategies are developed, it is estimated this pest will likely spread to 25 states in the next 10 years, resulting in an estimated 10.0 billion dollars of economic damage (Kovacs et al. 2009). The USDA's Animal and Plant Health Inspection Service (APHIS), Forest Service (FS), and Agricultural Research Service (ARS) are working together to implement an EAB biological control program.

A classical biological control effort was initiated by APHIS and FS scientists shortly after the beetle was first found in Michigan. Foreign exploration to identify candidate biological control agents initially focused in The People's Republic of China (P.R. China), which led to the discovery of three promising parasitoid species: a gregarious larval ectoparasitoid, *Spathius agrili* Yang (Hymenoptera: Braconidae) (Yang et al. 2005); a gregarious larval endoparasitoid, *Tetrastichus planipennisi* Yang (Hymenoptera:

Eulophidae) (Liu et al. 2003; Yang et al. 2006); and a solitary, parthenogenic, egg parasitoid, *Oobius agrili* Zhang and Huang (Hymenoptera: Encyrtidae) (Zhang et al. 2005). In P.R. China, EAB populations are patchily distributed and population densities are low in stands of native ash, due to a combination of factors including host plant resistance and natural enemies. Based on the rates of parasitism of EAB by these species in P.R. China, their introduction has significant potential to reduce EAB population densities in the United States (Liu et al. 2007). Following host range testing in P.R. China and the United States, an environmental assessment was prepared outlining the risks and benefits of releasing these three parasitoids. After a 60-day public comment period and a Finding-of-No-Significant-Impact[2], APHIS and the State of Michigan approved release of these parasitoids in July 2007.

The first small-scale releases of these three parasitoids (few hundred parasitoids per release site) were conducted in Michigan in the summer and fall of 2007. Limited releases also took place in 2008, with more substantial releases (few thousand parasitoids per release site) occurring in 2009 in Michigan, Ohio, Indiana, Illinois and Maryland. All releases thus far have been conducted by researchers from APHIS, FS and ARS to establish the parasitoids as well as to answer basic biological questions. These "research" release sites are being monitored to determine numbers of parasitoids and site conditions for establishment, dispersal rates, impacts on EAB populations and ash health, interactions among released and native natural enemies, and effects on non-target species.

S. agrili released in Michigan in the fall of 2007 was recovered at one site in 2008 and *O. agrili* released in 2007 was recovered at two sites. Thus, it does appear that these parasitoids can survive Michigan winters. In 2009, within season recoveries of both *O. agrili* and *T. planipennisi* occurred at several release sites. Moreover, *T. planipennisi* was recovered almost ½-mile from the original release points at two different sites, confirming parasitoid dispersal. Research continues at these sites to monitor long-term parasitoid establishment and impacts on EAB populations.

Foreign exploration for additional biological control agents is on-going. In 2008 and 2009, additional natural enemies were found in Korea and the Russian Far East, including the discovery of new species of *Spathius* and *Tetrastichus*. Efforts are underway to rear and evaluate these species both in the countries of origin and in quarantine in the United States. If new agents are approved for environmental release, they will be incorporated into on-going research and operational programs to determine how they can best be utilized to support EAB area-wide management efforts.

Native parasitoids and predators do not appear to be providing a significant level of control (generally <5%). However, a number of species have been found to be locally abundant on EAB. For example, a native parasitic wasp in the genus *Atanycolus* (Hymenoptera: Braconidae) has been found attacking EAB larvae at a number of sites in Michigan. This may be an indication of a native predator learning to attack EAB. This and other native entomophagous species found associated with EAB are being studied by FS and ARS scientists to determine their biology, distribution and phenology relative to their impact on EAB populations.

TIMELINE

A 5-year plan (FY2010-2014) has been formulated to facilitate the development and field testing of biological control technologies for area-wide-management of EAB. An EAB Biological Control Production Facility was established at Brighton, Michigan, (=Brighton Production Facility) to mass-rear the three approved exotic parasitoids and potentially other natural enemies as they become available in the future. Operational releases of the different species will start in 2010 as production levels permit and will be monitored for establishment and impacts on EAB. Parasitoid release sites will be established across a range of EAB densities, ash species, and environs to determine the conditions under which each species is most effective. Results at the different sites will help determine the locations for mass-releases in subsequent years and potentially for establishing locations for field insectaries.

GOAL

Develop and evaluate biological control of EAB as a long-term management strategy in the United States.

OBJECTIVES

1. **Develop and implement mass-rearing efforts** for approved and permitted biological control agents of EAB.

2. **Facilitate the release of permitted EAB biological control agents** in all states infested with EAB.

3. **Determine overwintering and establishment of released biological control agents and the impact** of these agents on EAB populations and ash survival.

4. **Continue methods development activities** aimed at improving the rearing, releasing and monitoring of EAB biological control agents.

ACTION STEPS

1. **Develop and Implement Mass-Rearing Efforts**

1.1. Maintain laboratory research colonies of *T. planipennis*, *S. agrili* and *O. agrili* at APHIS, FS and ARS research facilities in an effort to refine rearing technologies and continue research efforts into natural enemy biology and behavior. Colonies from these research facilities will be used as needed to establish and maintain colonies at the Brighton Production Facility. Insects from China will be collected

periodically and incorporated into the Brighton colonies to help minimize the selection of laboratory adapted insects

1.2. The primary mission of the Brighton Production Facility is to mass-rear parasitoids for field release. This includes the collection of adequate host life stages to support the parasitoid rearing as well as assisting in the field collection of host life stages for evaluation of parasitoid establishment and impacts. EAB and its natural enemies are difficult insects to mass-rear. As such, the challenges of rearing these natural enemies will limit their availability for releases. However, as rearing methods improve and production increases, the goal is to be able to provide natural enemies for releases in all infested states on a priority basis.

2. **Facilitate Releases**

2.1. Develop an EAB Biological Control Manual and other outreach materials that can be provided to state cooperators and the public to aid in understanding and conducting the release, monitoring and evaluation of parasitoids.

Criteria for choosing suitable release sites include the following:

- positive evidence of EAB infestation (emergence holes, crown decline, epicormic shoots, woodpecker feeding)
- relatively high percentage (>25%) of ash in the overstory
- predominance of ash trees that are $\leq$25cm in diameter
- accessibility
- land owners have granted permission to conduct parasitoid releases
- sites are not subject to disturbances (logging, development, etc.) for at least 3 years

Each release will consist of a specified number of female parasitoids previously exposed to male parasitoids. The number of parasitoids released will be determined based on discussions with researchers. The releases must occur when the appropriate EAB life stages (freshly laid eggs for *O. agrili* and late 3rd or 4th instar for *S. agrili* and *T. planipennisi*) are present in the field. Because of geographic climate differences, the release season and the timing of releases will be different for different locations. Also, the duration of EAB life cycles needs to be considered when developing release and monitoring protocols (e.g., low EAB densities on healthy ash often need two years to complete their life cycles whereas EAB on heavily infested ash usually have a one year life cycle).

2.2. Initiate operational releases of EAB parasitoids in 2010 at a limited number of sites. States and sites chosen to receive parasitoids will be determined based on discussions between State Plant Health Directors and State Plant Regulatory Officials from EAB infested states and the PPQ EAB National Program Manager. The criteria for selecting release sites will be determined and modified as needed based on data collected from “research” sites. New detection sites that have or will have active eradication programs will not receive parasitoids. Program staff and

APHIS/FS/ARS scientists will work with Program managers and cooperators to ensure proper site selection and release protocols are followed.

2.3. Obtain State release permits and land use permits in a timely manner. These are necessary before any releases can occur at an infested site. This process can take 2-3 months. Cooperators interested in receiving parasitoids need to fill out APHIS PPQ Form 526 "Application for permit to move live plant pests, biological control agents, or noxious weeds". The application process and permits are offered through an on-line web-based ePermits system. The URL for this site is: http://www.aphis.usda.gov/permits/ppq_epermits.shtml.

3. **Determine Establishment and Impacts**

3.1. Seek agreement from State cooperators to follow standardized release and monitoring protocols provided by the Brighton Production Facility. They also must agree to monitor release sites for parasitoid establishment for minimum three years following each release. This information will influence the location and timing of future releases and will be integrated into GIS and available on the internet.

3.2. Seek agreement from all research and state cooperators making releases with material provided by the Brighton Production Facility to submit their data into a centrally managed, online, searchable database. The database will store precisely where, when, what and how parasitoids are being released and recovered in the United States. Stand health and EAB population data will also be included.

4. **Continue Methods Development**

Commit to on-going methods development activities that improve Program delivery. The EAB Biological Control Program is still very much in the initial stages of development and implementation. For example, current parasitoid rearing systems have not been optimized for such factors as temperature, humidity, photoperiod and host density. Similarly in the field, the appropriate number and combination of each parasitoid species to release and the frequency of parasitoid releases to best ensure establishment are not known. As such, the Program will actively encourage and support research and development efforts that specifically focus on these and other Program priorities.

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and its natural enemies *Oobius agrili* (Hymenoptera: Encyrtidae) and *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in China. *Biological Control* 42: 61-71.

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[1] Link to APHIS Emerald Ash Borer Program Manual
http://www.aphis.usda.gov/import_export/plants/manuals/domestic/downloads/emerald_ash_borer_manual.pdf

[2] Link to Environmental Assessment
http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=APHIS-2007-0060

Biological Control of Emerald Ash Borer (*Agrilus planipennis*)

The Pest: The emerald ash borer (EAB), an exotic invasive wood-boring beetle (Fig. 1) native to Asia, is threatening ash trees throughout North America. EAB was first detected in Michigan in 2002 although it likely arrived more than ten years earlier in solid wood packing materials. As of December 2008, EAB has been detected in ten states (Indiana, Illinois, Maryland, Michigan, Missouri, Ohio, Pennsylvania, Virginia, Wisconsin and West Virginia) and the Canadian provinces of Ontario and Quebec. EAB is well suited for climatic conditions on this continent. EAB larvae feed under the bark of ash trees (Fig. 2). cutting off the transport of nutrients, which results in tree death over a period of several years (Fig. 3). Forest inventories report 8 billion ash trees on U.S. timberlands, of which 693 million occur in Michigan. It is estimated that over 30 million of Michigan's ash trees have already succumbed to EAB. Clearly, the risk EAB poses to ash trees in North America is substantial. EAB is difficult to detect and control on an area-wide basis. Treatment options are limited and relatively few native natural enemies (parasitoids, predators and pathogens) attack EAB. As EAB spreads throughout North America, Federal and State agencies, land managers, and the public are seeking management tools that would reduce EAB population densities, slow its spread and reduce its impact on ash trees.

Biological Control: Biological Control (or biocontrol) is the practice of importing and releasing host specific natural enemies from a pest's native range to control populations in the area of introduction. Biocontrol has been used for over 100 years in the U.S. and has successfully controlled invasive insect and weed pests such as gypsy moth, winter moth, ash whitefly, eucalyptus longhorned borer, purple loosestrife and Klamath weed. Because EAB is from northeastern Asia, U.S. and Chinese scientists have been searching for EAB and its natural enemies in that region since 2003. Numbers of EAB in Asia are very low as it is only a sporadic pest of ash because of resistant host plants, climatic conditions and natural enemies. Several EAB parasitoids (small stingless relatives of ants and wasps) were discovered in collaboration with scientists at the Chinese Academy of Forestry. USDA scientists are currently evaluating three parasitoids from China for biological control of EAB in the U.S. The biology of these EAB natural enemies is described below.

Spathius agrili was found parasitizing up to 90 percent of EAB larvae in ash trees in China. Female *Spathius* parasitize EAB larvae by drilling through the bark (Fig. 4) and laying up to 20 eggs on its host. The hatching parasitoid larvae feed and develop on the EAB larva, resulting it its death. The cycle is repeated 3-4 times each summer and fall. *Spathuis* overwinter as pupae inside cocoons under the bark of ash trees and emerge as adults in the summer**.**

Figure 1. Adult EAB (Tracy Ayer, USDA APHIS PPQ).
Figure 2. EAB larva (David Cappaert, Michigan State University, www.forestryimages.org).
Figure 3. Juli Gould and Ivich Fraser release *Spathius* in Genesee County, MI (Nicole Smith, USDA APHIS PPQ).
Figure 4. *Spathius agrili* ovipositing on EAB through ash bark (Dr. Yang Zhong-qi, Chinese Academy of Forestry).
Figure 5. *Spathius agrili* larvae consuming EAB host (Dr. Yang Zhong-qi).

Tetrastichus planipennisi is another parasitoid of EAB from China where it attacks and kills up to 50 percent of EAB larvae. The life cycle of *Tetrastichus* is similar to that of *Spathius*, however, the female parasitoid lays eggs inside EAB larvae where the parasitoid larvae grow, eventually killing their host. *Tetrastichus* completes at least four generations each year and one EAB larva can produce up to 127 *Tetrastichus* adults. They survive the winter as larvae inside their host or host gallery under the bark of ash trees.

Oobius agrili kills up to 60 percent of EAB eggs laid during the summer. Tiny female *Oobius* accomplish this by searching the bark of ash trees for EAB eggs, which are laid in bark crevices and between layers of bark. When *Oobius* finds an EAB egg, it injects its own egg inside where it will hatch, grow, and kill the host egg. An *Oobius* adult will emerge and repeat the cycle for at least two generations during the EAB egg-laying season. Each *Oobius* adult can parasitize up to 62 EAB eggs during its life time. *Oobius* spends the winter as larvae inside EAB eggs and emerge the following spring as adults.

Project Status: Laboratory methods for continuous rearing of these species of *Spathius*, *Tetrastichus*, and *Oobius* have been developed. The specificity of these parasitoids was studied extensively on native beetles and other insects. In laboratory no-choice assays, *Tetrastichus* rejected all non-EAB species as hosts attacking only actively-feeding EAB larvae in ash branches. Although *Spathius* and *Oobius* parasitized other species of wood borers in the genus *Agrilus*, parasitism rates were significantly lower than when parasitizing EAB. The preference of these parasitoids for EAB and ash habitats has been further confirmed through surveys in China and olfactometer tests.

An Environmental Assessment outlining the benefits of releasing these three parasitoids without posing a significant risk to native wood borers or their environs was prepared and published in the Federal Register for a 60-day comment period. Permit applications for field release of *Spathius*, *Tetrastichus* and *Oobius* were reviewed by international, national and state scientists and regulators, and permits were granted in July of 2007. Small numbers of each species were released in Michigan in the fall of 2007. Scientists have confirmed *Spathius* and *Oobius* successfully reproduced in Michigan field sites and survived the winter. Releases of the three species will continue while scientists further determine how these natural enemies can best be used to help suppress EAB populations. Scientists also continue to survey for and investigate the potential of additional EAB natural enemies that might be used in a biological control program. Most recently, two new species of *Spathius* were discovered in Korea and Russia respectively.

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http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=APHIS-2007-0060
http://www.emeraldashborer.info/
http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/background.shtml

Figure 6. *Tetrastichus planipennisi* adult parasitizing EAB larva (Dr. Houping Liu).
Figure 7. *Oobius agrili* adult parasitizing EAB egg (Dr. Houping Liu).

Insecticide Options for Protecting Ash Trees from Emerald Ash Borer

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Contents

Answers to Frequently Asked Questions. 3

What options do I have for treating my ash trees? 3

I know my tree is already infested with EAB. Will insecticides still be effective? 3

My ash tree looks fine but my county is quarantined for EAB. Should I start treating my tree?. 4

I realize that I will have to protect my ash trees from EAB for several years. Is it worth it? 4

Insecticide Options for Controlling EAB 5

Using Insecticides to Control EAB 6

Soil-Applied Systemic Insecticides 6

Trunk-Injected Systemic Insecticides 7

Noninvasive, Systemic Basal Trunk Sprays 7

Protective Cover Sprays 7

How Effective Are Insecticides for Control of EAB? 8

Soil-Applied Systemic Insecticides 8

Trunk-Injected Systemic Insecticides 9

Emamectin benzoate 9

Imidacloprid 9

Noninvasive Basal Trunk Sprays with Dinotefuran 10

Protective Cover Sprays 10

Acknowledgements. 10

Key Points and Summary Recommendations 11

Insecticide Options for Protecting Ash Trees from Emerald Ash Borer

Emerald ash borer (*Agrilus planipennis* Fairmaire), an invasive insect native to Asia, has killed tens of millions of ash trees in urban, rural and forested settings. This beetle was first discovered in 2002 in southeast Michigan and Windsor, Ontario. As of June 2009, emerald ash borer (EAB) infestations were known to be present in 12 states and two Canadian provinces. Many homeowners, arborists and tree care professionals want to protect valuable ash trees from EAB. Scientists have learned much about this insect and methods to protect ash trees since 2002. This bulletin is designed to answer frequently asked questions and provide the most current information on insecticide options for controlling EAB.

Answers to Frequently Asked Questions

What options do I have for treating my ash trees?

If you elect to treat your ash trees, there are several insecticide options available and research has shown that treatments can be effective. Keep in mind, however, that controlling insects that feed under the bark with insecticides has always been difficult. This is especially true with EAB because our native North American ash trees have little natural resistance to this pest. In university trials, some insecticide treatments were effective in some sites, but the same treatments failed in other sites. Furthermore, in some studies conducted over multiple years, EAB densities continued to increase in individual trees despite annual treatment. Some arborists have combined treatments to increase the odds of success (e.g., combining a cover spray with a systemic treatment).

Our understanding of how EAB can be managed successfully with insecticides has increased substantially in recent years. The current state of this understanding is detailed in the bulletin. It is important to note that research on management of EAB remains a work in progress. Scientists from universities, government agencies and companies continue to conduct intensive studies to understand how and when insecticide treatments will be most effective.

I know my tree is already infested with EAB. Will insecticides still be effective?

If a tree has lost more than 50 percent of its canopy, it is probably too late to save the tree. Studies have shown that it is best to begin using insecticides while ash trees are still relatively healthy. This is because most of the insecticides used for EAB control act systemically — the insecticide must be transported within the tree. In other words, a tree must be healthy enough to carry a systemic

insecticide up the trunk and into the branches and canopy. When EAB larvae feed, their galleries injure the phloem and xylem that make up the plant's circulatory system. This interferes with the ability of the tree to transport nutrients and water, as well as insecticides. As a tree becomes more and more infested, the injury becomes more severe. Large branches or even the trunk can be girdled by the larval galleries.

Studies have also shown that if the canopy of a tree is already declining when insecticide treatments are initiated, the condition of the tree may continue to deteriorate during the first year of treatment. In many cases, the tree canopy will begin to improve in the second year of treatment. This lag in the reversal of canopy decline probably reflects the time needed for the tree to repair its vascular system after the EAB infestation has been reduced.

My ash tree looks fine but my county is quarantined for EAB. Should I start treating my tree?

Scientists have learned that ash trees with low densities of EAB often have few or no external symptoms of infestation. Therefore, if your property is within a county that has been quarantined for EAB, your ash trees are probably at risk. Similarly, if your trees are outside a quarantined county but are still within 10-15 miles of a known EAB infestation, they may be at risk. If your ash trees are more than 15 miles beyond this range, it is probably too early to begin insecticide treatments. Treatment programs that begin too early are a waste of money. Remember, however, that new EAB infestations have been discovered every year since 2002 and existing EAB populations will build and spread over time. Stay up to date with current EAB quarantine maps and related information at www.emeraldashborer.info. You can use the links in this Web site to access specific information for individual states. When an EAB infestation is detected in a state or county for the first time, it will be added to these maps. Note, however, that once an area has been quarantined, EAB surveys generally stop, and further spread of EAB in that area will not be reflected on future maps.

I realize that I will have to protect my ash trees from EAB for several years. Is it worth it?

The economics of treating ash trees with insecticides for EAB protection are complicated. Factors that can be considered include the cost of the insecticide and expense of application, the size of the trees, the likelihood of success, and potential costs of removing and replacing the trees. Until recently, insecticide products had to be applied every year. A new product that is effective for two years or even longer (emamectin benzoate) has altered the economics of treating ash trees. As research progresses, costs and methods of treating trees will continue to change and it will be important to stay up to date on treatment options.

Benefits of treating trees can be more difficult to quantify than costs. Landscape trees typically increase property values, provide shade and cooling, and contribute to the quality of life in a neighborhood. Many people are sentimental about their trees. These intangible qualities are important and should be part of any decision to invest in an EAB management program.

It is also worth noting that the size of EAB populations in a specific area will change over time. Populations initially build very slowly, but later increase rapidly as more trees become infested. As EAB populations reach their peak, many trees will decline and die within one or two years. As untreated ash trees in the area succumb, however, the local EAB population will decrease substantially. Scientists do not yet have enough experience with EAB to know what will happen over time to trees that survive the initial wave of EAB. Ash seedlings and saplings are common in forests, woodlots, and right-of-ways, however, and it is unlikely that EAB will ever completely disappear from an area. That means that ash trees may always be at some risk of being attacked by EAB, but it seems reasonable to expect that treatment costs could eventually decrease as pest pressure declines after the EAB wave has passed.

Insecticide Options for Controlling EAB

Insecticides that can effectively control EAB fall into four categories: (1) systemic insecticides that are applied as soil injections or drenches; (2) systemic insecticides applied as trunk injections; (3) systemic insecticides applied as lower trunk sprays; and (4) protective cover sprays that are applied to the trunk, main branches, and (depending on the label) foliage.

Insecticide formulations and application methods that have been evaluated for control of EAB are listed in Table 1. Some are marketed for use by homeowners while others are intended for use only by professional applicators. The "active ingredient" refers to the compound in the product that is actually toxic to the insect.

Formulations included in Table 1 have been evaluated in multiple field trials conducted by the authors. Inclusion of a product in Table 1 does not imply that it is endorsed by the

Table 1. Insecticide options for professionals and homeowners for controlling EAB that have been tested in multiple university trials. Some products may not be labeled for use in all states. Some of the listed products failed to protect ash trees when they were applied at labeled rates. Inclusion of a product in this table does not imply that it is endorsed by the authors or has been consistently effective for EAB control. See text for details regarding effectiveness.

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Professional Use Products			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Mid-fall and/or mid- to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Mid-fall and/or mid- to late spring
IMA-jet®	Imidacloprid	Trunk injection	Early May to mid-June
Imicide®	Imidacloprid	Trunk injection	Early May to mid-June
TREE-äge™	Emamectin benzoate	Trunk injection	Early May to mid-June
Inject-A-Cide B®	Bidrin®	Trunk injection	Early May to mid-June
Safari™ (20 SG)	Dinotefuran	Systemic bark spray	Early May to mid-June
Astro®	Permethrin	Preventive bark and foliage cover sprays	2 applications at 4-week intervals; first spray should occur when black locust is blooming (early May in southern Ohio to early June in mid-Michigan)
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Homeowner Formulation			
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Mid-fall or mid- to late spring

authors or has been consistently effective for EAB control. Please see the following sections for specific information about results from these trials. Results of some tests have also been posted on www.emeraldashborer.info.

Strategies for the most effective use of these insecticide products are described below. It is important to note that pesticide labels and registrations change constantly and vary from state to state. It is the legal responsibility of the pesticide applicator to read, understand and follow all current label directions for the specific pesticide product being used.

Using Insecticides to Control EAB

Soil-Applied Systemic Insecticides

Systemic insecticides applied to the soil are taken up by the roots and translocated throughout the tree. The most widely tested soil-applied systemic insecticide for control of EAB is imidacloprid, which is available under several brand names for use by professional applicators and homeowners (see Table 1). All imidacloprid formulations can be applied as a drench by mixing the product with water, then pouring the solution directly on the soil around the base of the trunk. Dinotefuran was recently labeled for use against EAB as a soil treatment (in addition to its use as a basal trunk spray discussed below). Studies to test its effectiveness as a soil treatment are currently underway in Michigan and Ohio.

Imidacloprid soil applications should be made when the soil is moist but not saturated. Application to water-logged soil can result in poor uptake if the insecticide becomes excessively diluted and can also result in puddles of insecticide that could wash away, potentially contaminating surface waters and storm sewers. Insecticide uptake will also be limited when soil is excessively dry. Irrigating the soil surrounding the base of the tree before the insecticide application can improve uptake.

The application rates for the homeowner product (Bayer Advanced™ Tree & Shrub Insect Control) and professional formulations of imidacloprid are very similar. Homeowners apply the same amount of active ingredient that professionals apply. However, there are certain restrictions on the use of homeowner formulations that do not apply to professional formulations. Homeowner formulations of imidacloprid can be applied only as a drench. It is not legal to inject these products into the soil, although some companies have marketed devices to homeowners specifically for this purpose. Homeowners are also restricted to making only one application per year. Several generic products containing imidacloprid are available to homeowners, but the formulations vary and the effectiveness of these products has not yet been evaluated in university tests.

Soil drenches offer the advantage of requiring no special equipment for application other than a bucket or watering can. However, imidacloprid can bind to surface layers of organic matter, such as mulch or leaf litter, which can reduce uptake by the tree. Before applying soil drenches, it is important to remove, rake or pull away any mulch or dead leaves so the insecticide solution is poured directly on the mineral soil.

Imidacloprid formulations labeled for use by professionals can be applied as a soil drench or as soil injections. Soil injections require specialized equipment, but offer the advantage of placing the insecticide under mulch or turf and directly into the root zone. This also can help to prevent runoff on sloped surfaces. Injections should be made just deep enough to place the insecticide beneath the soil surface (2-4 inches). Soil injections should be made within 18 inches of the trunk where the density of fine roots is highest. As you move away from the tree, large radial roots diverge like spokes on a wheel and studies have shown that uptake is higher when the product is applied at the base of the trunk. There are no studies that show that applying fertilizer with imidacloprid enhances uptake or effectiveness of the insecticide.

Optimal timing for imidacloprid soil injections and drenches is mid-April to mid-May, depending on your region. Allow four to six weeks for uptake and distribution of the insecticide within the tree. In southern Ohio, for example, you would apply the product by

mid-April; in southern Michigan, you should apply the product by early to mid-May. When treating larger trees (e.g., with trunks larger than 12 inches in diameter), treat on the earlier side of the recommended timing. Large trees will require more time for uptake and transportation of the insecticide than will small trees. Recent tests show that imidacloprid soil treatments can also be successful when applied in the fall.

Trunk-Injected Systemic Insecticides

Several systemic insecticide products can be injected directly into the trunk of the tree including formulations of imidacloprid and emamectin benzoate (see Table 1). An advantage of trunk injections is that they can be used on sites where soil treatments may not be practical or effective, including trees growing on excessively wet, compacted or restricted soil environments. However, trunk injections do wound the trunk, which may cause long-term damage, especially if treatments are applied annually.

Products applied as trunk injections are typically absorbed and transported within the tree more quickly than soil applications. Allow three to four weeks for most trunk-injected products to move through the tree. Optimal timing of trunk injections occurs after trees have leafed out in spring but before EAB eggs have hatched, or generally between mid-May and mid-June. Uptake of trunk-injected insecticides will be most efficient when trees are actively transpiring. Best results are usually obtained by injecting trees in the morning when soil is moist but not saturated. Uptake will be slowed by hot afternoon temperatures and dry soil conditions.

Noninvasive, Systemic Basal Trunk Sprays

Dinotefuran is labeled for application as a noninvasive, systemic bark spray for EAB control. It belongs to the same chemical class as imidacloprid (neonicotinoids) but is much more soluble. The formulated insecticide is sprayed on the lower five to six feet of the trunk using a common garden sprayer and low pressure. Research has shown that the insecticide penetrates the bark and moves systemically throughout the rest of the tree.

Healthy ash trees that have been protected with insecticides growing next to untreated ash trees killed by EAB.

Dinotefuran can be mixed with surfactants that may facilitate its movement into the tree, particularly on large trees with thick bark. However, in field trials, adding a surfactant did not consistently increase the amount of insecticide recovered from the leaves of treated trees.

The basal trunk spray offers the advantage of being quick and easy to apply and requires no special equipment other than a garden sprayer. This application technique does not wound the tree, and when applied correctly, the insecticide does not enter the soil.

Protective Cover Sprays

Insecticides can be sprayed on the trunk, branches and (depending on the label) foliage to kill adult EAB beetles as they feed on ash leaves, and newly hatched larvae as they chew through the bark. Thorough coverage is essential for best results. Products that have been evaluated as cover sprays for control of EAB include some specific formulations of permethrin, bifenthrin, cyfluthrin and carbaryl (see Table 1).

Protective cover sprays are designed to prevent EAB from entering the tree and will have no effect on larvae feeding under the bark. Cover sprays should be timed to occur when most adult beetles are feeding and beginning to lay eggs. Adult activity can be difficult to monitor because there are no

effective pheromone traps for EAB. However, first emergence of EAB adults generally occurs between 450-550 degree days (starting date of January 1, base temperature of 50˚F), which corresponds closely with full bloom of black locust (*Robinia pseudoacacia*). For best results, consider two applications, one at 500 DD_{50} (as black locust approaches full bloom) and a second spray four weeks later.

EAB adults must feed on foliage before they become reproductively mature.

How Effective Are Insecticides for Control of EAB?

Extensive testing of insecticides for control of EAB has been conducted by researchers at Michigan State University (MSU) and The Ohio State University (OSU). Results of some of the MSU trials are available at www.emeraldashborer.info.

Soil-Applied Systemic Insecticides

Efficacy of imidacloprid soil injections for controlling EAB has been inconsistent; in some trials EAB control was excellent, while others yielded poor results. Differences in application protocols and conditions of the trials have varied considerably, making it difficult to reach firm conclusions about sources of variation in efficacy. For example, an MSU study found that low-volume soil injections of imidacloprid applied to small trees averaging 4 inches in DBH (diameter of the trunk at breast height) using the Kioritz applicator (a hand-held device for making low-volume injections) provided good control at one site. However, control was poor at another site where the same application protocols were used to treat larger trees (13-inch DBH). Imidacloprid levels may have been too low in the larger trees to provide adequate control. Higher pest pressure at the second site also may have contributed to poor control in the large trees.

In the same trials, high-pressure soil injections of imidacloprid (applied in two concentric rings, with one at the base of the tree and the other halfway to the drip line of the canopy) provided excellent control at one site. At another site, however, soil injections applied using the same rate, timing and application method were completely ineffective, even though tree size and infestation pressure were very similar. It should be noted that recent studies have shown that imidacloprid soil injections made at the base of the trunk result in more effective uptake than applications made on grid or circular patterns under the canopy.

Imidacloprid soil drenches have also generated mixed results. In some studies conducted by MSU and OSU researchers, imidacloprid soil drenches have provided excellent control of EAB. However, in other studies, control has been inconsistent. Experience and research indicate that imidacloprid soil drenches are most effective on smaller trees and control of EAB on trees with a DBH that exceeds 15 inches is less consistent.

This inconsistency may be due to the fact that application rates for systemic insecticides are based on amount of product per inch of trunk diameter or circumference. As the DBH of a tree increases, the amount of vascular tissue, leaf area and biomass that must be protected by the insecticide increases exponentially. Consequently, for a particular application rate, the amount of insecticide applied as a function of tree size is proportionally decreased as trunk diameter increases. Hence, the DBH-based application rates that effectively protect relatively small trees can be too low to effectively protect large trees. Some systemic insecticide products address this issue by increasing the application rate for large trees.

In an OSU study with larger trees (15- to 22-inch DBH), Xytect™ (imidacloprid) soil drenches provided consistent control of EAB when applied experimentally at twice the rate that was allowed at that time. Recently, the Xytect™ label was modified to allow the use of this higher rate, which we now recommend when treating trees larger than 15-inch DBH. Merit® imidacloprid formulations, however, are not labeled for application at this high rate. Therefore, when treating trees greater than 15-inch DBH with Merit® soil treatments, two applications are recommended, either in the fall and again in the spring, or twice in the spring, about four weeks apart (for example in late April and again in late May). This is not an option for Bayer Advanced™ Tree and Shrub Insect Control and other

homeowner formulations of imidacloprid, which are limited by the label to one application per year. Homeowners wishing to protect trees larger than 15-inch DBH should consider having their trees professionally treated.

Treatment programs must comply with any limits specified on the label regarding the maximum amount of insecticide that can be applied per acre during a given year.

Trunk-Injected Systemic Insecticides

Emamectin benzoate • In several intensive studies conducted by MSU and OSU researchers, a single injection of emamectin benzoate in mid-May or early June provided excellent control of EAB for at least two years, even under high pest pressure. For example, in a highly-replicated study conducted on trees ranging in size from 5- to 20-inch DBH at three sites in Michigan, untreated trees had an average of 68 to 132 EAB larvae per m^2 of bark surface, which represents high pest pressure. In contrast, trees treated with emamectin benzoate had, on average, only 0.2 larvae per m^2, a reduction of > 99 percent. When additional trees were felled and debarked two years after the emamectin benzoate injection, there were still virtually no larvae in the treated trees, while adjacent, untreated trees at the same sites had hundreds of larvae.

In two OSU studies conducted in Toledo with street trees ranging in size from 15- to 25-inch DBH, a single application of emamectin benzoate also provided excellent control for two years. There was no sign of canopy decline in treated trees and very few emergence holes, while the canopies of adjacent, untreated trees exhibited severe decline and extremely high numbers of emergence holes.

One study suggests that a single injection of emamectin benzoate may even control EAB for three years. Additional studies to further evaluate the long-term effectiveness of emamectin benzoate are underway. To date, this is the only product that controls EAB for more than one year with a single application. In addition, in side-by-side comparisons with other systemic products (neonicotinoids), emamectin benzoate was more effective.

Imidacloprid • Trunk injections with imidacloprid products have provided varying degrees of EAB control in trials conducted at different sites in Ohio and Michigan. In an MSU study, larval density in trees treated with Imicide® injections were reduced by 60 percent to 96 percent, compared to untreated controls. There was no apparent relationship between efficacy and trunk diameter or infestation pressure. In another MSU trial, imidacloprid trunk injections made in late May were more effective than those made in mid-July, and IMA-jet® injections provided higher levels of control than did Imicide®, perhaps because the IMA-jet® label calls for a greater amount of active ingredient to be applied on large trees. In an OSU study in Toledo, IMA-jet® provided excellent control of EAB on 15- to 25-inch trees under high pest pressure when trees were injected annually. However, trees that were injected every other year were not consistently protected.

In a discouraging study conducted in Michigan, ash trees continued to decline from one year to the next despite being injected in both years with either Bidrin (Inject-A-Cide B®) or imidacloprid. The imidacloprid treatments consisted of two consecutive years of Imicide® (10% imidacloprid) applied using Mauget® micro-injection capsules, or an experimental 12% formulation of imidacloprid in the first year followed by Pointer™ (5% imidacloprid) in the second year with both applied using the Wedgle™ Direct-Inject™ System. All three treatment regimes suppressed EAB infestation levels in both years, with Imicide® generally providing best control under high pest pressure in both small (six-inch DBH) and larger (16-inch DBH) caliper trees. However, larval density increased in treated and untreated trees from one year to the next. Furthermore, canopy dieback increased by at least 67 percent in all treated trees (although this was substantially less than the amount of dieback observed in untreated trees). Even consecutive years of these treatments only slowed ash decline under severe pest pressure. In another MSU study, ACECAP® trunk implants (active ingredient is acephate) did not adequately protect large trees (greater than 15-inch DBH) under high pest pressure.

EAB larvae damage the vascular system of the tree as they feed, which interferes with movement of systemic insecticides in the tree.

Noninvasive Basal Trunk Sprays with Dinotefuran

Studies to date indicate that systemic basal trunk sprays with dinotefuran are about as effective as imidacloprid treatments. MSU and OSU studies have evaluated residues in leaves from trees treated with the basal trunk spray. Results show that the dinotefuran effectively moved into the trees and was translocated to the canopy at rates similar to those of other trunk-injected insecticides, and faster than other soil-applied neonicotinoid products.

As with imidacloprid treatments, control of EAB with dinotefuran has been variable in research trials. In an MSU study conducted in 2007 and 2008, dinotefuran trunk sprays reduced EAB larval density by approximately 30 percent to 60 percent compared to the heavily infested untreated trees. The treatment was effective for only one year and would have to be applied annually. In general, control is better and more consistent in smaller trees than in large trees, but more research is needed with larger trees. Studies to address the long-term effectiveness of annual dinotefuran applications for control of EAB are underway.

Protective Cover Sprays

MSU studies have shown that applications of Onyx™, Tempo® and Sevin® SL provided good control of EAB, especially when the insecticides were applied in late May and again in early July. Acephate sprays were less effective. BotaniGard® (*Beauvaria bassiana*) was also ineffective under high pest pressure. Astro® (permethrin) was not evaluated against EAB in these tests, but has been effective for controlling other species of wood borers and bark beetles.

In another MSU study, spraying Tempo® just on the foliage and upper branches or spraying the entire tree were more effective than simply spraying just the trunk and large branches. This suggests that some cover sprays may be especially effective for controlling EAB adults as they feed on leaves in the canopy. A single, well-timed spray was also found to provide good control of EAB, although two sprays may provide extra assurance given the long period of adult EAB activity.

It should be noted that spraying large trees is likely to result in a considerable amount of insecticide drift, even when conditions are ideal. Drift and potential effects of insecticides on non-target organisms should be considered when selecting options for EAB control.

Acknowledgements

Production and distribution of this bulletin were supported in part by cooperative agreements from the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) and the U.S. Forest Service, Northeastern Area, Forest Health Protection. This bulletin may not necessarily express the views of the USDA.

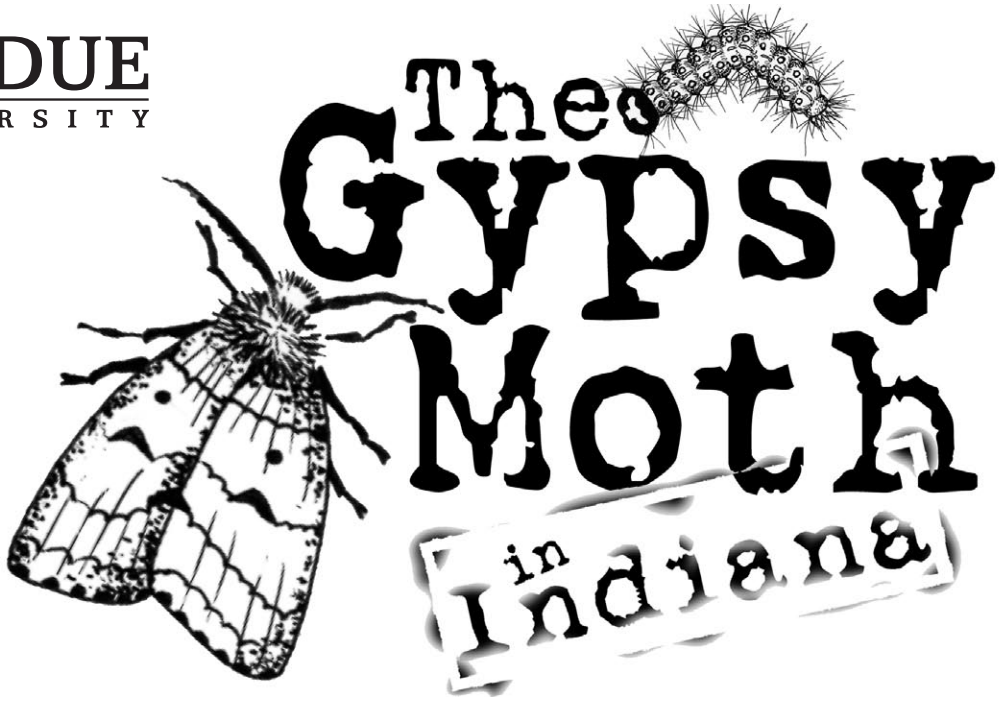
Key Points and Summary Recommendations

- Insecticides can effectively protect ash trees from EAB.
- Unnecessary insecticide applications waste money. If EAB has not been detected within 10-15 miles, your trees are at low risk. Be aware of the status of EAB in your location. Current maps of known EAB populations can be found at www.emeraldashborer.info. Remember, however, that once a county is quarantined, maps for that county are no longer updated.
- Trees that are already infested and showing signs of canopy decline when treatments are initiated may continue to decline in the first year after treatment, and then begin to show improvement in the second year due to time lag associated with vascular healing. Trees exhibiting more than 50 percent canopy decline are unlikely to recover even if treated.
- Emamectin benzoate is the only product tested to date that controls EAB for more than one year with a single application. It also provided a higher level of control than other products in side-by-side studies.
- Soil drenches and injections are most effective when made at the base of the trunk. Imidacloprid applications made in the spring or the fall have been shown to be equally effective.
- Soil injections should be no more than 2-4 inches deep, to avoid placing the insecticide beneath feeder roots.
- To facilitate uptake, systemic trunk and soil insecticides should be applied when the soil is moist but not saturated or excessively dry.
- Research and experience suggest that effectiveness of insecticides has been less consistent on larger trees. Research has not been conducted on trees larger than 25-inch DBH. When treating very large trees under high pest pressure, it may be necessary to consider combining two treatment strategies.
- Xytect™ soil treatments are labeled for application at a higher maximum rate than other imidacloprid formulations, and we recommend that trees larger than 15-inch DBH be treated using the highest labeled rate. Merit® imidacloprid formulations are not labeled for use at this higher rate. When treating larger trees with Merit® soil treatments, best results will be obtained with two applications per year. Imidacloprid formulations for homeowners (Bayer Advanced™ Tree & Shrub Insect Control and other generic formulations) can be applied only once per year.
- Homeowners wishing to protect trees larger than 15-inch DBH should consider having their trees professionally treated.
- Treatment programs must comply with any label restrictions on the amount of insecticide that can be applied per acre in a given year.

PURDUE UNIVERSITY

GM-1

The Gypsy Moth in Indiana



Clifford S. Sadof & Jodie A. Ellis, *Department Entomology, Purdue University*
Gayle R. Jansen & Robert D. Waltz, *Indiana Department of Natural Resources, Division of Entomology and Plant Pathology*

Gypsy moths, one of the most serious forest and urban landscape pests in North America, have arrived in Indiana. Gypsy moths are not native to North America. Since their accidental introduction in Massachusetts in 1869, they have spread steadily westward.

Gypsy moths were first detected in Indiana in Lake County (NW Indiana) in 1973, and have since been found in Whitley, Vigo, Elkhart, Porter, Allen, DeKalb, and Lagrange counties. It is likely that gypsy moths will gradually move into the rest of Indiana, but programs conducted by the Indiana Department of Natural Resources in conjunction with the U.S. Forest Service will help to slow the insects' spread.

Although oak leaves are gypsy moths' preferred food, caterpillars consume foliage of 500 species of trees and plants. While most trees will produce new leaves after defoliation, repeated annual defoliation may kill even formerly healthy trees in two to four years.

Because adult female gypsy moths cannot fly, natural spread of the insect occurs by other means. Young caterpillars crawl to treetops and are blown by wind. People can increase the rate of gypsy moth spread when they unknowingly carry them from infested areas. You can help reduce losses from gypsy moths as they move through Indiana in the following ways.

Slow the spread. Learn the gypsy moth's biology, how to recognize its life stages, and where it can be found so you do not transport it to uninfested parts of the state or country.

Maintain tree health. Keep trees watered, particularly during dry periods in the summer. Apply a 2-inch mulch of composted hardwood chips around the bases of your trees to prevent the wounding of trunks with lawnmowers and weed trimmers.

Diversify new plantings. When designing new landscape plantings, be sure to include some trees that are less preferred by gypsy moth. (See tree species preference list on page 2.)

Gypsy Moth Management Approach

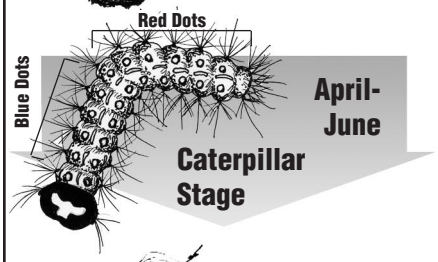
The battle to rid the Midwest of gypsy moth was lost long ago. Treating isolated infestations with insecticides ahead of the generally infested area will slow the spread of gypsy moth, but spraying insecticides will only temporarily reduce the numbers of caterpillars. The wide range of insects, diseases, and animals that feed on gypsy moth provides more long-lasting control. These natural enemies are the reason that trees and forests still thrive in areas where this pest has been present for over 100 years.

Where gypsy moth is already established in Indiana, environmentally safe tools that foster and conserve the natural enemies of gypsy moth will be used to maintain the appearance of urban forests and the health of woodland ecosystems. The Indiana Department of Natural Resources will continue the trapping program it began in 1973 to detect man-made introductions in areas where gypsy moth is not yet established in Indiana.

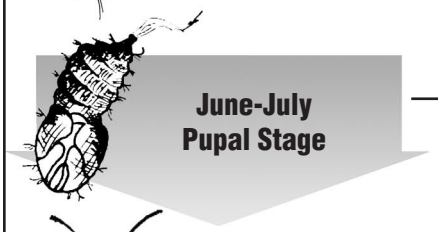
Gypsy Moth Biology and Identification

The gypsy moth goes through four developmental stages during its life: egg, caterpillar, pupa, and adult.

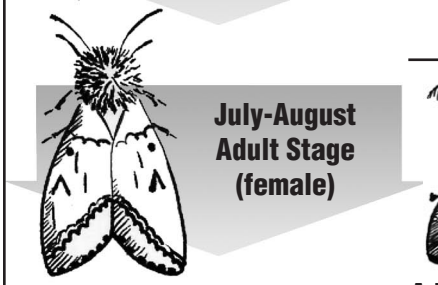
Eggs—After mating, female moths lay their eggs on any convenient surface. They hide their eggs just about anywhere, including on branches, firewood, picnic tables, tents, recreational vehicles, and automobiles. Females cover eggs in tan, furry masses coated with buff or tan-colored hairs to protect them from environmental stress. Each egg mass contains between 500 and 1000 eggs. Eggs do not hatch until the following spring.



Caterpillars—In late April, small black-headed caterpillars hatch from eggs. They then climb to the tops of trees, where they feed on foliage or dangle from silk strands until they are blown to other trees. Then they enter a second growth stage and grow to 1/2-inch long. At this time, they are largely black with irregularly shaped yellow marks visible on the upper body surface. Older caterpillars (4th - 6th instars) have distinct color markings on their backs, with five pairs of blue dots followed by six pairs of red dots. Each caterpillar consumes 11 square feet of foliage during its lifetime. Most feeding occurs at night. Caterpillars move to the base of trees and hide during daytime, which protects them from extreme heat and predation by birds. They migrate back up to the leaves at dusk where they feed until dawn.



Pupae—By early June, caterpillars stop feeding and transform into pupae, the transition stage between caterpillars and adult moths. Pupae are enclosed in brown-colored, shell-like cases that are about 2 inches long and sparsely covered with hairs. Gypsy moths do not spin webs or make cocoons.



Adult Stage (male)

Adults—Adults emerge from pupal cases in July and August. Females have creamy white wings and a tan body. Females cannot fly because their bodies are heavy with eggs. Males are smaller, dark brown, and have feathery antennae. Both have distinct inverted V-shape marks that point to small black dots on their wings.

Gypsy Moth Preference for Common Indiana Trees

Most Preferred	Somewhat Preferred	Least Preferred
Aspen *(Populus)*	Alder *(Alnus)*	Arborvitae *(Thuja)*
Apples and crabapples *(Malus)*	Balsam fir *(Abies)*	Ash *(Fraxinus)*
Birches *(Betula)*	Black walnut *(Juglans)*	Azalea *(Azalea)*
Blue spruce *(Picea)*	Butternut *(Juglans)*	Black locust *(Robinia)*
American beech *(Fagus)*	Cherry *(Prunus)*	Catalpa *(Catalpa)*
Basswood *(Tilia)*	Eastern hemlock *(Tsuga)*	Dogwood *(Cornus)*
Hawthorn *(Crataegus)*	Easter redbud *(Cercis)*	Eastern redcedar *(Juniperus)*
Hazelnut *(Corylus)*	Elm *(Ulmus)*	Horsechestnut *(Aesculus)*
Oaks *(Quercus)*	Hickory *(Carya)*	Lilac *(Syringa)*
Poplar *(Populus)*	Honey locust *(Gleditzia)*	Rhododenron *(Rhododendron)*
Sweetgum *(Liquidambar)*	Hophornbeam *(Ostrya)*	Tuliptree poplar *(Liriodendron)*
Serviceberry *(Amelanchier)*	Hornbeam *(Carpinus)*	Viburnum *(Viburnum)*
Mountain ash *(Sorbus)*	Maples *(Acer)*	
Witch hazel *(Hamamelis)*	Paw Paw *(Asimina)*	
White pine *(Pinus)*	Plum *(Prunus)*	
	Sassafrass *(Sassafrass)*	
	White and Norway spruce *(Picea)*	

Distinguishing Gypsy Moths from Other Fuzzy Caterpillars

Time of Year

Gypsy moths are only in their caterpillar stage from late April through mid-June. Other caterpillars commonly present at this time of year do not have the gypsy moth's distinctive pairs of blue and red dots.

Presence of Webs

Several web-producing caterpillars that might be confused with gypsy moths have been fairly abundant in recent years, but remember that gypsy moths do **not** produce extensive webbing.

Eastern tent caterpillars are present in April and May, but, unlike gypsy moth, they spend their days in masses of white webs in the centers of trees. Eastern tent caterpillars have distinctive white stripes on their backs and lack the gypsy moth's paired blue and red dots.

Fall webworms are white, hairy caterpillars with two rows of black spots down the middle of their backs. Clusters of these caterpillars enclose branch ends in webs which are commonly visible during late summer along roadsides.

Moving Out of Generally Infested Areas

People moving from areas infested with gypsy moths to uninfested parts of the country or state are required to inspect their household items prior to moving. They can either do the inspection themselves or hire a Qualified Certified Approved inspector (QCA). Guidelines for self-inspection are detailed in USDA APHIS Program Aid 1329, "Don't Move Gypsy Moth." This guide and a list of QCA Inspectors can be obtained from the Indiana Department of Natural Resources (317-232-4120) upon request.

FAQ's Frequently Asked Questions

Will gypsy moth kill my trees?

Not immediately and not always. If healthy oaks or other hardwood trees are completely defoliated during summer, they may appear dead but will usually recover. These trees will produce a second set of leaves, usually in late July or August, that allows them to produce enough energy to survive winter.

If trees are unhealthy to begin with or affected by other stress factors, such as drought, disease, or poor growing conditions, there is a greater chance that defoliation by gypsy moth will kill them. Repeated heavy defoliation can kill even healthy hardwood trees. Pines and spruce trees do not survive heavy defoliation, although mild defoliation does not always kill them.

Can the gypsy moth ever be completely eliminated from Indiana?

No. The gypsy moth is already established in parts of Indiana. Current efforts focus on slowing the spread to uninfested areas.

Can I get a trap for my lawn to control the gypsy moths in my yard?

No. The only traps available are sex pheromone traps. These attract males and do not kill enough moths to protect your trees.

How can I kill gypsy moths to protect my trees?

You are the first line of defense for protecting your trees from gypsy moth. Learn what gypsy moths look like, and inspect your yard for egg masses hidden on trees, firewood, and outdoor structures. Destroy those that you find. Use cloth or barrier bands to trap and kill gypsy moth caterpillars as they crawl up and down the trunks of trees.

Timely application of biological insecticides like *Bacillus thuringiensis* when caterpillars are less than 1-inch long can protect valued trees without harming natural enemies of gypsy moth and other insects. Commonly available chemical insecticides, such as Orthene, Sevin, and Malathion, will kill caterpillars when applied in accordance with label directions, but may also harm the natural enemies that keep other landscape pests from becoming problems.

How will the gypsy moth change Indiana forests?

The first wave of defoliation will cause the most substantial changes to our forests. Changes include:

- Reduction in numbers of preferred trees, such as oaks, in the forest.
- Increased surface water runoff in areas where large numbers of trees have been killed.
- Forest regeneration in open areas.

After the gypsy moth's initial pass through Indiana, subsequent outbreaks will probably not be as severe or cause as much tree damage. In states where forests have been infested for over 100 years, forests have eventually recovered from gypsy moth damage and are still standing. Forests will continue to be prominent features of Indiana landscapes long after the gypsy moth has become established.

FAQ's

How will the gypsy moth change urban areas?

The first wave of gypsy moths will cause the most alarming effects. Expect enormous populations of caterpillars dropping fecal material from trees, allergic reactions to airborne caterpillar hairs, and large numbers of pupae and egg masses plastered to homes and outdoor items.

When large numbers of gypsy moths are killed by diseases or pesticide applications, the abundance of unsightly decaying caterpillars and their associated odor will add to the nuisance. Fortunately, because gypsy moth populations cycle, these problems will not be a permanent feature of any one landscape.

My county has been quarantined for gypsy moth. What does this mean?

Counties become quarantined after small, isolated areas of infestation can no longer be eradicated. This action is designed to prevent accidental shipment of live gypsy moths to uninfested counties and thus slow the spread of gypsy moth.

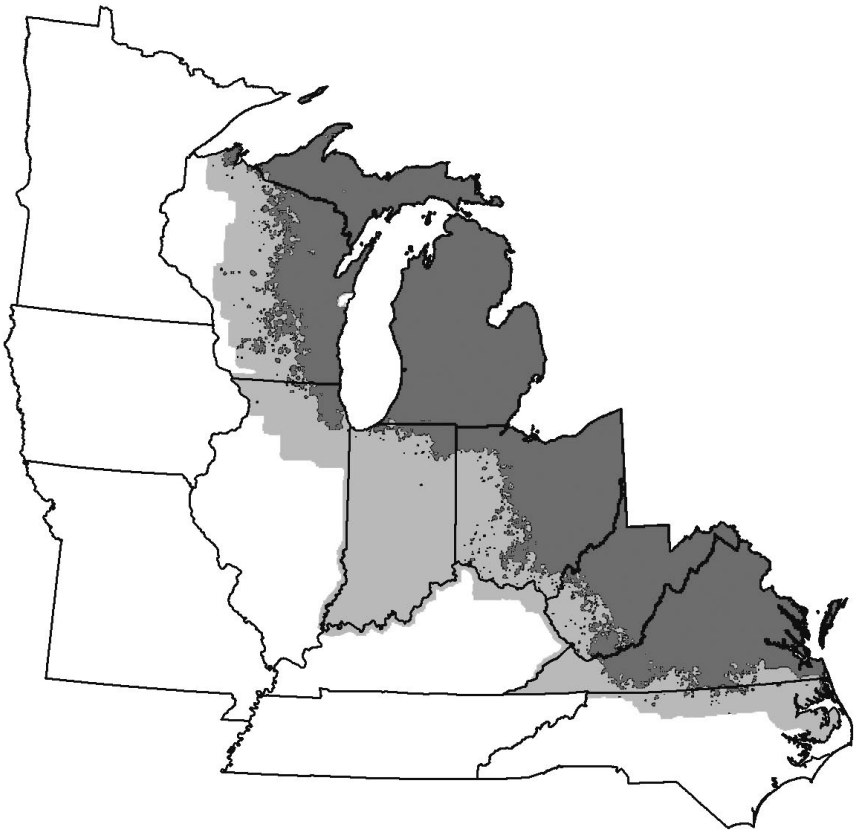
In quarantined areas, outdoor items such as lumber, Christmas trees, and nursery stock need to be inspected and certified free of gypsy moths before they're shipped to uninfested counties. Shipment within the area regulated for gypsy moth (see map) is not restricted. (Also see the section above on "Moving Out of Generally Infested Areas.")

For More Information on Gypsy Moths

- Visit Purdue Extension Entomology's Gypsy Moth Information Web site <http://www.entm.purdue.edu/g_moth/> to download free GM series bulletins and to get the latest information.
- Contact Exotic Insects Education at the Department of Entomology, Purdue University, W. Lafayette, IN, 47907-1158; (765) 494-0822.
- To report gypsy moth in your area, call the Indiana Department of Natural Resources toll-free hotline at 1-866-NO-EXOTIC (1-866-663-9684)
- Visit <www.invasivespecies.in.gov>.
- Contact your county Extension office. (Call 1-888-EXT-INFO for your county office's phone number.)

Gypsy moth detections–2003

Dark gray = areas where gypsy moth was detected
Light gray = surveyed areas
White = uninfested areas (not surveyed)



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E-27-W

Landscape & Ornamentals

Department of Entomology

BAGWORMS

Timothy J. Gibb and Clifford S. Sadof, Extension Entomologists

During July and August, bagworms may defoliate arborvitae, junipers and other trees and shrubs. Bagworms are caterpillars that live inside spindle-shaped bags which they construct to protect themselves against birds and other enemies. These bags, composed of silken threads and bits of foliage, look so much like a part of the tree that they may go unnoticed until extensive damage has occurred. Bagworms are common throughout the state.

LIFE HISTORY

Early in June, the insects hatch from eggs which wintered in the old bags attached to tree branches. As soon as the young worms appear, they start to spin bags and continue to enlarge these as they feed and grow. The caterpillars crawl part way out of the bags to feed. If disturbed, they retreat safely inside, and it is almost impossible to pull them out. Each female bag can produce over 1,000 bagworms.

Bagworms mature in late August or early September. At this time the bags are about 2 inches long and can no longer be killed by pesticides. The worms then attach the bags firmly to branches or other objects and change into the adult stage. The wingless female never leaves the bag and is fertilized by the winged male. The eggs are laid in the bag where they pass the winter. Eggs of bagworms located south of Monticello, Peru and Bluffton, or near Lake Michigan usually survive the winter. In other parts of the State, eggs can be killed during cold winters. There is only one generation each year.

Bagworm caterpillar feeding

Bagworm hanging from branch

CONTROL MEASURES

Bagworms tend to be a problem on trees that are isolated or in urban settings. When bags are found in the tree, simply pick the bagworms off and drown them in a bucket of soapy water. This method is most effective before eggs hatch out of the bags in June.

Young bagworm covering itself with leaves

Bagworms can be controlled by spraying the foliage with insecticides after eggs have hatched and small bags are seen on the trees. Caterpillars must consume the foliage for the insecticide to kill them. For best results, use a biorational pesticide listed in Table 1. The biorational materials will kill the caterpillars without killing the natural enemies of spider mites and scale insects that can cause additional damage to the plant. (See E-42-W Spider Mites on Ornamentals and E-29-W Scale Insects on Shade Trees and Shrubs). Caterpillars may have to feed on treated leaves for 1-2 days to get a lethal dose of these materials. In contrast, rescue materials can kill caterpillars feeding on the foliage within hours after application. All pesticides are most effective when directed against worms in bags that are still small. Dipel is only effective on bags < 1" long. Two weeks after any pesticide application look for live bagworms to determine if additional treatment is needed.

Alternatively, a soil application of dinotefuran may be applied to the base of the tree. Applications should be made in early May to allow enough time for this material to get into the foliage before eggs hatch. Our research has shown this product to be most effective on young bagworms. A homeowner product will be available for use in 2010.

Table 1. Pesticide List

Insecticide	Formulation	Amount per 100 gallons	Amount per gallon	Suggested Use	General Use Restriction (Check label) H=Homeowner C=Commercial
Acephate (Orthene)	75% S 15.6% EC	1/3 lb. 1 1/5 cup	1/3 tsp. 1 1/2 Tbsp.	Rescue	H, C
Bacillus thuringiensis (Kurstaki) (Dipel, Biotrol, others)	See label	See label	See label	Biorational	H, C
Bifenthrin (Talstar L&T and other site specific products	0.7 F	5.5 - 10.9 oz.	1/3 - 2/3 tsp.	Rescue	H, C
Carbaryl (Sevin and others)	4 F 2 F	1 qt. 2 qt.	2 tsp. 4 tsp.	Rescue	H, C
Chlorantraniliprol (Acelepryn)	1.67 SC	1-2 fl. oz.	-	Biorational	C
Cyfluthrin (Tempo, Decathalon) (Bayer Lawn & Garden)	20 WP 0.75 EC	1.9 oz. -	- 1 Tbsp.	Rescue	C H (Bayer)
Deltamethrin (Deltagard T&O) (Suspend SC)	4.75% EC	4 - 8 oz.	1/4 - 1/2 tsp.	Rescue	H, C
Dinotefuran (Safari)	20 G	See label	See label	Rescue	C
Fluvalinate (Mavrik)	2 F	5 - 10 oz.	1/4 - 1/2 tsp.	Rescue	H, C
Indoxacarb (Provaunt)	2.4 SC	1.2-2.5 fl. oz.	-	Biorational	C
Lambda-cyhalothrin (Scimitar CS)	9.7% EC	1.5 - 5 oz.	-	Rescue	H, C
Malathion	57% EC	2 - 4 pt.	2 tsp.	Rescue	H, C
Permethrin (Astro EC) (Spectracide Bug Stop) (Eight)	36.8% EC 2.5% EC	4 - 8 oz. -	1/4 - 1/2 tsp. 2 Tbsp.	Rescue Rescue	C H
Spinosad (Conserve) Bulls-Eye Bioinsecticide Fertilome Borer, Bagworm, Leafminer & Tent Caterpillar Spray	SC SC	6 oz. -	1/2 tsp. 4 Tbsp. 4 Tbsp.	Biorational	C H H
Tebufenozide (Confirm)	25% EC	4 - 8 oz.	1/4 - 1/2 Tsp.	Biorational	C

READ AND FOLLOW ALL LABEL INSTRUCTIONS. THIS INCLUDES DIRECTIONS FOR USE, PRECAUTIONARY STATEMENTS (HAZARDS TO HUMANS, DOMESTIC ANIMALS, AND ENDANGERED SPECIES), ENVIRONMENTAL HAZARDS, RATES OF APPLICATION, NUMBER OF APPLICATIONS, REENTRY INTERVALS, HARVEST RESTRICTIONS, STORAGE AND DISPOSAL, AND ANY SPECIFIC WARNINGS AND/OR PRECAUTIONS FOR SAFE HANDLING OF THE PESTICIDE.

Revised 11/2009

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Landscape & Ornamentals

Department of Entomology

JAPANESE BEETLES IN THE URBAN LANDSCAPE

Timothy J. Gibb and Clifford S. Sadof, Extension Entomologists

Infestations of the Japanese beetle are found in rural and urban areas throughout Indiana. This insect is most damaging to lawns, trees, flowers, fruits, and gardens in urban landscapes but may also cause economic injury to some agriculture crops.

DESCRIPTION AND HABITS

The Japanese beetle is about 1/2 inch long, and is metallic green and bronze in color with a row of white tufts (spots) of hair on each side of its body. Adult beetles are most active from mid-July through August. They can feed upon more than 300 different species of plants, but are especially fond of roses, grapes, smartweed, soybeans, corn silks, flowers of all kinds, flowering crab, plum and linden trees, as well as, overripe and decaying fruit.

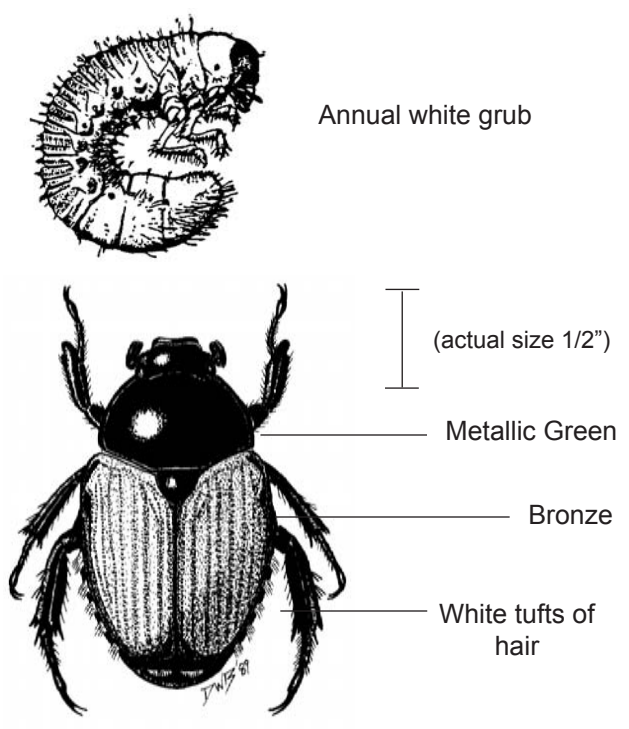
The beetle larvae (grubs) develop in lawns, turf, and cultivated land from eggs laid by the female in mid-summer. These grubs feed primarily on the roots of grasses and other plants. They pass the winter in the grub stage, complete their growth the following spring and emerge as beetles beginning in mid-June.

Adults can fly considerable distances (1-2 miles) to feed on leafy plants or to lay eggs. In areas of heavy infestation, the adults will attack and injure flowers and foliage, and the grubs may seriously damage lawns and cultivated crops by feeding on the root systems.

PROTECTING LAWNS

Control with Insecticides. Several insecticides will protect lawns from Japanese beetle grubs and other soil insects (see also *Extension Publication E-61 "Turfgrass Insect Management"* <*http://extension.entm.purdue.edu/publications/E-61.pdf*>) if applied at the proper time and according to label directions (Table 1). A rule of thumb to remember for grub control is that the smaller the grub - the easier it is to control.

Granules (G) can be applied with a fertilizer spreader calibrated to insure even distribution. Emulsifiable concentrates (EC, E) must first be diluted in water, then applied as a spray. Both spray and granular applications should be watered in for best results. Watering turf both before and after pesticide application has been shown to increase efficacy. Japanese beetle grubs hatch from eggs in late July or early August. Because they are most susceptible to insecticides at this time and also because feeding damage can be prevented, early August is the critical time to have controls in place. Also remember that insecticides are applied to protect the turfgrass from grub damage. That is why it is important to know ***IF*** grubs are present and ***WHAT DEVELOPMENTAL STAGE*** they are in at the time of application. Recent studies have shown that many grub control applications are wasted because grubs were not present in the first place. Apply controls only if a history of grub problems warrant an application or if sampling the soil indicates 5 or more grubs per square foot.



Japanese Beetle: *Popillia japonica* Newman

Table 1. Recommended Turfgrass Insecticides

Chemical Insecticides* for White Grub Control	Type of Application
Bacillus popillae (Doom, Milky Spore)	Alternative
carbaryl (Sevin)	Curative
chlorantraniliprole (Acelepryn)	Preventative, Curative
clothianidin (Arena)	Preventative, Curative
dinotefuran (Safari)	Preventative
halofenozide (Mach II)	Preventative
imidacloprid (Merit)	Preventative
thiamethoxam (Meridian)	Preventative, Early Curative
parasitic nematodes (Several trade names)	Alternative
trichlorfon (Dylox)	Curative

*Always apply according to current label directions and rates.

Preventative Applications. Preventative applications include the use of persistent chemicals that remain active in the soil for long periods of time. These may provide excellent grub control even when applied 2 months before egg hatch (early August). However, they are more effective the closer to the egg hatch date that they are applied.

Curative Applications. Curative applications are designed to control existing populations of grubs regardless of how mature they are. Curative only applications typically have less residual in the soil than preventatives but will kill the grubs more quickly after application. Irrigation also increases the effectiveness of these applications.

Alternative Applications. *Control with "Milky Disease" Spore Dust.* A specific bacterial spore dust has been shown to provide limited grub control in the soil, provided the population level is at least one grub per square foot. The spore dust is available in some garden supply stores or is available on-line. It should be applied in the spring or early fall. One treatment is usually sufficient since the bacteria that cause milky disease in the grubs continues to multiply in later generations.

Keep in mind that this material is effective **only** on Japanese beetle grubs and may require several years to provide control. Maximum results may not be seen for the first 2 to 3 years after application. Its major limitation is that it cannot be used in combination with other grub control products. Do not apply chemical insecticides to the milky spore treated areas. Insecticides drop the grub population level too low for the spores to multiply.

Control with "Parasitic Nematodes". Recent developments in the use of parasitic nematodes to control grubs has met with variable results. Under special conditions, nematodes can be effective and are a viable, environmentally sound approach to Japanese beetle grub control.

PROTECTING ORNAMENTAL AND FOOD PLANTS

Control on ornamentals with insecticides. To protect ornamentals against the feeding of adult Japanese beetles, leaves should be coated with insecticide (Table 2) during the adult flight period. Typically, this may entail 2 treatments during the peak beetle flight. Homeowners should make their first application when damage is becoming intolerable and beetles are still abundant. The need for repeated applications can be curtailed by inspecting plants for additional beetle damage prior to applying a second treatment. Neem products containing Azadirachtin can be effective repellants that can reduce defoliation when applied regularly (but no more than weekly) during beetle flight. Apply before defoliation becomes intolerable. Soil application of imidacloprid, or acetamiprid can reduce the amount of defoliation caused by adults when applied to soil at the base of a tree. Applications to the soil in late May should give enough time for the trees to take up the materials into the leaves. In years when beetle populations are very high, noticeable defoliation may occur because adults need to consume insecticide tainted leaves in order to be killed.

Concentrate control efforts on trees that are susceptible to beetles (Table 3). When possible, replant with plants that are resistant to adult feeding (Table 4). Consult Table 5 to find crabapple varieties resistant to Japanese beetle.

Control on food plants with insectides. Carbaryl, permethrin and malathion are safe to use on grapes and other food plants if harvest restrictions on the label are followed. Sevin is also available as a 5% dust to be used at the rate of 1/2 pound per 1,000 square feet.

Traps. Pheromone traps have long been used to monitor the activity of the Japanese beetle. The "Bag-A-Bug" trap utilizes both a pheromone and a floral scent to catch both sexes of the beetle. However, these traps are not recommended for beetle management because they attract more beetles than they can control, resulting in increased plant damage. Do not put traps in or near plants that are susceptible to Japanese beetle (Tables 3, 5).

Japanese beetle (white grub)

Japanese beetle (adult stage)

Table 2. Recommended Insecticides to Kill Adult Japanese Beetles on Plants

Insecticide	Formulation	Amount per 100 gallons	Amount per gallon	General Use Restriction (check label) H = Homeowner C = Commercial
Acephate (Orthene)	75% S 15.6% EC	1/3 lb. 1 1/5 cup	1/3 tsp. 1 1/2 Tbsp.	H, C
Acetamiprid (TriStar 70 WSP)	70 WSP	See label	See label	Soil application C
Azadirachtin (Various products)	Varies	See label	See label	Works as repellant
Bifenthrin (Talstar L&T and other site specific products)	0.7 F	5.5 - 10.9 oz.	1/3 - 2/3 tsp.	H, C
Carbaryl (Sevin and others)	4 F 2 F	1 qt. 2 qt.	2 tsp. 4 tsp.	H, C
Cyfluthrin (Tempo, Decathalon) (Bayer Lawn & Garden)	20 WP 0.75 EC	1.3 oz. -	- 1 Tbsp.	H, C H (Bayer)
Deltamethrin (Deltaguard (T&O))	4.75% EC	4 - 8 oz.	1/4 - 1/2 tsp.	H, C
Fluvalinate (Mavrik)	2 F	5 - 10 oz.	1/4 - 1/2 tsp.	H, C
Imidacloprid (Bayer Tree and Shrub)	2.9% C	See label	See label	Soil application H, C
Lambda-cyhalothrin (Scimitar CS)	9.7% EC	1.5 - 5 oz.	-	C
Malathion	57% EC	2 - 4 pt.	2 tsp.	H, C
Permethrin (Astro EC) Spectracide Bug Stop (Eight)	36.8% EC 2.5% EC	4 - 8 oz. -	1/4 - 1/2 tsp. 2 Tbsp.	H, C

Table 3. Landscape Plants Nearly Always Severely Attacked by Adult Japanese Beetle[1]

Scientific Name	Common Name
Acer palmatum	Japanese maple
Acer platanoides	Norway maple
Aesculus hipposastanum	Horsechestnut
Atlbaca rosea	Hollyhock
Betula populifolia	Gray birch
Castanea dentuta	American chestnut
Hibiscus syriacus	Rose-of-Sharon Shrub Althea
Juglans nigra	Black walnut
Malus species	Flowering crabapple, apple
Plananus acerifolia	London planetree
Populus nigra italica	Lombardy poplar
Prunus species	Cherry, black cherry, plum, peach, etc.
Rosa species	Roses
Sassafras albidum	Sassafras
Sorbus americana	American mountain-ash
Tilia americana	American linden
Ulmus americana	American elm
Ulmus protera	English elm
Vitis species	Grape

[1]Courtesy of Sheiner, Townsend and Potter, University of Kentucky

Table 4. Landscape Plants Relatively Free of Feeding by Adult Japanese Beetle[1]

Scientific Name	Common Name
Acer negundo	Boxelder*
Acer rubrum	Red maple
Acer saccharinum	Silver maple
Buxus sempervirens	Boxwood
Carya ovata	Shagbark hickory
Cornus florida	Flowering dogwood
Diospyros virginiana	Persimmon
Euonymus species	Euonymus (all species)
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green ash
Ilex species	Holly (all species
Jaglans cinerea	Butternut
Liriodendron tulipifera	Tuliptree
Liquidamar styraciflua	American sweetgum
Magnolia species	Magnolia (all species)
Morus rubra	Red mulberry
Popuus alba	White poplar
Pyrus communis	Common pear
Quercus alba	White oak
Quercus coccinea	Scarlet oak
Quercus rubra	Red oak
Quercus velutina	Black oak*
Sambucus canadensis	American elder*
Synga vulgaris	Common lilac

Most evergreen ornamentals, including Abies (fir), Juniperus, Taxus, Thuja (arborvitae), Rhododendron, Picea (spruce), Pinus (pine) and Tsuga (hemlock) are not attacked.

[1]Courtesy of Sheiner, Townsend and Potter, University of Kentucky

*Unmarked species undergo little or no feeding. Species marked with an asterisk may suffer occasional light feeding.

Table 5. Classes of Crabapples Based on their Resistance to Japanese Beetle[1]

Class I High Resistance	Class II Moderate Resistance	Class III High Susceptibility
Ann E.	Candymint Sargent	Adams
Bob White	David	Baskatong
Brandywine	Indian Summer	Donald Wyman
Canar	Japanese Flowering	Doubloons
Candied Apple	Molten Lava	Indian Magic
Centurion	Ormiston Roy	Liset
Harvest Gold	Profusion	Madonna
Jack	Redbud	Mary Potter
Jewelberry	Sinai Fire	Prairie Maid
Louisa	Snowdrift	Robinson
Prairiefire		Selkirk
Red Jewel		Sentinel
Sargent		Sugar Tyme
Silver Moon*		Velvet Pillar
Silverdrift		White Candle
Tea		
White Angle		
White Cascade		

[1]See ID-217 for varieties resistant to both Apple scab and Japanese beetle

*Not recommended for planting because of susceptibility to fireflight

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