An Investigation of Tree Root Biology Curricula in Two-Year Arboriculture and Urban Forestry Post-Secondary Degree Programs in the United States

by

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A Research Paper
Submitted in Partial Fulfillment of the
Requirements for the
Masters of Science Degree
in

Career and Technical Education

Approved: 2 Semester Credits

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August 4, 2011

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Title: ***An Investigation of Tree Root Biology Curricula in Two-Year Arboriculture and Urban Forestry Post-Secondary Degree Programs in the United States***

Graduate Degree/ Major: MS Career and Technical Education

Research Adviser: **Carol T. Mooney, EdD**

Month/Year: **August, 2011**

Number of Pages: **132**

Style Manual Used: ***American Psychological Association,*** **6th edition**

Abstract

This study investigated tree root biology curricula at 89 two-year post-secondary arboriculture, urban forestry, and related-disciplinary degree programs in the United States. An eighteen question survey was used to learn about arboriculture and urban forestry academic programs, tree biology courses, and the importance of forty-six topics from tree biology instructors. Thirty-nine surveys were returned for a 43.8% response rate. Eleven percent of respondents offered degrees titled Arboriculture and Urban Forestry. Most respondents represented broader programs of study: 65% Horticulture/Landscape; 20% Natural Resource Management/Environmental Science; and 4% others. Tree biology topical ratings confirm that two-year tree biology education priorities are well-aligned with industry. Tree biology content is

principally found in courses with titles other than Tree Biology; “Arboriculture” being the most commonly reported at 42% of the courses. Less than 50% of “Arboriculture” course content was devoted to the study of tree biology topics, and 10% or less of that time was spent learning about roots. A variety of textbook, printed, and electronic resources are used to support tree biology education. It is noteworthy that many respondents referred to using materials from the International Society of Arboriculture to support their tree biology education efforts.

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Acknowledgements

The researcher wishes to thank Dr. Howard Lee for guidance during the first half of this project, and Dr. Carol Mooney for encouragement and assistance in seeing it through to completion. Also, thanks to Drs. Richard Hauer and Les Werner of the University of Wisconsin – Stevens Point for providing valuable and timely insight for arboriculture and urban forestry content, and Ms. Vicki Weber for document formatting and assuring compliance with APA standards.

Special thanks go to colleagues and superiors at Mid-State Technical College for being extremely flexible and absorbing extra work throughout the process so that a strong project-oriented focus was maintained, especially Dr. Sue Budjac, Ms. Kris Buss, Dr. Debra Crunkilton, Mr. Joseph Hoffman, Mr. Al Javaroski, and Mr. Ronald Zillmer.

Heart-felt gratitude goes to Katie, Nathanael, Jeremiah, and Joseph Rudquist for their continuous support and unending patience throughout the entire process.

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Chapter I: Introduction

Tree biology is the study of all the structures, processes and functions within a tree. It is a view of a tree that zooms microscopically to the cellular level and pans macroscopically to view the collection of the whole referred to as the tree system. It is the science that reveals and explains how a tree grows, survives, defends itself against pathogens, and interacts with ecological associates and the surrounding environmental conditions. It is the study and the basic understanding of earth's largest and longest living organisms (Shigo, 1986).

The arboriculture and urban forestry profession was revolutionized by the publication of Dr. Alex L. Shigo's tree biology research in the late 1970's, and the book *A New Tree Biology* in 1986. Dr. Shigo's work has changed the way trees are viewed and treated in a significant way by clarifying how trees respond internally to wounding and how branches are attached (Shigo & Shortle, 1977). This new tree biology explained by Dr. Shigo is the science that under-pins the professional practices administered within the arboriculture and urban forestry industry today. This is evidenced by two standards embraced by the industry:

1. *Arborist Certification* coordinated by the International Society of Arboriculture (ISA) is an accreditation program based primarily on knowledge. The Arborist Certification exam focuses on all aspects of tree biology and how it translates into common practices and treatments used by professional practitioners today (International Society of Arboriculture, 2009; Lilly, 2010).
2. The *A300 Best Management Practices* published by the International Society of Arboriculture, is a collection of industry standards that define proper treatments and arboricultural practices. The latest findings and understanding of tree biology provide the

framework for these standards. Participating members throughout industry voluntarily follow these standards.

A New Tree Biology provides a foundation from which management decisions are made in arboriculture and urban forestry, but Dr. Shigo admitted that his information and work came up short on the segment hidden below-ground: the tree roots (Shigo, 1986). Tree roots are difficult to study because it takes hard physical effort to reveal them, and the subject is most often damaged or destroyed (Shigo, 1994). Early research made one conclusion clear: many secrets relating to growing healthy trees lay hidden amongst the root system and soil environment, an area that few have travelled (Shigo, 1986). Many researchers have worked to close the gap of information, research, and recommendations since the publication of *A New Tree Biology.*

The International Society of Arboriculture placed the importance of understanding roots at the forefront of industry research recently by instigating and commissioning a comprehensive literature review project. Day, Wiseman, Dickinson, and Harris (2010) completed a comprehensive summary of tree root biology literature that is published in three distinct articles *Contemporary Concepts of Root System Architecture of Urban Trees*. *Tree Root Ecology in the Urban Environment and Implications for a Sustainable Rhizosphere,* (Day, Wiseman, Dickinson, & Harris, 2010) and *Root Growth and Development Literature Review Bibliography* (International Society of Arboriculture, 2009). This three-article synopsis devoted to the topics of tree root system research demonstrates a wealth of knowledge and information, but reveals many areas related to roots that lack research and information.

There is a high demand for knowledgeable, skilled entry-level workers in arboriculture/urban forestry. In fact, the shortage of a qualified workforce is the principle

limiting factor for business growth and expansion for many arboriculture and urban forestry companies (Roose, 2007). Growth in jobs and careers in arboriculture has remained strong for the last two decades. Therefore, the need "for educated, skilled graduates" will continue to increase (Wiseman, Hoffman, Day, & Clements, 2011).

Educators across the United States play a critical role in preparing the next generation of arboriculture and urban forestry professionals and leaders (Ryan, 1981; Sydnor, 1997; Wiseman, Hoffman, Day, & Clements, 2011). One important component of this preparation is the development of a thorough knowledge of tree biology and the role which roots play in overall tree health. This level of knowledge provides the foundation for successfully entering the arboriculture and urban forestry profession.

Many researchers have surveyed, researched, evaluated, and commented on post-secondary arboriculture and urban forestry education (Andresen, 1977; Deneke, 1978; Andresen, 1981; Elmendorf, Watson, & Lily, 2005). Deneke points out that forestry and horticulture are parallel professions that did not provide an adequate focus to prepare graduates well for arboriculture and urban forestry. The principle reason is that not enough emphasis was placed on understanding tree biology and single tree management. Arboriculture and urban forestry programs are a blend of forestry and horticulture that expand on issues associated with people, urban environments, and small groupings and individual trees (Deneke, 1978). Educational programs devoted to arboriculture and urban forestry were viewed as well-focused on appropriate subject matter, there was a good balance of curricula that built an understanding about the tree and how to manage it in an urban setting, and industry involvement was considered strong and well-connected (Andresen, 1981). The number of two- and four-year degree programs with a major or minor emphasis in arboriculture and urban forestry education

have progressively grown from 43 in 1977 (Andresen, 1977) to 96 in 2009 (Wiseman, Hoffman, Day, & Clements, 2011).

Each institution has its own focus, or specialty. Comparison of syllabi reveals common ground in curricula in many areas including: tree structure and function, tree biology, tree anatomy, tree identification, arboriculture, tree benefits and values, street and park tree inventories, ordinances, municipal advisory boards and commissions, tree management plans, work planning and budgeting, funding, conflict resolution, public relations, volunteer management, land use planning and regulation, preserving trees during construction, and utility forestry (Elmendorf, Watson, & Lilly, 2005). Educators agree that these are important subjects, yet very little is known throughout industry of how tree biology is being taught to future arborists and urban foresters. The impression is that the new tree biology revealed by Dr. Shigo is being taught in very few places in the United States (Gilman, 2002).

In 2002, Elmendorf, Watson, and Lilly (2005) hosted a two-day education summit, followed up by a survey of 192 educators at the post-secondary level in the United States that offer a degree in arboriculture or urban forestry. A 71% response rate helped yield very interesting and important information. The principle research objectives were to learn about curriculum and research, barriers to teaching, and teaching techniques. Educators were consistent in their ranking of the importance of student mastery of tree biology related subjects, such as: tree structure and function, tree anatomy and physiology, decay and compartmentalization, tree condition risk management, plant identification and treatment, and tree pruning. Researchers and industry practitioners have agreed that the below-ground segment of a tree plays an important role in managing tree health. The work done by Elmendorf, et al.,

(2005) in the 2002 survey does not reveal any information to the extent in which arboriculture and urban forestry educators are focusing on the below-ground segment of tree biology.

Wiseman, Hoffman, Day, and Clements initiated an effort in 2009 to reveal more specific information about college arboriculture and urban forestry education in a project titled, *A Syllabus-based Review of Collegiate Arboriculture Course Content in the United States*. They found that courses titled "Arboriculture" focus on managing trees from "cradle to grave" "… with greater emphasis on their preservation." The five most frequently reported topics in Arboriculture courses included "pruning, disorders, tree physiology/biology, risks/hazards, and soil/nutrition," respectively. Wiseman, et al., concluded that "… frequent mention of tree physiology/biology, disorder diagnosis, soils/nutrition, and water relations suggests that these courses are well founded in the basic scientific principles underpinning sound arboricultural practices" (2009, p. 55).

Although the International Society of Arboriculture has set standards of knowledge for the arboriculture and urban forestry industry in the form of *Arborist Certification* and *A300 Best Management Practices*, Wiseman, Hoffman, Day, and Clements found that no standard exists in Arboriculture course content among participating educational institutions in the United States. There were no significant differences between the content in Arboriculture courses in two-year and four-year programs. What is taught in Arboriculture courses "… may be more a function of an instructor's education and training, personal experiences, and preferences" (p. 52). They go on to conclude that "… we still do not know to what depth course topics are being taught or how conducive instruction is to student learning" (Wiseman, et al., 2011, p. 56).

Statement of the Problem

There is a lack of information on what two- and four-year arboriculture and urban forestry programs are including about the below-ground segment of tree biology curriculum.

Purpose of the Study

The principle focus of this research topic is to learn the extent in which the two-year post-secondary classrooms at arboriculture and urban forestry programs in the United States are teaching tree biology. Much of the arboriculture and urban forestry curricula research work has focused on four-year degree programs. Additionally, the consensus is that understanding tree biology and roots is important, yet little has been done to evaluate the extent to which tree biology is taught over the course of a student's educational experience in post-secondary education. This investigation was undertaken to learn about tree root biology curricula in arboriculture and urban forestry two-year programs in the United States.

Research Objectives

The following research objectives were addressed in this study:

1. How many two-year colleges in the United States offer tree biology coursework within arboriculture and urban forestry or related degree curricula?
2. What is the title of the principle course in which tree biology topics are taught?
3. How many credits is the tree biology course worth?
4. When do students encounter this tree biology course within their educational career?
5. What topics are covered in tree biology-related courses?
6. How much of the tree biology coursework is devoted to the study of roots?

7. What resources, including textbooks, printed publications and resources, and electronic resources, are being used to help support tree root biology education?
8. How many two-year colleges in the US offer a degree with arboriculture and urban forestry as the major area of study?
9. How many two-year colleges in the US offer a related degree with arboriculture and urban forestry as a minor area of study?

Importance of the Study

A thorough understanding of tree biology and roots is important to managing trees in an urban-setting and developing a successful arboriculture and urban forestry career. It is not well-known to what extent this subject area is being taught at the post-secondary level. Findings will help all aspects of arboriculture and urban forestry education, including administration of degree programs and curriculum, educational delivery of tree root biology courses, educational experiences available for students, and opportunities for researchers. Industry, too, will benefit from a more concise understanding of tree biology and root education in many ways. These include:

1. Education administrators will benefit from the information from this research in two ways. First, it provides information from across the United States which may aid curriculum assessments and quality review processes of arboriculture and urban forestry educational programs. Second, this research may assist organizations in the process of curriculum development and program expansion in arboriculture and urban forestry.
2. Educators in two- and four-year arboriculture and urban forestry education will benefit from this research in many ways. As a whole, educators in arboriculture

and urban forestry are fragmented and not well connected. This project may increase communication among education professionals. It provides an opportunity to share information, resources, techniques, and activities that may bolster tree root biology education for post-secondary students. The information derived from this research may reveal important gaps in educational needs, or shortages of resources.

3. Arboriculture and urban forestry students stand to benefit from this research by an improved educational experience. Education may improve by educators sharing successes and learning from others' weaknesses. Future graduates may be better prepared to enter the workforce armed with a better understanding of tree biology and roots.
4. Researchers may also benefit from additional information about arboriculture and urban forestry education in the US. This specific research project will help expand the view of what is happening in education at the two-year post-secondary level in the delivery of tree root biology. It may reveal important areas and topics which need further attention and research.
5. This research project may provide the arboriculture and urban forestry industry with a better understanding of how students at the two-year level are being prepared in tree root biology. The hope is that this information will improve the quality of education for all, resulting in graduates that are better prepared to enter the arboriculture and urban forestry profession. This project will provide helpful information and educational methods that may be used in continuing education for existing workers in the industry, too.

Limitations of the Study

Limitations of the study are:

1. This project is an investigation of tree root biology curricula at the two-year post-secondary level. There are varying degrees offered at the two year level including a one-year Diploma, one-year Certificate, and an Associate Degree. Although the topic is constant, the degree of difficulty of the instruction may vary depending upon the degree being offered or pursued by the student.
2. The target participants for this research are faculty teaching tree root biology in the classroom setting at a two-year arboriculture and urban forestry or related degree program. The individual responding to the survey is a variable because they may misunderstand the survey, provide incomplete information, or may not be the best person to provide the information.

Definitions

Arboriculture: Is a subset specialty of horticulture that focuses on "the planting, care, and scientific cultivation of trees and woody vegetation in a non forest context." (Helms, 1998)

Associate Degree: Is a credential earned by students attending a technical college, community college, or other post-secondary institution for a two-year period. Most coursework is centered on a specialty, but some general education and elective courses are required to round out the students' educational experience. Students must complete approximately 60 - 70 credits, depending on the institution, to fulfill the degree requirements.

Certificate: Is a career-focused credential earned by students attending a technical college, community college or other post-secondary institution for one or two semesters.

Students must complete 10 – 20 credits of coursework focused on their chosen specialty to earn this credential.

Diploma: Is a discipline-centered technical degree earned by students attending a technical college, community college, or other post-secondary institution for one or two semesters. Students must complete 10 – 20 credits of coursework considered essential to their career specialty to earn a diploma.

International Society of Arboriculture (ISA): Is an international organization, founded in 1924, that serves professionals in the arboriculture and urban forestry industry. The mission of the ISA is "…Through research, technology, and education, the International Society of Arboriculture promotes the professional practice of arboriculture and fosters a greater worldwide awareness of the benefits of trees" (International Society of Arboriculture, 2011, para. 1).

Urban forestry: Is a subset of forestry that "is the art, science and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society" (Konijnendijk, Ricard, Kinney, & Randrup, 2006, p. 94).

Chapter II: Literature Review

Tree biology is the science of all of the parts and the processes that occur in a tree. Tree roots are considered to play a critical role in the health and function of trees. However, very little is known about roots. The arboriculture and urban forestry industry is a profession dependent upon a fundamental understanding of tree biology. Arboriculture and urban forestry is an economically significant industry in the United States. Continued growth and expansion have occurred and are forecasted to continue, despite recent tough economic times. A consistent demand exists for a trained, skilled workforce to enter the arboriculture and urban forestry profession. Colleges and universities play an important role in supplying candidates for this industry. Some research has been done to assess arboriculture and urban forestry education in the United States. The topic of tree biology has been rated as high and an important topic to include in arboriculture and urban forestry education. No research has been done prior to this project, looking specifically into tree root biology education in the United States.

In *A New Tree Biology*, Dr. Alex L. Shigo describes tree biology as the study of all the structures, processes and functions within a tree. It is a focus on the biology of trees from a molecular and cellular level, and expands the view to include the entire collection of parts and processes. It is a science that reveals and explains how a tree grows, survives, defends against pathogens, and interacts with ecological associates and surrounding environmental conditions. (Shigo, 1986, p. 51).

Alternate terms have been commonly used to describe aspects of tree biology. For example, tree structure, tree anatomy, and tree morphology are used as titles for the study and naming of the internal and external parts of a tree. Tree function and tree physiology are used to

describe the physiological, chemical, and biological processes that occur within a tree. Tree biology is an inclusive term to describe all aspects of this science.

Professions Reliant Upon Tree Biology Knowledge

Knowledge of the science of tree biology is put into practice by professionals in the industry known as arboriculture and urban forestry. Arboriculture is an industry and profession devoted to "… the cultivation of woody plants, particularly trees, shrubs, and vines" (Harris, Clark, & Matheny, 2004, p. 1). It is considered a subset of horticulture (Acquaah, 2005, p. 8). Urban forestry, on the other hand, is considered a specialty within forestry and focuses on managing groups of trees and individual trees in urban areas. Arboriculture and urban forestry have so many similarities that … "Rather than try to split the two fields along artificial lines, we embrace the overlap between the two and build on the common ground they share" (Harris et al., 2004, p. 6).

Practitioners within arboriculture and urban forestry are referred to as arborists and urban foresters. "Many arborists consider themselves urban foresters and vice versa" (Harris et al., 2004, p. 6). "An arborist [and urban forester] by definition is an individual who is trained in the art and science of planting, caring for, and maintaining individual trees" (International Society of Arboriculture, 2011, "What is a Certified Arborist?" para. 1).

Tree Biology Education

A solid understanding of tree biology is "essential" to a practicing arborist and urban forester (Harris, Clark, & Matheny, 2004, p. 13). "Like physicians, arborists use knowledge of tree growth and development to diagnose problems, assess potential, and prescribe treatments" (Lilly, 2010, p. 3). Lilly goes on to point out what professional arborists and urban foresters

must know and that they understand their subject well, and that begins with a thorough understanding of tree biology.

A New Tree Biology revolutionized the arboriculture and urban forestry industry by providing clarity to the scientific understanding about how trees respond internally to wounding and how branches are attached (Shigo & Shortle, 1997). *A New Tree Biology* has become generally accepted as an important standard of knowledge about trees within the arboriculture and urban forestry industry. This is evidenced in two prominent ways.

First, the International Society of Arboriculture (ISA) maintains a voluntary, professional accreditation program called "Arborist Certification." It is a credential that is intended to distinguish a professional arborist from all others. Attaining this credential demonstrates a high level of professionalism and knowledge, and a commitment to continuing education (International Society of Arboriculture, 2009). Tree biology is a separate and distinct chapter within the publication *Arborists' Certification Study Guide* and on the arborists' certification exam. Knowing the parts of a tree and what they do, or tree biology, provides the foundation for understanding other subjects in the "Arborist Certification" program, like Tree Nutrition and Fertilization, Installation and Establishment, Pruning, Tree Support and Lightning Protection, Diagnosis and Disorders, Plant Health Care, Tree Assessment and Risk Management, and Trees and Construction (Lilly, 2010).

Second, the International Society of Arboriculture has published a series of "A300 Best Management Practices" to outline the standards for practices in arboriculture and urban forestry. Adhering to these standards is voluntary. This series of publications details the best "science" to date as it relates to planting, pruning, fertilizing, support systems, etc. The science that

underpins these publications is revealed, in a large part, in *A New Tree Biology* and expanded on in another book by Dr. Shigo called *Modern Arboriculture* (Shigo, 1991).

Despite all this work, there is a distinct lack of information and research about an important segment of tree biology; namely, the roots. Dr. Shigo admitted that his information and work came up short relative to the root systems of trees (Shigo, 1986, p. 201). "Healthy roots must also be included, for without them proper branch and foliage growth cannot continue" (Pirone, Hartman, Sall, & Pirone, 1988, p. 15). Tree biology, physiology, and arboriculture reference books all cover the subject of roots. However, the amount of information is limited and is minimal in proportion to the segment of the tree that is visible above ground. Dr. Shigo explains that it is extremely difficult to study roots. They are hidden by soil, it is hard and messy work to expose a trees' root system, and larger trees will suffer, or even die, when the soil and roots are disturbed (Shigo, 1994, p. 201). As a result, there is no specific text or reference that captures the subject of tree root biology well in comparison to the information available about the portion of the tree above ground.

Efforts are underway to close the gap of knowledge and research about roots. Research is increasing as evidenced by the number and frequency of informational and educational articles published in industry publications like the *Journal of Arboriculture and Urban Forestry*, *Arborist News*, and *Tree Care Magazine*. A series of three separate industry conferences devoted specifically to tree roots have been held and the proceedings published under the title The Landscape Below-ground I, II, and III (International Society of Arboriculture, 1994; International Society of Arboriculture, 1998; International Society of Arboriculture, 2004).

The International Society of Arboriculture recently initiated a literature review project devoted to compiling all the research documents and publications devoted to tree roots. The

results of this effort are compiled in a three article summary by *Contemporary Concepts of Root System Architecture of Urban Trees* (Day, Wiseman, Dickinson, & Harris, 2010). *Tree Root Ecology in the Urban Environment and Implications for a Sustainable Rhizoshpere* (Day, Wiseman, Dickinson, & Harris, 2010) *and Root Growth and Development Literature Review Bibliography* (International Society of Arboriculture, 2009).

Contemporary Concepts of Root System Architecture of Urban Trees is an article that sets out to accomplish three primary objectives: provide a thorough summary of current knowledge about the physical and structural-side of tree root systems and how they form, "identify gaps" in understanding and research related to tree roots, and "propose areas where further research is priority" (Day, Wiseman, Dickinson, & Harris, 2010, p. 149). *Tree Root Ecology in the Urban Environment and Implications for a Sustainable Rhizosphere* presents the latest knowledge and research of the processes and functions that comprise the ecology of the tree root system and soil environment. "Current advances and implications for emerging research are discussed" as well (Day, et al., 2010, p. 193). *Root Growth and Development Literature Review Bibliography* is a thorough compilation of known urban forest belowground/tree root research to date (International Society of Arboriculture, 2009).

Trained Workers/Labor Market Needs

Recent studies have evaluated the economic impact of the tree care industry in the United States and economic patterns in arboriculture (Hall, Hodges, & Haydu, 2005; O'Bryan, Straka, Templeton, & Caldwell, 2007). They conclude that business and job growth would continue in arboriculture and urban forestry above the national average in spite of recent economic down-turns. Ryan explains this in an August 2005 article for *Tree Care Magazine* …

> Commercial tree care is inflation-proof. The amount of work may go up and down depending on the economy, but if you have a dead tree in your yard, it's got to come down. There'll always be work, because there are trees out there, and we're the people who have got to do the work on them. (Rattigan, 2005, p. 26)

Consistent growth in the arboriculture industry means the need for an increase in workforce to carry out the work. The United States Department of Labor, Bureau of Labor Statistics has forecast an increase in workforce for the job classification "Tree Trimmers and Pruners" by 27.4% from 2008 to 2018. This forecast is slightly higher than the 26.7% increase of all occupations over the same period (United States Department of Labor, Bureau of Labor Statistics, 2010).

The arboriculture and urban forestry industry increasingly needs a knowledgeable, educated workforce. In the paper, *Responding to Workforce Challenges in the Tree Care Maintenance & Removal Industry*, Kristi Roose describes the impact of training and education and its' effects on success. A trained arboriculture workforce is safer and leads to greater employee retention (Roose, 2007). Knowledgeable workers are better positioned to respond to the demands of urban tree populations. National disasters like hurricanes, ice storms, etc. demand an efficient and thorough response from tree care experts in restoration efforts. Imported tree insect pests and diseases continue to threaten populations of urban trees in the United States. Knowledge and training in these areas is essential in the efforts to controlling these predators (Roose, 2007).

A survey was conducted in 1984 to learn about employer perspectives on arboriculture education. Although there was a difference between employers from private and public sectors, the themes are similar (McPherson, 1984). A majority of respondents to this survey, public and

private, ranked the following subject areas as important: identification and selection, botany and plant physiology, insect and disease diagnosis and treatment, and tree care techniques (like planting, pruning, fertilizing). An educational background that includes these subject areas is essential to individuals entering the arboriculture and urban forestry industry (McPherson, 1984).

Throughout much of its history, there has been a shortage of trained, skilled and qualified workers to fulfill the needs of the consistently expanding tree care industry (Roose, 2007). This condition has led some to conclude that it is the single limiting factor for the growth of many tree care businesses in the United States (Sydnor, 1997; Penn-Del Chapter, 2001). As a result, employers have been forced to hire unskilled and inexperienced workers and train them on the job. This is very expensive to individual employers and leads to unsafe conditions for an already dangerous profession. One result is a high turnover rate of 25%. Employees discover they do not like the field, or they move to another arboriculture company they like better after they have been trained in (Roose, 2007). This is obviously a loss of investment and time by the employers that provide this training on the job.

Formal educational institutions offering two- and four-year degrees in arboriculture and urban forestry have an important and continuing role to play in meeting the workforce needs of the tree care industry (Wiseman, Hoffman, Day, & Clements, 2011). Much study and resulting research has been published in the area of arboriculture and urban forestry education in recent years. There is a long history of formal education in arboriculture and urban forestry. Elmendorf, Watson, and Lilly (2005) found that "… the care of trees and other plants has been a part of U.S. university curricula since the initial founding of colleges and universities" (p. 139).

The International Society of Arboriculture maintains a database listing of two-and four-year colleges and universities across the United States that offer a degree or coursework in

arboriculture and urban forestry. The author visited the International Society of Arboriculture's website to view this database and made the following observations on August 3, 2010. There are currently 204 institutions listed; 34 offer degrees that specifically focus on arboriculture and urban forestry. The remainder offer related degrees and include coursework or a minor focus in arboriculture and urban forestry (International Society of Arboriculture, 2010).

Elmendorf, Watson, and Lilly (2005) published a 2003 study of arboriculture and urban forestry curricula in the United States titled, "Arboriculture and Urban Forestry Education in the United States: Results of an Educator Survey." The effort began as a two-day educator summit hosted during the 2002 International Society of Arboriculture annual conference in Chicago, Illinois. This summit brought together educators and a variety of industry representatives "… to discuss curriculum and research, barriers to teaching, and teaching techniques" (Elmendorf et al., 2005, p. 140). A limited number of educators were present at the summit, so a follow up survey was mailed to gather similar data from educators not in attendance. This effort included two-year and four-year arboriculture and urban forestry post-secondary education programs in the United States. Out of the 192 surveys initially mailed, 136 surveys were returned, totaling a 71% response rate (Elmendorf, et al., 2005). A number of interesting findings resulted from this effort.

Educators ranked the importance of a variety of urban forestry educational topics. The study lists the top fourteen topics in order: tree planting (98%), tree pruning (97%), tree selection (95%), tree soil/water relations (93%), tree structure/decay (92%), plant insect identification (92%), tree identification (90%), preserving tree in construction (89%), tree risk management (88%), tree anatomy and physiology (88%), tree nutrition (85%), safe work practices (85%), ethics (84%), and urban forest management (80%). (Elmendorf et al., 2005)

This ranking of urban forestry educational topics emphasizes the importance of a thorough knowledge of tree biology as a foundation to understanding and mastering most of these topics for students. The number one ranked topic is tree planting. Planting a tree is a simple action. However, this high ranking implies the importance of understanding the biology of the root system of trees.

Elmendorf et al. (2005) found that "… seventy-two percent of respondents agreed that the ISA Certified Arborist test is a valid and reliable test. Eighty-seven percent thought that certification helped provide unifying standards …" (p. 143). This finding is a confirmation of the status of the International Society of Arboriculture arborists' certification as an industry standard among those that participated.

Participating urban forestry educators felt that their educational efforts effectively met the needs of industry employers (Elmendorf et al., 2005). There is a strong working relationship between academics and industry (93% felt relationship was strong), and practitioners are actively involved in assisting educational programs (81% ranking to support his point) (Elmendorf et al., 2005). Two studies of the opinions of industry representatives confirm this point (McPherson, 1984; Penn-Del ISA Chapter, 2001). However, both studies gathered information from a localized perspective and are not necessarily generalizable to the population of arboriculture/urban forestry employers nationally. More research is needed to discover whether or not educator perceptions in the Elmendorf et al. (2005) study are accurate.

In 2011, another arboriculture and urban forestry education-focused research project was summarized assessing arboriculture and urban forestry education in the United States by Wiseman, Hoffman, Day, and Clements (2011) titled *A Syllabus-based Review of Collegiate Arboriculture Course Content in the United States.* The perspective of Wiseman, et al. (2011)

was "… even though educators tend to agree on some fundamental aspects of arboriculture education (see discussion of Elmendorf et al., 2005), the actual selection of classroom topics can be very much a function of an instructor's personal experiences and preferences ..." (p. 52). This effort specifically looked at courses with the term "Arboriculture" for the title.

Wiseman, et al., (2011) found that the content included in arboriculture course syllabi was very similar to the ranking of topics found by Elmendorf et al., (2005). Also, two-year and four-year colleges were very comparable in the topics included in an arboriculture course. Results were unclear in this study about teaching methods employed for arboriculture courses. An inference was made that current arboriculture courses are more theory-based, as opposed to practical or application-based.

Important pieces of information are missing in this review of Arboriculture course content by Wiseman, et al., (2011) There is no reference or discussion related to a prerequisite course, or set of courses, required for student enrollment in Arboriculture. As a result, it is unknown whether Arboriculture serves as a foundational course that leads to another course (or series of courses) of greater complexity; or, if an Arboriculture course is the culmination of an arboriculture and urban forestry students' education. Specifically, tree physiology/biology content is ranked as the third highest topic covered in Arboriculture syllabi. However, it remains unclear whether this course is the principle place students' gain this critical information within the larger context of arboriculture and urban forestry education and curricula. Lastly, there is no mention to the extent in which roots are studied.

Wiseman, et al., (2011) concluded by recommending that further study is needed to better understand "… the depth to which topical instruction occurs [in arboriculture education]" (p. 56). This further study is recommended within each local chapter of International Society of

Arboriculture to assess the degree to which arboriculture education is meeting the needs of students and the profession (Wiseman, et al., 2011).

Summary

An arborist and urban forester have been likened to a doctor for trees. Tree biology is the science of understanding trees and what makes them live. More arborists and urban foresters with tree biology training will be needed to keep pace with the employment demand as the arboriculture and urban forestry industry continues to grow. Colleges and universities across the United States are a good place to go to find people with this essential background. Some research has been done to understand how the next generation of arborists and urban foresters are being prepared for successful careers. This project, *An Investigation of Tree Root Biology Curricula in Two-Year Arboriculture and Urban Forestry Post-Secondary Degree Programs in the United States*, was the first to specifically study tree root biology education at the two-year post-secondary level in the United States.

Chapter III: Methodology

The methods and procedures used in this investigation of tree root biology curricula in two-year arboriculture and urban forestry post-secondary education in the United States are explained in this chapter under the headings of research objectives, research design, description of sample, selection of sample, instrumentation, data collection procedures, method of analysis, and limitations of method, sample, and procedures.

Research Objectives

The following research objectives were addressed in this study:

1. How many two-year colleges in the United States offer tree biology coursework within arboriculture and urban forestry or related degree curricula?
2. What is the title of the principle course in which tree biology topics are taught?
3. How many credits is the tree biology course worth?
4. When do students encounter this tree biology course within their educational career?
5. What topics are covered in tree biology-related courses?
6. How much of the tree biology coursework is devoted to the study of roots?
7. What resources, including textbooks, printed publications and resources, and electronic resources, are being used to help support tree root biology education?
8. How many two-year colleges in the United States offer a degree with arboriculture and urban forestry as the major area of study?
9. How many two-year colleges in the United States offer a related degree with arboriculture and urban forestry as a minor area of study?

Research Design

This study employed the descriptive research method by developing and distributing a survey as a way of gathering data and information about tree root biology curricula in two-year arboriculture and urban forestry post-secondary programs in the United States. This effort was to learn from the instructors that are directly involved in tree biology education about their courses, the resources they use to teach, their perspective on which tree biology topics are important, and their overall degree programs. A copy of the survey that was distributed is attached in Appendix A.

Description of Subjects

The subjects selected for this study included one instructor at each of the two-year arboriculture, urban forestry, and related post-secondary degree programs in the United States. The individual selected to receive the research instrument was the one known to teach the tree biology course(s) at each institution, or was the one most likely to be involved in tree biology education. Names of individuals were retrieved from the Davey Tree Expert Company's college/university contact list (M. Noark, personal communication, 2011), college/university web page searches (*Associate degrees and majors*, 2011), and personal communications by the research investigator.

Selection of the Sample

The entire population of tree biology instructors in two year arboriculture, urban forestry, and related post-secondary degree programs in the United States was selected as the sample for this study because the list is small, 89 in total. The following is a description of criterion used in developing the sample population for this study.

The principle focus for sample selection was to identify faculty directly involved in teaching about tree biology within arboriculture and urban forestry curricula in the United States. Institutions offering a two-year degree in arboriculture, urban forestry, horticulture, landscape management, or natural resource management were selected from three primary sources:

-The personnel recruiting staff with the Davey Tree Expert Company corporate office; (M. Noark, personal communication, March 24, 2011)

- *CampusExplorer.com*, an internet search engine that enables users to filter United States colleges and universities for associate degree programs in arboriculture, urban forestry, horticulture, landscape management, and natural resource management (*Associate degrees and majors*, 2011),

-The International Society of Arboriculture's *Arboriculture and Urban Forestry College and University Directory* provided on their website. (International Society of Arboriculture, 2011)

Further investigation was conducted to refine the list of subjects to include in the research project, along with contact information. It was necessary to identify one person to contact at each of the targeted institutions; the person most likely to be involved in teaching tree biology. This was accomplished by visiting each institutional program-area web site. Follow-up phone calls were made or email correspondence sent to discern which faculty member to include in this project. The final list of 89 individuals included 24 from colleges that offer an arboriculture and urban forestry degree, 12 that offer a related degree with an area of emphasis or minor in arboriculture and urban forestry, and 53 from colleges that offer a related degree and included a course in arboriculture or urban forestry. See Appendix B for the complete list of individuals included in this study.

The initial distribution list of subjects was then tested by sending a letter of introduction for the project via email (see Appendix C). The goal was to check the email addresses to make sure they worked correctly. In addition, participants were asked to reply to the letter of introduction if they were not the person most directly involved in tree biology education at their school. One person replied to provide a referral to a colleague more involved in tree biology education. Six email addresses were incorrect and were fixed.

Instrumentation

Content Description/Construction - An electronic survey was created and distributed, titled *Tree Root Biology Curricula Survey*, to gather information and data about tree biology curricula in two-year arboriculture and urban forestry education in the United States (Appendix A). This approach was selected for this project rather than postal mail service for two primary reasons. First, electronic surveys provide an effective means to gather research data and may provoke a good response rate yielding powerful information. In addition, it is generally thought that most colleges and universities and their faculty and staff have switched to electronic means of communication to keep pace with technological developments today. (Dillman, Smyth, and Christian, 2009) Second, electronic survey distribution has significant cost savings and does a better job of conserving resources than printed surveys and postal mail service distribution.

A computer software product called Qualtrics was used for the *Tree Root Biology Curricula Survey* development and distribution. Qualtrics was the product selected for this project because it is provided and supported by the University of Wisconsin-Stout for graduate student use in conducting research.

Development of a new survey was necessary because no known survey previously existed that specifically addressed the interests, focus, and needs for this project. Previous

efforts to study urban forestry curricula were done in person (Elmendorf, Watson & Lilly, 2005) or by phone (Wiseman, Hoffman, Day & Clements, 2011).

The survey included a total of eighteen distinct questions designed to gather information and data related to the research objectives for this study.

1. Does your curriculum offer a course (or courses) that address Tree Biology topics taught by faculty within your program area?
2. Have you taught Tree Biology topics for your school's arboriculture/urban forestry program in the last two years?
3. What is the title of the course, how many credits is it, and when do students encounter it within their curriculum.
4. How much of the overall class is devoted to Tree Biology topics?
5. How much of the Tree Biology topics specifically focus on the study of roots?
6. How do you use these books to teach Tree Biology in this specific course?
7. Do you use any other printed resources to teach Tree Biology?
8. Please list the titles and author's name(s) for any other printed resources used to teach Tree Biology.
9. Do you use electronic resources to teach Tree Biology related topics?
10. Please list electronic resources used to teach Tree Biology.
11. Importance of Growth Processes in my Curricula.
12. Importance of Structure/Anatomy in my Curricula.
13. Importance of Functions/Processes in my Curricula.
14. Importance of Concepts, Hypotheses, and Theories in my Curricula.

15. Does your school/institution offer diploma(s), certificate(s), or degree(s) in Arboriculture or Urban Forestry?
16. Please note the credential(s) students earn in Arboriculture or Urban Forestry from the list below.
17. Does your school/institution offer a diploma(s), certificate(s), or degree(s) related to Arboriculture or Urban Forestry?
18. Please check all of the credential(s) students may earn through your school/institution related to Arboriculture or Urban Forestry from the table below.

The survey for this study was designed to employ descriptive statistics to analyze and summarize the data. Questions 1 – 10 and 15 – 18 were set up to provide statistical frequencies and categorical lists of information. Questions 11 – 14 were designed to gain insight into the importance of tree biology topics to each individuals program. A system of Index Scores were established to discern each instructors perception; 0 = Not Important, 1 = Low, 2 = Moderate, and 3 = High. Respondents were provided with a fourth choice titled "Unsure" that had no Index Score rating. The mean Index Score was calculated for each topic and a Weighted Index Score was calculated for each of the four topical categories.

Validity and Reliability Discussion – Questions were carefully written to make the meaning simple and clear. Simplicity and clarity have a direct relationship with motivation to participate and the quality of resulting data (Dillman, Smyth & Christian, 2009). The survey was developed by the research investigator with close direction from the project research advisor. Input was solicited from two research and tree biology specialists. The survey went through three stages of editing and revising to produce a final draft.

The final draft of the survey was field-tested by a committee of tree biology and research specialists organized specifically for this project. The survey was reviewed for functionality, readability, and content. Feedback and findings were incorporated to finalize the survey used for this research project.

The survey was evaluated by the University of Wisconsin-Stout, Institutional Review Board (UW-Stout, IRB) to check for potential harm to participants. Formal approval was granted by the UW-Stout, IRB on April 6, 2011 providing the basis in which to proceed with the survey distribution and data collection (Appendix D). A copy of the final version of the *Tree Root Biology Curricula Survey* is found in Appendix A.

Data Collection Procedures

Eighty-nine surveys were distributed using the survey software, Qualtrics. Thirty-nine surveys were completed and returned yielding a 43.8% response rate. Eight others were partially answered but left un-submitted and, as a result, were excluded from the results for this project.

Eight distinct contacts were implemented in attempts to motivate and encourage participation.

1. Prior to survey distribution, an introductory letter was sent on April 25, 2011 to all individuals on the mailing list explaining the project, requesting their participation, and presenting benefits to themselves and the arboriculture and urban forestry industry (Appendix C).
2. A letter with a link to the survey was distributed via email to all individuals on the mailing list on April 27, 2011 (Appendix E).
3. The first follow up letter was subsequently emailed with a link to the survey on May 4, 2011 (see Appendix F).

4. The second follow up letter was emailed with a link to the survey on May 11, 2011 (Appendix G).
5. The third follow up letter was emailed with a link to the survey on May 18, 2011 (Appendix H).
6. The fourth follow up letter was emailed with a link to the survey on May 24, 2011 (Appendix I).
7. The fifth follow up letter was emailed with a link to the survey on May 26, 2011 to remind individuals that had not yet responded to do so (Appendix J).
8. A final letter encouraging participation was emailed with the survey link on June 1, 2011 (Appendix K).

A thank you letter was emailed on June 3, 2011 to all that participated for sharing their time and for their willingness to help with this research project (Appendix L). The survey officially closed at the end of that day.

Method of Analysis

A data analysis plan was developed by University of Wisconsin-Stout research staff with input from the research investigator and research advisor (Appendix M). Descriptive statistics were used on all the data to summarize and report the results. The principle method of analysis was to compile a database of responses and note the frequencies and percentages of responses to the different questions. Themes and conclusions about the data were drawn and inferred from using these methods of analysis. Statistical means were calculated for the Index Scores provided to the forty-six topics included in Questions 11 – 14 of the survey (Appendix N).

Limitations

Limitation of method - The descriptive research method may yield information that is too vague to be meaningful, or information that is already widely known.

Limitation of the sample – Addresses listed for individual instructors may be incorrect and surveys may be delayed in arriving, or not make it at all. The individuals that received the survey may or may not be the best person to provide the information. For example, faculty may resign or retire. The programs they represented may no longer have an arboriculture or urban forestry instructor on staff. The individual that completes the survey may not be the instructor involved in teaching tree biology topics.

Limitations of procedures - Timing of the year in which the survey was sent may hinder the response rate because instructors are too busy, away on a sabbatical or semester break, or off for the summer. Although electronic surveys are not new, there may be some individuals that are not computer literate enough to participate effectively.

Chapter IV: Results and Discussion

This investigation was undertaken to learn about tree root biology curricula in arboriculture and urban forestry two-year programs in the United States. The following research objectives were addressed in this study:

1. How many two-year colleges in the United States offer tree biology coursework within arboriculture and urban forestry or related degree curricula?
2. What is the title of the principle course in which tree biology topics are taught?
3. How many credits is the tree biology course worth?
4. When do students encounter this tree biology course within their educational career?
5. What topics are covered in tree biology-related courses?
6. How much of the tree biology coursework is devoted to the study of roots?
7. What resources, including textbooks, printed publications and resources, and electronic resources, are being used to help support tree root biology education?
8. How many two-year colleges in the United States offer a degree with arboriculture and urban forestry as the major area of study?
9. How many two-year colleges in the United States offer a related degree with arboriculture and urban forestry as a minor area of study?

To answer these research questions, a survey questionnaire was developed and distributed to tree biology instructors at two-year arboriculture, urban forestry, and related degree programs in the United States. A letter of introduction was distributed on April 25, 2011 to test the distribution list and request participation. Six invitations with an internet link were distributed, encouraging participation in this study beginning on April 27, 2011. A final invitation to

participate was distributed June 1, 2011 and the survey closed at the end of the business day June 3, 2011.

Results

Eighty-nine *Tree Root Biology Curricula Surveys* were distributed; one survey for each institution known to teach arboriculture, urban forestry, or related disciplines at two-year degree programs in the United States. The individual that received the survey was identified as the faculty member most likely to be involved in teaching tree biology. Thirty-nine surveys were returned and completed for a 43.8% response rate, as shown in Table 1.

Table 1

Tree Root Biology Curricula Survey Distribution and Response Rate

Surveys Sent	Responses	Response Rate
89	39	43.8%

The *Tree Root Biology Curricula Survey* was organized to gather information about tree biology curricula in three distinct categories: Academic Program, Description of Tree Biology Courses, and Important Tree Biology Topics within Arboriculture and Urban Forestry Curricula. Descriptive statistics were applied to the data collected. The following information summarizes the data collected using this survey.

Academic Program

A series of four questions were used on the *Tree Root Biology Curricula Survey* to learn about the academic programs offered by schools/institutions involved in arboriculture, urban forestry, or related fields of study. The goal was to learn how many schools/institutions offer

arboriculture and urban forestry degrees; what type of arboriculture and urban forestry degree or credential is offered; how many schools/institutions offer areas of study closely related to arboriculture and urban forestry; and what type of closely related degree or credential is offered. These questions were numbered 15 – 18 on the survey.

Seven respondents (18%) indicated that their school/institution offered degree options in arboriculture or urban forestry in Question 15 of the survey, and 32 respondents or 82%, indicated they did not offer degree options in this field. Table 2 presents these findings.

Table 2

Number of Colleges Offering Diploma(s), Certificate(s), Associate Degree(s), and/or Minor Emphasis in Arboriculture or Urban Forestry

	Credentials Offered in Arboriculture and Urban Forestry	
Yes	7	18%
No	32	82%
Total	39	100%

Question 16 revealed that nine different credentials are offered in Arboriculture by schools/institutions that responded; eight different credentials are offered in Urban Forestry. Table 3 presents these findings, including 1 respondent offering a Diploma, 2 respondents offering a Certificate, 5 respondents offering an Associate Degree and 1 respondent indicated their institution offered a Minor in Arboriculture. Two respondents indicated their institution offered a Diploma, one respondent offered a Certificate, four respondents' institutions offered an Associate Degree and one offered a Minor in Urban Forestry.

Table 3

Credentials Students Earn in Arboriculture or Urban Forestry

	Diploma	Certificate	Associate Degree	Minor	Responses
Arboriculture	1	2	5	1	9
Urban Forestry	2	1	4	1	8

Respondents to the *Tree Root Biology Curricula Survey* represent schools/institutions that offer credentials in a variety of specialties that are closely related to arboriculture and urban forestry. Results from Question 17 indicated that thirty-five participating schools/institutions (90%) offer credentials in these disciplines that are closely related to Arboriculture and Urban Forestry. Table 4 presents these findings.

Table 4

Number of Colleges Offering Diploma(s), Certificate(s), Associates Degree(s), and/or Minor Emphasis in a Specialty Related to Arboriculture or Urban Forestry

	Credentials Offered Related to Arboriculture and Urban Forestry	
Yes	35	90%
No	4	10%
Total	39	100%

Question 18 responses revealed a wide range of titles that were very different, but closely related to one another (Appendix O). Respondents were provided an opportunity to enter

additional titles under a category "Other." Titles of all responses were evaluated and regrouped along the lines of the major areas of the plant sciences including "Horticulture/Landscape" and "Natural Resource Management/Environmental Science" and titles with no direct relationship were maintained in a category titled "Other."

The data summary to Question 18 revealed the following. One hundred and one different credentials are offered in Horticulture/Landscape; thirty-two different credentials are offered in Natural Resources Management/Environmental Sciences; and six different credentials were offered in a category title "Others." "Others" titles included Golf Course Operations, Parks and Recreation Operations, Turfgrass Management, and Sports Turfgrass Management. Two additional titles were provided, Agribusiness and Turf and Turfgrass Management, but were excluded because no credentials were provided. Table 5 summarizes the data reported in Question 18 of the survey for this study.

Table 5

Credentials Offered by Participating Schools/Institutions that are Closely Related to Arboriculture or Urban Forestry

	Diploma	Certificate	Associates Degree	Minor	Responses
Horticulture/Landscape	17	32	50	2	101
Natural Resources Management/Environmental Sciences	8	4	18	2	32
Others*	1	1	4		6

**Others includes degrees offered in Golf Course Operations, Parks and Recreation Operations, Turfgrass Management, and Sports Turf Management.*

Combining the data from Tables 3 and 5, or Questions 16 and 18, respectively, provided a complete summary of all degrees offered by the participating institutions. One hundred fifty-six credentials are offered to students in arboriculture, urban forestry, and related fields of study at the 39 different institutions that participated in this study. One hundred one credentials, or 64.7% of those reported, were offered in specialties that were categorized as Horticulture/Landscape; thirty-two credentials, or 20.5% of those reported, were offered in the fields categorized as Natural Resource Management/Environmental Science; nine credentials were reported, or 5.8% of those that responded, in Arboriculture; eight credentials, or 5.2%, were offered in Urban Forestry; and six credentials, or 3.8%, were offered in a category titled "Others" that included Golf Course Operations, Parks and Recreation Operations, Turfgrass Management, and Sports Turf Management. Table 6 provides a summary of the credentials offered by institutions that participated in this study.

Table 6

Compilation of Credentials Offered by Participating Institutions

	Diploma	Certificate	Associate Degree	Minor	Responses	%
Horticulture/Landscape	17	32	50	2	101	64.7
Natural Resource Management/Environmental Science	8	4	18	2	32	20.5
Arboriculture	1	2	5	1	9	5.8
Urban Forestry	2	1	4	1	8	5.2
"Others"*	1	1	4		6	3.8
Totals					156	100%

**"Others" included credential titles Golf Course Operations, Parks and Recreation Operation, Turfgrass Management, and Sports Turf Management.*

Description of Tree Biology Courses

Respondents of the *Tree Root Biology Curricula Survey* were asked a series of questions related to specific coursework covering tree biology in Questions 1 - 3. The goal was to learn if program curricula included a course that focuses on tree biology topics, what titles are used for the principle tree biology course; how much time within the principle tree biology course is devoted to this topic, and the study of roots in specific; and what printed and electronic resources are being used to support the courses.

Thirty-four participating schools/institutions (87%) reported offering a course with tree biology content that is taught by faculty within their degree-specific program in Question 1. These findings are presented in Table 7.

Table 7

Colleges Offering a Course (or Courses) with Tree Biology Topics Taught by Program-specific Faculty

	Tree Biology Courses Offered	
Yes	34	87%
No	5	13%
Total	39	100%

Question 2 revealed that twenty-four respondents (62%) taught Tree Biology topics in the last two years. These twenty-four participants were presented with additional, detailed questions about tree biology education through a function in Qualtrics software called "Display Logic." These additional questions were intended to learn more about the courses they teach, and to gain an understanding of their perspective on the importance of specific tree biology topics.

The remaining fifteen respondents (38%) were guided to the end of the survey and were not afforded the opportunity to provide more specific information about tree biology topics taught at their schools/institutions. These fifteen respondents possess perspectives and information that are valuable; however, the project investigator determined that the focus must remain on the information from individuals that are most intimately involved in tree biology education today. As a result, respondents not directly involved in teaching tree biology were not included in the following section of the survey. Table 8 presents these findings.

Table 8

Number of Respondents Directly Involved in Teaching Tree Biology Courses Taught in the Past Two Years

	Number of Respondents that Teach Tree Biology	
Yes	24	62%
No	15	38%
Total	39	100%

Titles of the courses provided in Question 3 by respondents of the survey varied. (A complete listing of course titles containing principle tree biology content provided by respondents is attached in Appendix P). As a result of this wide variation, five categories of titles including "Arboriculture," "Horticulture/Landscape," "Botany/Plant Science," "Tree/Forest Biology," and "Forest Ecology" were developed as a part of the data analysis process. The results revealed that ten courses, or 42%, had "Arboriculture" in the title; eight courses, or 33%, had "Horticulture" or "Landscape;" three courses, or 13%, had "Botany" or "Plant Science;" two courses, or 8%, had "Tree Biology" or "Forest Biology;" and one course, or 4%, was titled "Forest Ecology." These findings are presented in Table 9.

Table 9

Titles of Courses with Tree Biology Content

Categories of Course Titles with Tree Biology Content	Number of Titles	Percent of Population
Arboriculture	10	42%
Horticulture/Landscape	8	33%
Botany/Plant Science	3	13%
Tree/Forest Biology	2	8%
Forest Ecology	1	4%
Total	24	100%

A second part to Question 3 revealed that two (or 8%) of the principle courses with tree biology content is worth two semester credits; twenty-one (or 80%) courses are worth three or four credits; and one (4%) is worth five credits. Seventeen (or 71%) of the courses are be taken by students in one of the two semesters during their first year of study. Table 10 presents these findings.

Table 10

Number of Credits for Tree Biology Courses and Semester in which Students Encounter this Course

	Number of Credits Earned				Semester Taken			
	Two	Three	Four	Five	First	Second	Third	Fourth
Arboriculture	1	7	2		2	3	3	2
Horticulture/Landscape		6	1	1	7	1		
Botany/Plant Science		3			1	1	1	
Tree/Forest Biology	1		1		1	1		
Forest Ecology		1					1	
Totals	2	17	4	1	11	6	5	2

Question 4 of the survey revealed that eight (80%) of the courses titled "Arboriculture" studied tree biology topics 50% of the class time, or less; seven (88%) of the "Horticulture/Landscape" classes studied tree biology topics 50% of the class time, or less; all "Botany/Plant Science" courses studied tree biology topics 50% of the class time or less, two (66.7%) from this group taught tree biology topics 10% of the class time or less; "Tree/Forest Biology" and "Forest Ecology" all devoted 51% of the class time or more to tree biology topics. These findings are presented in Table 11.

Table 11

Percentage of Course Content Devoted to Tree Biology Topics

	Tree Biology Course Content				
	<10%	11 - 25%	26 - 50%	51 - 75%	76 - 100%
Arboriculture	2	2	4	1	1
Horticulture/Landscape	3	2	2	1	
Botany/Plant Science	2		1		
Tree/Forest Biology				1	1
Forest Ecology					1
Totals	7	4	7	3	3

Responding tree biology instructors were asked to estimate the amount of time devoted to studying roots within the principle tree biology course content in Question 5. In general, five (21%) courses studied roots 26 – 50% of the time; seventeen (71%) courses studied roots 25% of the time, or less. One (4%) respondent answered "Unsure" to the question, and one (4%) did not respond at all. The following summary provides details of the amount of time devoted to the study of roots by course title.

Three (30%) of the courses titled "Arboriculture" estimated that 26 – 50% of the class time was devoted to the study of roots; three (30%) more estimated that roots were the focus of class time 11- 25% of the time; another three (30%) courses titled "Arboriculture" were estimated to study roots 10% of the time, or less; and one (10%) did not respond to the question.

Five (62.5%) of the courses titled "Horticulture/Landscape" estimated their time devoted to roots to be 10% or less; two reported that 11 – 25% of the time was devoted to studying roots; and one (12.5%) studied roots 26 – 50% of the time.

One (33.3%) course titled "Botany/Plant Science" responded that they focus on roots 10% of the time or less; one (33.3%) course reported spending 11 – 26% of the time on roots; and one (33.3%) was "Unsure."

One (50%) course titled "Tree/Forest Biology" emphasized roots 11 – 25% of the class time; one (50%) devoted 26 – 50% of the class to the study of roots.

The one course titled "Forest Ecology" estimated focusing 10% or less of the time on the study of roots. Table 12 presents these findings from Question 5 of the survey.

Table 12

Percentage of Tree Biology Topics Devoted to Studying Roots

	Tree Biology Course Content Devoted to Roots				
	<10%	11 - 25%	26 - 50%	Unsure	No Response
Arboriculture	3	3	3		1
Horticulture/Landscape	5	2	1		
Botany/Plant Science	1	1		1	
Tree/Forest Biology		1	1		
Forest Ecology	1				
Totals	10	7	5	1	1

Survey respondents were presented with a list of textbooks known to contain tree biology content in Question 6, and were asked to indicate which are used to support their teaching of tree

biology. Ten (42%) of the instructors indicated that they use *Arboriculture* (Harris, Clark, and Matheny, 2004) as a primary/secondary textbook for their tree biology course; eleven (46%) noted using *A New Tree Biology* (Shigo, 1986) as their primary/secondary textbook; eleven (46%) more use *Arborist's Certification Study Guide* (Lilly, 2010) as a primary/secondary textbook. These findings are presented in Table 13.

Table 13

Books with Tree Biology Content and their Use

	Primary/Secondary Reference	Not Used	No Response
Arboriculture (Harris, Clark & Matheny, 2004)	10	13	1
A New Tree Biology (Shigo, 1986)	11	11	2
Arborist's Certification Study Guide (Lilly, 2010)	11	11	2

Fourteen (58%) tree biology instructors indicated using book titles not provided on the survey in Question 6. Two (14%) of the respondents to this question did not provide information about the titles or the authors of the books they use. A list of eleven titles is provided in the Table 14 below.

Table 14

Other Books Used to Teach Tree Biology

Book Title	Author
Biology of Plants (2005)	Peter H. Raven, Ray F. Evert, and Susan Eichorn
Botany For Gardeners	Brian Capon
Botany for Beginners	(Unknown)
Diseases of Trees and Shrubs*	Sinclair and Lyons
Horticulture	(Unknown)
Introduction to Horticulture	Reilly and Shry
Manual of Woody Landscape Plants	Michael Dirr
Modern Arboriculture	Alex Shigo
Physiology of Woody Plants	T. T. Kozlowski and Pallardy
Up by Roots**	James Urban
Urban Soils in Landscape Design**	Phillip Craul
No title provided**	No author given

**Used "… to show the link between healthy tree biology and disorders …"*
***Mentioned two times*

In Questions 7 and 8 of the survey, eleven (46%) tree biology instructors indicated using additional printed resources to support teaching tree biology topics. Eight (73%) of those answering this question cited the use of articles from industry or trade journals/periodicals; two

(18%) did not provide titles or sources for the additional printed resources; and one (9%) noted using a tree biology notebook they personally created. Table 15 presents these findings.

Table 15

Other Printed Resources Being Used by Participants to Teach Tree Biology Topics

Resource Title	Publisher/Author
Arborist News magazine articles*	International Society of Arboriculture
Articles from many peer reviewed periodicals**	(various publishers/authors)
Articles by Dr. Robert Miller	Dr. Robert Miller, University of Wisconsin – Stevens Point
Tree Biology Notebook	Personal
(No response)*	

**Indicated two times*
***Mentioned five times*

Fifteen (62.5%) tree biology instructors indicated using electronic resources in Questions 9 and 10 to support teaching tree biology topics (see detailed list of titles in Table 16 below). Eight (53%) of the electronic resources are produced by the International Society of Arboriculture (ISA). One instructor noted that a majority of the tree biology course topics are currently taught online. Two respondents indicated they use electronic resources, but did not provide titles, authors, or sources. Table 16 presents these findings.

Table 16

Electronic Resources Used to Teach Tree Biology Topics

Resource Title	Publisher/Author
Tree Biology interactive CD*	ISA
Practically Speaking video (Volume 1)	ISA
Soils interactive CD	ISA
Tree Biology PowerPoints available online	Dr. Ed Gilman, University of Florida
ISA Information**	ISA
Assorted websites***	(unknown)
"Most all is taught as online class currently"	
No title, author, or source provided**	

**Noted four times*
***Noted two times*
****Noted three times*

Important Tree Biology Topics within Arboriculture and Urban Forestry Curricula

Twenty-four instructors indicated that they have taught tree biology topics to students in two year arboriculture, urban forestry, or related fields of study programs in the United States within the past two years. These instructors were presented Questions 11, 12, 13, and 14 on the survey where they were provided an opportunity to rate a total of forty-six different tree biology topics using an Index Scoring of 0 = Not Important, 1 = Low, 2 = Moderate, 3 = High, and

Unsure. The goal was to gain insight from each tree biology instructor about the importance of the different tree biology topics.

The forty-six tree biology topics were organized and presented in four categories on the survey. Question 11 had nine tree biology topics that related to Growth Processes; Question12 had thirteen Structure/Anatomy topics; Question 13 had fourteen Functions/Processes topics; and Question 14 had ten Concepts, Hypotheses, and Theories topics. Instructors were given the Index Score options of 0 = Not Important; 1 = Low; 2 = Moderate; 3 = High; and Unsure. The presentation of the topics within the survey was in the form of matrices with topics oriented vertically along the left margin and the Index Scoring options horizontally across the top.

Question 11 had nine different tree biology topics that related to Growth Processes in trees. Mycorrhizal Associations was rated Moderate in importance with an Index Score of 2.29. The remaining eight topics were rated Low in importance including: Root Cambium Zone Growth (1.74); Non-Woody Root Formation (1.71); Root Tip Meristem Growth (1.65); Callus Tissue and Woundwood Formation in Roots (1.64); Root Zone Reactionwood Formation and Self-Optimization (1.57); Root Growth in a 3-Dimensional View (1.50); Seed Germination (1.33); and Seedling Development (1.29). The Weighted Index Score for the category of topics titled Growth Processes was rated Low in importance at 1.64. These findings are presented in Table 17.

Table 17

Index Score Rating for Tree Biology Growth Processes Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Mycorrhizal Associations	1	3	8	12	24	2.29
Root Cambium Zone Growth	2	8	7	6	23	1.74
Non-Woody Root Formation	2	10	5	7	24	1.71
Root Tip Meristem Growth	2	8	9	4	23	1.65
Callus Tissue and Woundwood Formation in Roots	2	8	8	4	22	1.64
Root Zone Reactionwood Formation and Self-Optimization	3	8	8	4	23	1.57
Root Growth in a 3-Dimensional View	5	7	7	5	24	1.50
Seed Germination	5	11	3	5	24	1.33
Seedling Development	4	12	5	3	24	1.29
					Weighted Index Score	1.64

Question 12 presented instructors with a set of thirteen tree biology topics related to Structure/Anatomy. Nine of the topics were rated Moderate (2.00) or higher, including: Branch Attachment (2.75); Support/Structural Roots (2.50); Outside Parts of the Trunk (2.50); Outside Parts of a Twig (2.46); Structural Defects (2.42); Internal Parts in a Cross-Sectional View of

Stems (2.21); Fine Roots (2.17); Lateral Root Formation (2.17); and Transition Zone Between Stem/Roots (2.00). Four of the Structure/Anatomy topics were rated Low, scoring below 1.99, including: Internal Parts in a Longitudinal View of Stems (1.96); Outside Parts of Woody Roots (1.96); Internal Parts in a Cross-Sectional View of Roots (1.70); and Internal Parts in a Longitudinal View of Roots (1.52). The Weighted Index Score for the category of Structure/Anatomy topics was rated Moderate in importance at 2.18. Table 18 presents these findings.

Table 18

Index Score Rating for Tree Biology Structure/Anatomy Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Branch Attachment	0	2	2	20	24	2.75
Support/Structural Roots	0	1	10	13	24	2.50
Outside Parts of the Trunk	0	4	4	16	24	2.50
Outside Parts of a Twig	0	4	5	15	24	2.46
Structural Defects	1	0	11	12	24	2.42
Internal Parts in a Cross-Sectional View of Stems	0	4	11	9	24	2.21
Fine Roots	1	4	8	10	23	2.17
Lateral Root Formation	1	2	12	8	23	2.17
Transition Zone Between Stem/Roots	3	2	11	8	24	2.00
Internal Parts in a Longitudinal View of Stems	1	5	12	6	24	1.96
Outside Parts of Woody Roots	0	6	12	5	23	1.96
Internal Parts in a Cross-Sectional View of Roots	2	9	6	6	23	1.70
Internal Parts in a Longitudinal View of Roots	2	9	10	2	23	1.52
					Weighted Index Score	2.18

Question 13 asked instructors to rate a list of fourteen tree biology topics related to Functions/Processes. Ten of the topics were rated Moderate including Water Relations (2.63); Photosynthesis (2.61); Wound Response (2.50); Water/Essential Element Uptake (2.46); Respiration (2.32); Energy Resource Allocation (2.25); Evapotranspiration (2.25); Fluid Conductivity/Transport in the Phloem (2.22); Fluid Conductivity/Transport in the Xylem (2.13); and Phenology (2.08). Four of the Functions/Processes topics were rated Low including Photorespiration (1.96); Fall Color and Leaf Senescence (1.79); Flower Formation/Fertilization (1.75); and Pollen Development/Dispersal (1.33). The Weighted Index Score for the category Functions/Processes was rated Moderate in importance at 2.16. These findings are presented in Table 19.

Table 19

Index Score Rating of Tree Biology Functions/Processes Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Water Relations	0	0	9	15	24	2.63
Photosynthesis	1	1	4	17	23	2.61
Wound Response	1	0	9	14	24	2.50
Water/Essential Element Uptake	0	3	7	14	24	2.46
Respiration	1	2	8	11	22	2.32
Energy Resource Allocation	1	1	13	9	24	2.25
Evapotranspiration	0	4	10	10	24	2.25
Fluid Conductivity/Transport in the Phloem	2	1	10	10	23	2.22
Fluid Conductivity/Transport in the Xylem	2	2	11	9	24	2.13
Phenology	2	5	6	11	24	2.08
Photorespiration	2	6	6	9	23	1.96
Fall Color and Leaf Senescence	2	6	11	5	24	1.79
Flower Formation/Fertilization	4	5	8	7	24	1.75
Pollen Development/Dispersal	7	5	9	3	24	1.33
					Weighted Index Score	2.16

Question 14 provided tree biology instructors with an opportunity to rate ten topics related to Concepts, Hypotheses, and Theories. One topic, Tree Nutrition, rated Moderate at 2.25. Nine topics were rated Low including Tree Associations (1.96); Survival (1.95); Energy and Stress (1.1.91); Allelopathy (1.46); Bio-Mechanics (1.43); Mass/Energy Ratio (1.30); Tree Pump Concept (1.18); and Three Tree Concept (1.00). Core/Skin Hypothesis (0.90) was the only topic rated as Not Important out of all of the categories by scoring below 1.00. The Weighted Index Score for Concepts, Hypotheses, and Theories was Low in importance being rated at 1.55. These findings are presented in Table 20.

Table 20

Index Score Rating for Concepts, Hypotheses, and Theories Tree Biology Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Tree Nutrition	0	6	6	12	24	2.25
Tree Associations	2	5	8	8	23	1.96
Survival	2	4	8	7	21	1.95
Energy and Stress	1	8	6	8	23	1.91
Allelopathy	2	13	5	4	24	1.46
Bio-Mechanics	4	9	6	4	23	1.43
Mass/Energy Ratio	4	11	5	3	23	1.30
Tree Pump Concept	4	12	4	2	22	1.18
Three Tree Concept	5	11	1	2	19	1.00
Core/Skin Hypotheses	6	12	2	1	21	0.90
					Weighted Index Score	1.55

A summary look at the Weighted Index Score for the four major categories from Questions 11 – 14 reveals that Structure/Anatomy (2.18) and Function/Processes (2.16) were rated as Moderate in importance; Growth Processes (1.64) and Concepts, Hypotheses, and Theories (1.55) were rated Low. Table 21 presents these findings.

Table 21

Weighted Index Scores for Tree Biology Topical Categories

	Number of Topics/Category	Weighted Index Score
Structure/Anatomy	13	2.18
Functions/Processes	14	2.16
Growth Processes	9	1.64
Concepts, Hypotheses, and Theories	10	1.55

Tree biology topics that relate to roots were mingled with the aboveground topics in Questions 11 – 14 on the survey. Tree biology instructors rated the importance of root related topics in the four categories. Growth Processes contained seven different topics related to roots, Structure/Anatomy contained seven root topics, Functions/Processes contained three root topics, and Concepts, Hypotheses, and Theories contained two topics that related to roots. The following information is a summary of data related to tree root biology topical rating.

Question 11 included seven tree root biology topics categorized as Growth Processes. Mycorrhizal Associations (2.29) was the only topic rated as Moderate; Root Cambium Zone Growth (1.74); Non-Woody Root Formation (1.71); Root Tip Meristem Growth (1.65); Callus Tissue and Woundwood Formation in Roots (1.64); Root Zone Reactionwood Formation and

Self-Optimization (1.57); and Root Growth in a 3-Dimensional View (1.50) were all rated as Low in importance. The Weighted Index Score for the category Growth Processes for tree root biology topics was Low in importance at 1.73. Table 22 presents these findings.

Table 22

Index Score Rating of Tree Biology Growth Processes Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Mycorrhizal Associations	1	3	8	12	24	2.29
Root Cambium Zone Growth	2	8	7	6	23	1.74
Non-Woody Root Formation	2	10	5	7	24	1.71
Root Tip Meristem Growth	2	8	9	4	23	1.65
Callus Tissue and Woundwood Formation in Roots	2	8	8	4	22	1.64
Root Zone Reactionwood Formation and Self-Optimization	3	8	8	4	23	1.57
Root Growth in a 3-Dimensional View	5	7	7	5	24	1.50
					Weighted Index Score	1.73

Question 12 included seven tree root biology topics categorized as Structure/Anatomy. Four tree root biology topics were rated as Moderate including Support/Structural Roots (2.50); Fine Roots (2.17); Lateral Root Formation (2.17); and Transition Zone Between Stem/Roots

(2.00). Three tree root biology topics were rated Low in importance including Outside Parts of Woody Roots (1.96); Internal Parts in a Cross-Sectional View of Roots (1.70); and Internal Parts in a Longitudinal View of Roots (1.52). The Weighted Index Score for tree root biology topics categorized as Structure/Anatomy was rated Moderate in importance at 2.01. These findings are presented in Table 23.

Table 23

Index Score Rating for Tree Root Biology Structure/Anatomy Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Support/Structural Roots	0	1	10	13	24	2.50
Fine Roots	1	4	8	10	23	2.17
Lateral Root Formation	1	2	12	8	23	2.17
Transition Zone Between Stem/Roots	3	2	11	8	24	2.00
Outside Parts of Woody Roots	0	6	12	5	23	1.96
Internal Parts in a Cross-Sectional View of Roots	2	9	6	6	23	1.70
Internal Parts in a Longitudinal View of Roots	2	9	10	2	23	1.52
					Weighted Index Score	2.01

Question 13 included three tree root biology topics categorized as Functions/Processes. All three were rated as Moderate in importance including Water Relations (2.63); Water/Essential Element Uptake (2.46); and Respiration (2.32). The Weighted Index Score for

tree root biology topics categorized as Functions/Processes was 2.47 and is considered Moderate in importance. Table 24 presents these findings.

Table 24

Index Score Rating of Tree Root Biology Functions/Processes Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Water Relations	0	0	9	15	24	2.63
Water/Essential Element Uptake	0	3	7	14	24	2.46
Respiration	1	2	8	11	22	2.32
					Weighted Index Score	2.47

Question 14 included two tree root biology topics categorized as Concepts, Hypotheses, and Theories. Tree Nutrition (2.25) was rated as Moderate in importance; Tree Associations (1.96) was rated Low. The Weighted Index Score for tree root biology topics categorized as Concepts, Hypotheses, and Theories was rated Moderate at 2.11. These findings are presented in Table 25.

Table 25

Index Score Rating of Tree Root Biology Concepts, Hypotheses, and Theories Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Tree Nutrition	0	6	6	12	24	2.25
Tree Associations	2	5	8	8	23	1.96
					Weighted Index Score	2.11

A summary look at the Weighted Index Scores for tree root biology topics in the four major categories from Questions 11 – 14 reveals Functions/Processes (2.47); Concepts, Hypotheses, and Theories (2.11); and Structure/Anatomy (2.01) are all rated Moderate in importance. The Weighted Index Score for the category called Growth Processes of tree root biology topics is rated Low in importance at 1.73. These findings are presented in Table 26.

Table 26

Weighted Index Scores for Tree Root Biology Topical Categories

	Number of Topics/Category	Weighted Index Score
Tree Root Biology Functions/Processes	3	2.47
Tree Root Biology Concepts, Hypotheses, and Theories	2	2.11
Tree Root Biology Structure/Anatomy	7	2.01
Tree Root Biology Growth Processes	7	1.73

Question 11 included two aboveground tree biology topics that related to the segment aboveground and categorized as Growth Processes. Both Seed Germination and Seedling Development were rated as Low in importance. The Weighted Index Score for Growth Processes for aboveground tree biology topics is rated Low at 1.31. Table 27 presents these findings.

Table 27

Index Score Rating of Aboveground Tree Biology Growth Processes Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Seed Germination	5	11	3	5	24	1.33
Seedling Development	4	12	5	3	24	1.29
				Index Score Average		1.31

Question 12 included six aboveground tree biology topics categorized as Structure/Anatomy. All but one of the topics were rated Moderate including Branch Attachment (2.75); Outside Parts of the Trunk (2.50); Outside Parts of a Twig (2.46); Structural Defects (2.42); and Internal Parts in a Cross-Sectional View of Stems (2.21). Internal Parts in a Longitudinal View of Stems (1.96) was rated Low in importance. The Weighted Index Score for aboveground tree biology topics categorized as Structure/Anatomy was rated Moderate at 2.38. Table 28 presents these findings.

Table 28

Index Score Rating of Aboveground Tree Biology Structure/Anatomy Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Branch Attachment	0	2	2	20	24	2.75
Outside Parts of the Trunk	0	4	4	16	24	2.50
Outside Parts of a Twig	0	4	5	15	24	2.46
Structural Defects	1	0	11	12	24	2.42
Internal Parts in a Cross-Sectional View of Stems	2	9	6	6	23	2.21
Internal Parts in a Longitudinal View of Stems	1	5	12	6	24	1.96
					Weighted Index Score	2.38

Question 13 included eleven aboveground tree biology topics categorized as Functions/Processes. Seven topics were rated Moderate in importance including Photosynthesis (2.61); Wound Response (2.50); Energy Resource Allocation (2.25); Evapotranspiration (2.25); Fluid Conductivity/Transport in the Phloem (2.22); Fluid Conductivity/Transport in the Xylem (2.13); and Phenology (2.08). Four aboveground tree biology topics were rated Low in importance including Photorespiration (1.96); Fall Color and Leaf Senescence (1.79); Flower Formation/Fertilization (1.75); and Pollen Development/Dispersal (1.33). The Weighted Index Score for aboveground tree biology topics categorized as Functions/Processes rated Moderate in importance at 2.08. Table 29 presents these findings.

Table 29

Index Score Rating Averages of Aboveground Tree Biology Functions/Processes Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Photosynthesis	1	1	4	17	23	2.61
Wound Response	1	0	9	14	24	2.50
Energy Resource Allocation	1	1	13	9	24	2.25
Evapotranspiration	0	4	10	10	24	2.25
Fluid Conductivity/Transport in the Phloem	2	1	10	10	23	2.22
Fluid Conductivity/Transport in the Xylem	2	2	11	9	24	2.13
Phenology	2	5	6	11	24	2.08
Photorespiration	2	6	6	9	23	1.96
Fall Color and Leaf Senescence	2	6	11	5	24	1.79
Flower Formation/Fertilization	4	5	8	7	24	1.75
Pollen Development/Dispersal	7	5	9	3	24	1.33
				Weighted Index Score		2.08

Question 14 included eight aboveground tree biology topics categorized as Concepts, Hypotheses, and Theories. Seven of the topics were rated Low in importance including Survival (1.95); Energy and Stress (1.91); Allelopathy (1.46); Bio-Mechanics (1.43); Mass/Energy Ratio (1.30); Tree Pump Concept (1.18); and Three Tree Concept (1.00). The topic Core/Skin Concept (0.90) was the only topic rated Not Important by tree biology instructors. The Weighted Index Score for aboveground tree biology topics categorized as Concepts, Hypotheses, and Theories was rated Low in importance at 1.40. These findings are presented in Table 30.

Table 30

Index Score Rating Averages of Aboveground Tree Biology Concepts, Hypotheses, and Theories Topics

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Survival	2	4	8	7	21	1.95
Energy and Stress	1	8	6	8	23	1.91
Allelopathy	2	13	5	4	24	1.46
Bio-Mechanics	4	9	6	4	23	1.43
Mass/Energy Ratio	4	11	5	3	23	1.30
Tree Pump Concept	4	12	4	2	22	1.18
Three Tree Concept	5	11	1	2	19	1.00
Core/Skin Hypotheses	6	12	2	1	21	0.90
					Weighted Index Score	1.40

A summary look at the Weighted Index Scores for aboveground tree biology topics in the four major categories from Questions 11 – 14 reveals Structure/Anatomy (2.38) and Functions/Processes (2.08) are rated as Moderate in importance. Concepts, Hypotheses, and Theories (1.40) and Growth Processes (1.31) are rated Low in importance. These findings are presented in Table 31.

Table 31

Weighted Index Scores for Aboveground Tree Biology Topical Categories

	Number of Topics/Category	Weighted Index Score
Aboveground Tree Biology Structure/Anatomy	6	2.38
Aboveground Tree Biology Functions/Processes	11	2.08
Aboveground Tree Biology Concepts, Hypotheses, and Theories	8	1.40
Aboveground Tree Biology Growth Processes	2	1.31

Questions 11 – 14 provided tree biology topical ratings for forty-six different topics within four categories called Growth Processes, Structure/Anatomy, Functions/Processes, and Concepts, Hypotheses, and Theories. Growth Processes had nine topics total; seven topics related to roots and two aboveground tree biology topics. Structure/Anatomy had thirteen topics total; seven topics devoted to roots and six aboveground tree biology topics. Functions/Processes had fourteen topics total; three topics related to roots and eleven aboveground tree biology topics. Concepts, Hypotheses, and Theories had ten topics total; two were devoted to roots and eight aboveground topics.

Tree biology instructor rating revealed the following order of importance of all tree biology topics presented in the *Tree Root Biology Curricula Survey*. Tree Root Biology Functions/Processes (2.47); Aboveground Tree Biology Structure/Anatomy (2.38); Tree Root Biology Concepts, Hypotheses, and Theories (2.11); Aboveground Tree Biology Functions/Processes (2.08); and Tree Root Biology Structure/Anatomy (2.01) all rated Moderate in importance. Tree Root Biology Growth Processes (1.73); Aboveground Tree Biology Concepts, Hypotheses, and Theories (1.40); and Aboveground Tree Biology Growth Processes (1.31) rated Low in importance. Table 32 presents these findings.

Table 32

Weighted Index Score Rankings for Aboveground/Tree Root Biology Topical Categories

	Number of Topics/Category	Weighted Index Score
Tree Root Biology Functions/Processes	3	2.47
Aboveground Tree Biology Structure/Anatomy	6	2.38
Tree Root Biology Concepts, Hypotheses, and Theories	2	2.11
Aboveground Tree Biology Functions/Processes	11	2.08
Tree Root Biology Structure/Anatomy	7	2.01
Tree Root Biology Growth Processes	7	1.73
Aboveground Tree Biology Concepts, Hypotheses, and Theories	8	1.40
Aboveground Tree Biology Growth Processes	2	1.31

Summary

The *Tree Root Biology Curricula Survey* was distributed to tree biology instructors at eighty-nine different arboriculture, urban forestry, and related two-year degree programs in the United States. Thirty-nine surveys were returned, yielding a 43.8% return rate. Survey respondents provided information about tree biology curricula in three areas Academic Program, Description of Tree Biology Courses, and Important Tree Biology Topics within Arboriculture and Urban Forestry Curricula.

Questions 15 – 18 of the *Tree Root Biology Curricula Survey* were devoted to learning about respondents' Academic Programs. Eighteen percent of respondents represented scholastic programs that specifically teach arboriculture and urban forestry as a specialty. Seventeen different arboriculture and urban forestry credentials are offered to the graduates of these programs. Ninety percent of respondents indicated their institution also offered credentials in related areas of study. The re-grouped titles included one hundred one different degree offerings in Horticulture/Landscape; thirty-two different offerings in Natural Resource Management/Environmental Science; and six different offerings categorized as "Others" including Golf Course Operations, Parks and Recreation Operations, Turfgrass Management, and Sports Turf Management.

Questions 1 through 10 of the *Tree Root Biology Curricula Survey* asked respondents to provide a Description of Tree Biology Courses and the resources used to support their efforts. Sixty-two percent of respondents indicated they have taught a course with tree biology content in the past two years. Forty-two percent of the courses have the term "Arboriculture" in the title, thirty-three percent have the term "Horticulture" or "Landscape," thirteen percent have "Botany/Plant Science" as the title, and the remaining twelve percent are named "Tree/Plant

Biology" and "Forest Ecology." Eighty percent of these courses are three or four credit courses, and seventy-one percent are taken by students during their first year of study.

Thirteen percent of respondents reported that they focus 76 – 100% of the time studying tree biology topics in their class. Of those reporting, twenty-one percent spent 26 – 50% of that time learning about roots. Eighty-percent of respondents said they spend 50% of the class time or less on the study of tree biology. Less than 25% of this time is spent learning about roots by seventy-one percent of respondents. Of this specific group of respondents, forty-two percent of them spent less than 10% of the time on tree root biology.

A wide variety of textbooks and printed resources are used to help support teaching tree biology by responding tree biology instructors. Forty-two percent of these individuals use the textbook selections provided on the survey including *Arboriculture* (Harris, Clark, & Matheny, 2004), *A New Tree Biology* (Shigo, 1986), and *Certified Arborists' Study Guide* (Lilly, 2010). Forty-six percent of respondents indicated using a variety of other printed resources; most of which (73%) used articles from a variety of trade journals and periodicals to support tree biology education. Fifty-four percent of respondents indicated using electronic resources to teach tree biology; most of which (63%) are produced and distributed by the International Society of Arboriculture.

Questions 11 through 14 of the *Tree Root Biology Curricula Survey* were devoted to learning about Tree Biology Topics that are Important within Arboriculture and Urban Forestry Curricula. Tree biology instructors were asked to rate forty-six tree biology topics categorized into four groups; twenty-seven of which related to Aboveground Tree Biology Topics and nineteen that focused on Tree Root Biology. The Functions/Processes of Tree Root Biology was rated Moderate in importance and ranked the highest in importance of all topics with an Index

Score of 2.47; Structure/Anatomy of Aboveground Tree Biology topics came next with an Index Score of 2.38. The category Concepts, Hypotheses and Theories related to roots was classified as Moderate in importance with an Index Score of 2.11; Functions/Processes Topics related to Aboveground Tree Biology (2.08) and Structure/Anatomy Topics of roots (2.01) also had similar Index Scores. Tree Root Biology Growth Processes Topics (1.73), Aboveground Tree Biology Concepts, Hypotheses, and Theories Topics (1.40), and Aboveground Tree Biology Growth Processes Topics (1.31) were all rated Low in importance by tree biology instructors.

Chapter V: Summary, Conclusions, and Recommendations

This chapter contains the project summary, conclusions, and recommendations based upon this study of tree root biology curricula at two year post-secondary arboriculture and urban forestry educational programs in the United States.

Summary

The summary of the *Tree Root Biology Curricula Survey* results are broken into three sections including Restatement of the Problem, Methods and Procedures, and Major Findings.

Restatement of the Problem

The purpose of this study was to learn more about tree biology curricula at two-year post-secondary arboriculture and urban forestry programs in the United States. The science of tree biology provides the basis for decision-making and management of trees in the urban forest. Colleges and universities play an important role in preparing future arboriculture and urban forestry practitioners; yet, little research has been conducted looking at two-year educational programs. The arboriculture and urban forestry industry has recently placed greater emphasis on the understanding and study of the biology of a tree roots due to trends in research and scientific clarifications of the importance of tree root health to overall tree health and function. This investigation was undertaken to learn about curricula in two-year arboriculture and urban forestry programs in the United States, specifically as it relates to tree root biology education.

Methods and Procedures

This research project was constructed applying descriptive research methodology. A survey questionnaire was developed to gain insight about tree root biology education within arboriculture and urban forestry two-year post-secondary curricula in the United States. Specifically, respondents were asked to provide information about the degrees conferred at the

institution they represented; about the tree biology courses they have taught; about the printed and electronic resources they utilize to support tree biology coursework; and about the importance of specified tree biology topics to their courses.

The subjects identified for this survey consisted of 89 different tree biology instructors at two-year arboriculture, urban forestry, and related-discipline institutions across the United States. The sample size included all 89 potential subjects because the list size was considered small for conducting descriptive research.

Distribution of the survey included eight different contacts as a way of encouraging participation. A letter to introduce the survey was sent at the end of the month of April 2011. Seven follow up email announcements containing a link to the survey were made to solicit information about tree biology educational efforts. The project ended in early June 2011. Thirty-nine surveys were completed and returned for a 43.8% response rate. Descriptive research statistical methods were applied to the survey data revealing the following findings.

Major Findings

Survey questions 15 – 18 of the *Tree Root Biology Curricula Survey* were designed to learn more about two-year, post-secondary arboriculture and urban forestry education in the United States. Seven respondents, or 18% of the sample, indicated offering credentials that were specifically titled arboriculture and urban forestry. Nine different credentials are offered with the title, Arboriculture; eight credentials are offered with the title, urban forestry.

Survey questions 17 and 18 revealed that most of the responding institutions (90%) offered educational options in fields of study related to arboriculture and urban forestry, but with a broader scope or tangent to arboriculture and urban forestry. Seventy-three percent of the related credentials fell under the category of “Horticulture/Landscape;” twenty-three percent of

respondents represented “Natural Resource Management/Environmental Science” programs; and four percent offered specialties that fell under the title “Other.” Titles classified as “Other” include Golf Course Operations, Parks and Recreation Operations, Turfgrass Management, and Sports Turf Management. Two other titles were mentioned, Agribusiness and Turf and Turfgrass Management, but no degree details were provided; as a result, the Agribusiness and Turf and Turfgrass Management were excluded from the results to this question.

Survey questions 1 – 3 of the *Tree Root Biology Curricula Survey* specifically ask about the course that serves as the principle course for teaching tree biology topics. Sixty-two percent of the respondents taught a class that fits this criterion. “Arboriculture” is the title used for forty-two percent of the courses taught by those responding; “Horticulture” was part of the title for thirty-three percent of the courses reported; “Botany/Plant Science” was the title given for the principle tree biology class for thirteen percent of the courses reported; and “Plant Biology” and “Forest Ecology” were both used as a title for a course for two different respondents. There was one respondent that reported using the title “Tree Biology.”

Survey questions 1 – 3 revealed that students earn 3 or 4 credits towards their degree by completing the course that contains principle tree biology content. Furthermore, students encounter this course during their first year of study in most of the cases.

Survey question 4 of the *Tree Root Biology Curricula Survey* was designed to learn how much class time was devoted to the study of tree biology topics. Only three out of the twenty-four courses described learning about tree biology topics for a majority (76 – 100%) of the class time; three others reported spending a significant portion (51 – 75%) of class on tree biology topics; and the remaining eighteen reported that they spend 50% or less of the class time studying tree biology.

Survey question 5 of the *Tree Root Biology Curricula Survey* asked how much time was devoted to the study of roots in specific, within the tree biology component of the course that was being described. Five of the instructors indicated devoting approximately half of the class learning about roots; seven indicated devoting approximately one-quarter of the class to the study of roots; and ten said they spent 10% of less of class studying roots. One respondent was unsure of how to answer this question.

Survey questions 6 - 8 of the *Tree Root Biology Curricula Survey* focused on printed resources used to support tree biology education. A variety of textbooks are reported to be used. But, there was no specific textbook title that was used by a majority of tree biology instructors.

The summary of textbook use from survey question 6 revealed that forty-two to forty-six percent of respondents indicated using a commonly known tree biology texts provided in a list on the survey. Thirty-two percent indicated the *Arborists' Certification Study Guide* (Lilly, 2010) is used as a primary textbook for their tree biology class. Twenty-six percent indicated using *Arboriculture – Integrated Management of Landscape Trees, Shrubs, and Vines* (4^{th} edition) (Harris, Clark, & Matheny, 2004) as their primary textbook. Forty-five percent noted using *A New Tree Biology* (Shigo, 1986) as a secondary reference for teaching tree biology topics. Respondents were provided with an opportunity to provide the titles and author names for texts not listed. The responses were as varied as the number of respondents.

Survey questions 7 and 8 of the *Tree Root Biology Curricula Survey* were aimed at learning about what other printed resources were being used to support tree biology education. Many instructors (63%) reported using a variety of articles from industry periodicals and journals; the International Society of Arboriculture (ISA) was most frequently cited as the source for other printed materials.

Survey questions 9 and 10 of the *Tree Root Biology Curricula Survey* asked respondents to describe the electronic resources used to support tree biology education. Many instructors (54%) reported using electronic resources in their coursework. The titles were varied, but the ISA was listed most frequently as the source for these materials. The ISA has a series of interactive, educational CDs covering a range of tree biology topics. Many instructors are utilizing these resources in their classrooms. One respondent indicated that a majority of the tree biology course content is taught as an online class.

Survey questions 11 – 14 of the *Tree Root Biology Curricula Survey* asked respondents to rate the importance a forty-six different tree biology topics from their perspective as an instructor involved in educating graduates that may enter the arboriculture and urban forestry industry. An inference could be made that the importance rating of tree biology topics may translate into what is being taught.

The rating of tree biology topics in survey questions 11 – 14 of the survey revealed that approximately half of the topics were rated as "Moderate" in importance; the other half were rated "Low." One topic, "Core/Skin Concept" was rated below 1.00 and was the only topic out of the list of forty-six to be considered "Not Important." Of the forty-six topics, twenty-seven related to the segment of the tree which is aboveground; nineteen related to roots. The following major findings were observed from the ratings of tree biology topics.

Two categories of topics were rated similarly in importance and were scored as the most important overall. "Tree Root Biology Functions/Processes" were rated as most important out of all the topical categories, at 2.47. The rating for "Aboveground Tree Biology Structure/Anatomy" was similarly rated, at 2.38.

The rating for three other topical categories were somewhat clustered and came in second in importance. "Tree Root Biology Concepts, Hypotheses, and Theories" (2.11), "Aboveground Tree Biology Functions/Processes" (2.08), and "Tree Root Biology Structure/Anatomy" (2.01) also rated as "Moderate" but not as important as the first group noted in the paragraph above.

"Tree Root Biology Growth Processes" (1.73), "Aboveground Tree Biology Concepts, Hypotheses, and Theories" (1.4), and "Aboveground Tree Biology Growth Processes" (1.31) were similarly rated and were considered "Low" in importance by responding instructors.

Conclusions

This section reveals detailed findings to the questions presented as "research objectives" articulated in Chapter One: Introduction of this paper.

A Small Number of Participating Institutions offer Credentials Titled Arboriculture and Urban Forestry

Survey questions 15 – 16 of the *Tree Root Biology Curricula Survey* revealed that seven of the responding institutions confer a diploma, certificate, associate degree, or a minor area of study specifically focusing on arboriculture and urban forestry. Previous research reported the number of institutions offering arboriculture and urban forestry degree credentials progressively increasing during the 1970s to a total of 96 in 2009. (Wiseman, Hoffman, Day, and Clements, 2011) This finding included two-year and four-year degree programs. There appears to be a significant discrepancy between the findings of this study and those previously reported relating to the number of institutions involved in arboriculture and urban forestry education.

Thirty-five of the responding institutions participating in the *Tree Root Biology Curricula Survey* reported offering degree credentials in fields of study related to arboriculture and urban forestry in survey questions 17 and 18, but did not have arboriculture or urban forestry as part of

the title. Seventy-three percent of the credential titles were clustered under "Horticulture/Landscape;" another twenty-three percent had titles clustered under "Natural Resource Management/Environmental Science;" and four percent of the titles were listed under "Other," including "Golf Course Operations, Parks and Recreation Operations, Turfgrass Management, and Sports Turf Management." Although the titles provided under the category of "Other" relate to a plant science, they do not appear to be directly connected to trees. This study would not classify them as an institution that is involved in arboriculture and urban forestry education.

This study provided a view of two-year degree programs. Respondents provided specific descriptions of the title and type of degree offered. Institutions offering four-year baccalaureate credentials were excluded here. Previous studies do not provide detailed data articulating participants' degrees; arboriculture or urban forestry degrees are generally stated with no substantiating information provided. It is unlikely that there are so many four-year degree programs to make up the difference reported in this study and the results provided in previous studies. A more likely explanation is that previous studies included a broader definition for degree inclusion like AgScience, Horticulture, or Natural Resource Management within their classification because they contained a component of arboriculture or urban forestry coursework. In this study, credentials like these were considered related, but not truly arboriculture or urban forestry in focus.

This study indicates that there may not be as many programs that focus specifically on arboriculture and urban forestry education, as previously thought. The implication is that graduates from disciplines tangent to arboriculture and urban forestry may not have the degree of knowledge and possess the discipline-specific skill-sets that would align them properly with the

needs of the industry. This could lead to greater needs for training, higher employee turn-over, and longer periods between hiring and employee productivity. There are a small number of schools that were specifically aligned with the arboriculture and urban forestry industry. These schools should be highlighted and emphasized for their specialized work because they appear to be more closely aligned to the needs of employers within this segment of industry.

Tree Biology Topics are taught by Most of the Participants in a Course Titled "Arboriculture," But Only for a Fraction of the Time

Ninety-six percent of the courses in which tree biology topics are taught lack the term "tree biology" in the title. Just one respondent reported teaching a course specifically titled "Tree Biology." Seventy-six to one-hundred percent of this "Tree Biology" course was devoted to tree biology topics; and 26 – 50% of the content focused on roots. This report of the class titled "Tree Biology" was the only direct match to the criteria selected and targeted for this study.

The results from this study related to tree biology course titles and content indicate a deficiency in tree biology education at the two-year post-secondary level, considering the emphasis the arboriculture and urban forestry industry places on a foundational understanding of tree biology. However, this study did not look at the progression of tree biology topics throughout all of the respective courses within the entire curricula of participating programs. It is unknown to what extent tree biology topics are taught in other courses, and to what degree students construct an understanding of tree biology leading to successful program completion and graduation. More study is necessary to discover the extent to which students are taught tree biology topics throughout the course of their educational careers. Work in this area would reveal whether any deficiencies exist in preparing graduates in the area of tree biology education.

The terms used to describe the titles of courses that served as the principle course for tree biology content ranged considerably, so re-grouping was done to describe them in this study. "Arboriculture" was the most frequently reported course title containing tree biology content (42%). This is consistent with the findings of Wiseman, Hoffman, Day, and Clements (2011) in which "Arboriculture" course syllabi was examined and found that "…frequent mention of tree physiology/biology … suggests that these courses are well founded in the basic scientific principles underpinning sound arboricultural practices." However, this study found that less than 50% of the course content was devoted to tree biology topics (in 80% of the courses responding), and of that, roots were examined less than 25% of the time. This indicates that tree biology is important, but not the entire focus of the educational effort in a course with "Arboriculture" in the title.

Most Students Encounter the Principle Course with Tree Biology Content in their First Year of Study

Seventeen of the respondents indicated that the principle course with tree biology content is encountered by students during their first year of studies. Two-year, post-secondary curriculum is typically designed to build subject-matter complexity over time, culminating with a capstone-course that brings all knowledge and skill together during the final year, or even final semester, of study. The fact that a large percent of tree biology-content courses occur during the first two semesters implies that it is intended to provide a foundational understanding, or serve as a prerequisite course for more complex coursework. More coursework containing tree biology topics are likely encountered during the second year of study in many of the participating programs/curricula.

No Single Textbook is Widely Used to Teach Tree Biology

This study found that no textbook title was consistently used for tree biology education among participating instructors. The book titled *Arborists' Certification Study Guide* by Sharon Lilly (2010) was reported to be used most often (by 32% of respondents) as a primary textbook for teaching tree biology. *Arboriculture – Integrated Management of Landscape Trees, Shrubs, and Vines* (4th edition) by Richard Harris, James Clark, & Nelda Matheny (2004) was reported to be used as a primary textbook by 26% of respondents. Forty-five percent of respondents indicated using *A New Tree Biology* by Alex Shigo (1986) as a secondary reference to support their tree biology educational efforts. These findings indicate a need for a tree biology textbook to that effectively supports classroom education at the two-year post-secondary level.

A Variety of Printed and Electronic Resources Used to Teach Tree Biology Topics

Tree biology instructors noted using a variety of printed and electronic resources from industry sources. In specific, the International Society of Arboriculture (ISA) is cited most frequently as a source for printed resources to help teach tree biology topics. In addition, the ISA has produced a series of electronic, interactive educational CDs on a variety of tree biology topics. These electronic resources from the ISA are the most frequently reported electronic resources used for teaching tree biology. Education is a principle goal of the ISA in their support of the arboriculture and urban forestry industry. This study confirms that the ISA tree biology resources are being used for this purpose by post-secondary instructors that participated in this study.

A final note of interest, one respondent mentioned that a majority of tree biology course content was being delivered via online learning at their institution. This may become a direction of the future for tree biology education.

Tree Biology Instructor Topical Ratings Confirm Two-Year Post-Secondary Education Aligned with Industry Priorities

Forty-six different tree biology topics were presented to participating instructors to learn what was determined to be important in two-year post-secondary arboriculture and urban forestry education. It can be inferred, by way of this study, that instructors are teaching the tree biology topics, at least to some degree, following the importance rating of topics.

There was no agreement on a specific topic or set of topics that were of "High" importance to teach by this set of respondents. A full list of tree biology topics, including their rated order from highest to lowest, can be found in the Appendix (Appendix N). Generally speaking, half of the topics were rated as Moderate in importance (Appendix Q) and the other half was rated as Low in importance (Appendix R).

Table 21 provides a summary view of "Weighted Index Score for Tree Biology Topical Categories." This rating presents a hierarchy of learning. In other words, it is no surprise that tree biology topics related to "Structure/Anatomy" are considered most important by participating instructors; getting to know the names for all of the distinct parts of a tree is considered most important. Learning about "Functions/Processes" is rated a close second place. Learning how the distinct parts fit together and knowing what they do, individually and collectively, follows Structure/Anatomy in importance. Both Structure/Anatomy and Functions/Processes are rated as "Moderate" in importance.

"Growth Processes" and "Concepts, Hypotheses, and Theories" are rated third and fourth in importance, respectively; and they are both considered "Low" in importance by participating instructors. Both categories of topics are more complex in understanding and are clearly not as

important for students to grasp right away. Learning about tree biology is a life-long process and it is more important to master the basics before moving to more complex information.

Of the forty-six topics presented to instructors for rating included twenty-seven that related parts of trees that are aboveground; nineteen of the topics relate to roots. One revealing aspect of the topical ratings was the "Weighted Index Score Rankings for Aboveground/Tree Root Biology Topical Categories" found in Table 32. The rating of the categories falls in line with the emphasis of topics by arboriculture industry standards like the *Arborist Certification* and *A300 Best Management Practices*. The greatest importance is rated with understanding the Tree Root Biology Functions/Processes. Another way to look at this is the health of the top of the tree is dictated by the health of the root system. This confirms that participating tree biology instructor's place a similar importance to tree biology understanding as prevailing industry wisdom.

Recommendations

A solid foundational understanding of tree biology, especially the structures and functions related to roots, is essential for practitioners in the arboriculture and urban forestry industry. Colleges and universities should continue to work hard to assure that graduates are well prepared to meet tree biology challenges and continue to advance the profession. This can be accomplished by regularly evaluating institutional curriculum to maintain alignment with the needs of students and the industry they serve. Arboriculture and urban forestry related-recommendations are offered here for issues related to this study, and for further research.

Recommendations Related to this Study

Standards exist for a basic level of knowledge for arboriculture and urban forestry industry practitioners via various certification credentials and best practices publications. This

study reveals that instructors' perceptions are aligned with industry in this regard. However, offering a degree in arboriculture and urban forestry that is well-aligned with the industry is very different from curriculum of a related field of study offering a single course in the subject. There is a need for industry to clarify what is necessary for post-secondary curricula to claim alignment.

Existing arboriculture and urban forestry two-year post-secondary programs that are well-aligned with industry should be highlighted and promoted. Industry practitioners and employers should be actively involved in promoting these educational programs and assisting with recruiting prospective degree candidates.

Two-year post-secondary institutions involved in arboriculture and urban forestry education should maintain the emphasis, or place a greater emphasis, on tree biology within their curricula, and roots in specific. Devoting a semester-long course entirely to the study of tree biology, equally distributed to above- and below-ground topics, would highlight the level of importance this knowledge is to being successful in industry. A concentration of study devoted to tree biology would advance the educational experience for students in preparation for the rigors and challenges of working in the arboriculture and urban forestry industry.

There is to be a need for development of a tree biology textbook specifically for use in post-secondary educational settings. Many resources are available and in use today. However, not one text today has the qualities necessary to fulfill this niche.

The International Society of Arboriculture should continue to promote their line of tree biology education materials and develop new ones to continue to meet the needs of the educational segment of industry. The current resources are being used and appear to be effective.

Recommendations for Further Study

The advancement of arboriculture and urban forestry post-secondary education will continue to improve through a clear understanding of the needs of its students, and matching those with the needs of the industry they serve. This study reveals the need for additional research related to the advancement in arboriculture and urban forestry post-secondary education in five areas.

Recommendation 1. Survey all educational programs that offer arboriculture, urban forestry, and related-disciplines to learn specifically what credentials and degrees are offered. Many institutions advertise involvement in arboriculture and urban forestry education. For example, the International Society of Arboriculture (ISA) has a directory listing of colleges and universities involved in arboriculture and urban forestry education. It is unclear to what extent each program is involved in preparing students for this industry. Degree titles reveal little about the curricula. Also, institutions may change focus or eliminate degree offerings. Clarification of the level of involvement and specific credentials offered in this area would help in future research efforts. Employers may also appreciate this clarification to focus or guide employee recruitment efforts.

Recommendation 2. Conduct a survey of arboriculture and urban forestry graduates to learn their perceptions about how well they were prepared for industry, and from a tree biology perspective in specific. Do graduates perceive themselves as being well-prepared for the tree biology challenges they encountered upon entering the industry?

Recommendation 3. Conduct a tree biology curricula assessment to learn the extent to which tree biology topics are included in all coursework to demonstrate how this skill-set is developed over the course of a students' educational career. This study was focused, looking

specifically at one course; the principle course containing tree biology content within a curriculum. A broader view of entire curricula would reveal more about how students are being prepared for a career in industry.

Recommendation 4. Research the successes of graduates from one-, two-, and four-year arboriculture and urban forestry degrees from an employers' perspective. The last study of employer perspectives of arboriculture education was done in 1984 (MacPherson, 1984). Much has changed in tree biology knowledge, research, education, and industry practices since then. Is arboriculture and urban forestry education aligned with the needs of industry, or is there a perception that areas of deficiencies exist?

Recommendation 5. Compare the successes of graduates from arboriculture and urban forestry degrees with the successes of graduates entering arboriculture and urban forestry from related-disciplines. Does it pay to focus education to the specific skill-set designed for arboriculture and urban forestry, or are students with a broader-based education just as successful?

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Appendix A

Tree Root Biology Curricula Survey

Introduction

Today, the arboriculture and urban forestry professions generally consider a thorough understanding of tree biology to be an important, foundational element in becoming a practicing professional. Surveys of college and university arboriculture and urban forestry programs have found that tree biology-related topics rank high as a part of the degree programs. It is assumed that arboriculture and urban forestry post-secondary programs are also placing a priority on tree root biology education. Healthy, functioning roots are a critical element in maintaining the health and vitality of a tree. Much attention among researchers and industry has recently shifted to bolstering our understanding of the biology of a tree's root system. A majority of problems affecting trees are attributed to dysfunction in the landscape below-ground. The International Society of Arboriculture, and many other arboriculture and urban forestry organizations routinely feature and emphasize tree root biology topics in continuing education events and publications.

Purpose of this study

Previous studies have mostly focused on four-year undergraduate arboriculture and urban forestry curricula. Very little is known about the curricula at one- and two-year degree programs in arboriculture and urban forestry in the US. The principal goal of this study is to describe the tree root biology educational efforts in one- and two-year degree curricula. A summary of the results from this survey will be shared with professional arboriculture and urban forestry organizations including the International Society of Arboriculture, Tree Care Industry Association, Society of American Foresters, and Professional Landcare Network. Would you please help describe the tree biology educational work that is being done to prepare graduates of one- and two-year degree programs?

Sincerely,

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This study has been reviewed and approved by The University of Wisconsin - Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies.
If you have any questions, concerns, or reports regarding your rights as a research participant, please contact the IRB Administrator, Sue Foxwell, Director, Research Services, 152 Vocational Rehabilitation Building, UW-Stout, Menomonie, WI 54751, (715) 232-2477.

Please describe the Tree Biology courses taught at your institution

Q1 Does your curricula offer a course (or courses) that address Tree Biology topics taught by faculty within your program area?

- ❍ Yes (1)
- ❍ No (2)

Q2 Have you taught Tree Biology topics for your school's arboriculture/urban forestry program in the last two years?

- ❍ Yes (1)
- ❍ No (2)

Please describe the primary Tree Biology Course that you taught in the past two years.

Q3 What is the title of the course, how many credits is it, and when do students encounter it within their curriculum?

Name/Title (1) Number of Credits (2) Which school term do students encounter this course? (e.g., First Term, Second Term, etc.) (3)	

Q4 How much of the overall class is devoted to Tree Biology topics? (Please estimate the percentage if you do not know exactly.)

Course with Tree Biology Content (1)	❍ 100 - 76% (1)	❍ 75 - 51% (2)	❍ 50 - 26% (3)	❍ 25 - 11% (4)	❍ 10% or less (5)	❍ Unsure (6)

Q5 How much of the Tree Biology topics (listed in the previous question) specifically focus on the study of roots?

Course with Tree Biology Content (1)	❍ 100 - 76% (1)	❍ 75 - 51% (2)	❍ 50 - 26% (3)	❍ 25 - 11% (4)	❍ 10% or less (5)	❍ Unsure (6)

Q6 How do you use these books to teach Tree Biology in this specific course?

"Arboriculture" by Richard Harris (1)	❍	❍	❍
"New Tree Biology" by Alex Shigo (2)	❍	❍	❍
"Certified Arborist Study Guide" by the International Society of Arboriculture (3)	❍	❍	❍
Other, please list (4)	❍	❍	❍

Q7 Do you use any other printed resources to teach Tree Biology?

❍ Yes (1)

❍ No (2)

Answer If Do you use any other printed resources to teach Tree Biol... Yes Is Selected

Q8 Please list the titles and author's name(s) for any other printed resources used to teach Tree Biology.

Q9 Do you use electronic resources to teach Tree Biology related topics (i.e., Tree Biology interactive CD produced by the International Society of Arboriculture)?

- ❍ Yes (1)
- ❍ No (2)

Answer If Do you use electronic resources to teach Tree Biology rel... Yes Is Selected

Q10 Please list electronic resources used to teach Tree Biology.

Please describe the Tree Biology Topics that are important within your institution's arboriculture and urban forestry curriculum.

"Arboriculture and Urban Forestry Education in the United States: Results of an Educator's Survey," (Elemendorf, Watson and Lilly, 2005) found that tree biology topics were considered important elements in a four-year degree undergraduate degree program. Tree biology is a vast topical area. One goal of this survey is to describe this aspect of arboriculture and urban forestry education in more specific terms.

Please rate the importance of each Tree Biology topic in the following four lists relative to your curricula.

Q11 **Importance of Growth Processes in my Curricula**

Seed Germination (1)	❍	❍	❍	❍	❍
Seedling Development (2)	❍	❍	❍	❍	❍
Root Tip Meristem Growth (3)	❍	❍	❍	❍	❍
Root Cambium Zone Growth (4)	❍	❍	❍	❍	❍
Root Growth in a 3-Dimensional View (5)	❍	❍	❍	❍	❍

Non-Woody Root Formation (6)	❍	❍	❍	❍	❍
Mycorrhizal Associations (7)	❍	❍	❍	❍	❍
Root Zone Reactionwood Formation and Self-Optimization (8)	❍	❍	❍	❍	❍
Callus Tissue and Woundwood Formation in Roots (9)	❍	❍	❍	❍	❍
Other (please list) (22)	❍	❍	❍	❍	❍
Other (please list) (23)	❍	❍	❍	❍	❍

Q12 **Importance of Structure/Anatomy in my Curricula**

Outside Parts of a Twig (1)	❍	❍	❍	❍	❍
Internal Parts in a Cross-sectional View of a Stem (2)	❍	❍	❍	❍	❍
Internal Parts in a Longitudinal View of a Stem (3)	❍	❍	❍	❍	❍
Outside Parts of the Trunk (4)	❍	❍	❍	❍	❍
Branch Attachment (5)	❍	❍	❍	❍	❍
Transition Zone Between Stem/Roots (6)	❍	❍	❍	❍	❍
Support/Structural Roots (7)	❍	❍	❍	❍	❍
Outside Parts of Woody Roots (8)	❍	❍	❍	❍	❍
Internal Parts in a Cross-sectional View of Woody Roots (9)	❍	❍	❍	❍	❍
Internal Parts in a Longitudinal View of Woody Roots (10)	❍	❍	❍	❍	❍
Lateral Root Formation (11)	❍	❍	❍	❍	❍
Structural Defects (12)	❍	❍	❍	❍	❍
Fine Roots (13)	❍	❍	❍	❍	❍
Other (please list) (14)	❍	❍	❍	❍	❍
Other (please list) (15)	❍	❍	❍	❍	❍

Q13 **Importance of Functions/Processes in my Curricula**

Photosynthesis (1)	❍	❍	❍	❍	❍
Photorespiration (3)	❍	❍	❍	❍	❍
Respiration (2)	❍	❍	❍	❍	❍
Fall Color and Leaf Senescence (4)	❍	❍	❍	❍	❍
Phenology (5)	❍	❍	❍	❍	❍
Energy Resource Allocation (6)	❍	❍	❍	❍	❍
Fluid Conductivity/Transport in the Phloem (7)	❍	❍	❍	❍	❍
Fluid Conductivity/Transport in the Xylem (8)	❍	❍	❍	❍	❍
Evapotranspiration (9)	❍	❍	❍	❍	❍
Flower Formation/Fertilization (10)	❍	❍	❍	❍	❍
Pollen Development/Dispersal (11)	❍	❍	❍	❍	❍
Wound Response (12)	❍	❍	❍	❍	❍
Water Relations (13)	❍	❍	❍	❍	❍
Water/Essential Element Uptake (14)	❍	❍	❍	❍	❍
Other (please list) (15)	❍	❍	❍	❍	❍
Other (please list) (16)	❍	❍	❍	❍	❍

Q14 **Importance of Concepts, Hypotheses, and Theories in my Curricula**

Core/Skin Hypothesis (1)	❍	❍	❍	❍	❍
Mass/Energy Ratio (2)	❍	❍	❍	❍	❍
Three Tree Concept (3)	❍	❍	❍	❍	❍
Survival (4)	❍	❍	❍	❍	❍
Tree Pump Concept (5)	❍	❍	❍	❍	❍
Energy and Stress (6)	❍	❍	❍	❍	❍
Allelopathy (7)	❍	❍	❍	❍	❍
Bio-Mechanics (8)	❍	❍	❍	❍	❍
Tree Associations (9)	❍	❍	❍	❍	❍
Tree Nutrition (10)	❍	❍	❍	❍	❍
Other (please list) (11)	❍	❍	❍	❍	❍
Other (please list) (12)	❍	❍	❍	❍	❍

Please Describe Your Academic Program

This next set of questions is intended to learn more about the school you represent and the degree(s) offered related to Arboriculture and Urban Forestry.

Q15 Does your school/institution offer diploma(s), certificate(s), or degree(s) in Arboriculture or Urban Forestry?

- ❍ Yes (1)
- ❍ No (2)

If No (skip to question 23) Is Selected, Then Skip To Does your school/institution offer a ...

Q16 Please note the credential(s) students earn in Arboriculture or Urban Forestry from the list below.

Arboriculture (1)	❑	❑	❑	❑
Urban Forestry (2)	❑	❑	❑	❑

Q17 Does your school/institution offer a diploma, certificate, and/or degree related to Arboriculture or Urban Forestry (for example: Horticulture, Natural Resources, etc.)?

- ❍ Yes (1)
- ❍ No (2)

Answer If Does your school/institution offer a diploma, certificate... Yes Is Selected

Q18 Please check all of the credential(s) students may earn through your school/institution related to Arboriculture or Urban Forestry from the table below.

Horticulture (1)	❑	❑	❑	❑
Landscape Management (2)	❑	❑	❑	❑
Natural Resource Management (3)	❑	❑	❑	❑
Environmental Science (4)	❑	❑	❑	❑
Other (please list) (5)	❑	❑	❑	❑
Other (please list) (6)	❑	❑	❑	❑

Please direct any comments, questions or requests for information to:

Pete Rudquist
c/o Mid-State Technical College
500 - 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429
rudquistp@uwstout.edu

Thank you for your participation and cooperation!

Appendix B

Tree Root Biology Curricula Distribution List

Mr. Kent Schwartz
Faulkner State Community College
1900 Highway 31 South
Bay Minette, AL 36507

Mr. Brian Morris
Reedley College
Forest and Park Technology
Reedley, CA 93654

Mr. John Peirsol
Florida Gateway College
149 SE College Place
Lake City , FL 32025

Mr. Tommy Peagler
Okefenokee Technical College
Forest Technology
Waycross, GA 31503

Kerry Watts
Wiregrass Georgia Technical College
4089 Val Tech Road
Valdosta, GA 31602-0929

Mr. Fredric Miller
Joliet Junior College
1215 Houbolt Ave.
Joliet, IL 60431

Mr. Stephen Coleman
Central Louisiana Technical College - Oakdale
117 Hwy 1152
Oakdale, LA 71463

Mr. Stephen Dubik
Montgomery College
20200 Observation Dr SA-267
Germantown, MD 20876

Mr. James Stickler
Allegany College of Maryland
12401 Willowbrook Rd. SE.
Cumberland, MD 21502

Mr. Marshall Baeckeroot
Oakland Community College
Auburn Hills Campus
Auburn Hills, MI 48326-2845

Mr. Tim Baker
College of the Redwoods
7351 Tompkins Hill Rd.
Eureka, CA 95501

Mr. Kenneth Nolte
Shasta College
P. O. Box 496006
Redding, CA 96049-6006

Mr. Shane Evans
Chatahoochee Technical College
5198 Ross Road
Acworth, GA 30102

Mr. Aaron Poulsen
Gwinnett Technical College
5150 Sugarloaf Parkway
Lawrenceville, GA 30043

Mr. Michael Burkle
Kirkwood Community College
6301 Kirkwood Blvd. S.W.
Cedar Rapids, IA 52404

Ms. Carla Hagan
Eastern Kentucky University
Rm 2 AB Carter Bldg
Richmond, KY 40475

Dr. Brian Kane
University of Massachusetts
80 Campus Center Way
Amherst, MA 01003-9246

Mr. Dan Friedman
Howard Community College
10901 Little Patuxent Parkway
Columbia, MD 21044

Mr. Doug Fox
Unity College
90 Quaker Hill Road
Unity, ME 04988

Mr. Jim Lynch
Lansing Community College
42219 N. Washington Street
Lansing, MI 49833

Mr. Fernando Fernandez
College of the Sequoias
2245 South Linwood
Visalia, CA 93277

Mr. Ray Daugherty
Front Range Community College
3645 West 112th Avenue
Westminter, CO 80031

Mr. Gregory Huber
Southern Crescent Technical College
501 Varsity Road
Griffin, GA 30223

Mr. John Thrift
Southeastern Technical College
Forest Technology
Swainsboro, GA 30401

Mr. Kaizad Irani
Parkland College
2400 W. Bradley Ave.
Champaign, IL 61821

Ms. Bettie Abbate
Delgado Community College
Horticulture Dept.
New Orleans, LA 70119

Mr. Thomas Smith
Springfield Technical Community College
Armory Square - Suite 1
Springfield, MA 01102-9000

Mr. Ken Henn
Catonsville Community College
7200 Sollers Point Rd
Dundalk, MD 21222-4649

Mr. David Palm
Southern Maine Community College
2 Fort Road
South Portland, ME 04106

Mr. Matt Brooks
Dakota County Technical College
1300 E. 145th Street
Rosemont, MN 55068

Mr. Doug Courneya
Rochester Community College
851 30th Ave. SE
Rochester, MN 55904-4999

Dr. Lekha Sreedhar
Johnson County Community College
12345 College Blvd.
Overland Park, MO 66210-1299

Mr. John Holmes
Central Piedmont Community College
P.O. Box 35009
Charlotte, NC 28235-5009

Mr. Justin Snyder
Alamance Community College
1247 Jimmie Kerr Rd.
Graham, NC 27253-8000

Mr. Bob Underwood
Dakota College at Bottineau
105 Simrall Blvd.
Bottineau, ND 58318

Dr. Steven Fischer
Bergen Community College
400 Paramus Rd
Paramus, NJ 07652

Ms. Birgitta Brophy
SUNY Delhi College
155 Farnsworth Hall
Delhi, NY 13753

Ms. Anne Schnell
Finger Lakes Community College
3325 Marvin Sands Drive
Canadaigua, NY 14424

Mr. Christopher Westbrook
SUNY Wanakena
257 Ranger School Road
Wanakena, NY 13695

Mr. Dave Emmitt
Cuyahoga Community College
4250 Richmond Rd.
Highland Hills, OH 74122

Mr. Jay Siedschlaw
Hennepin Technical College
13100 Collegeview Road
Brooklyn Park, MN 55445

Ms. Martha Hill
Hinds Community College
P. O. Box 1100
Raymond, MS 39154

Ms. Dee Johnson
Sandhills Community College
2200 Airport Rd.
Pinehurst, NC 28374

Mr. Russell Strong
Montgomery Community College
1011 Page Street
Troy, NC 27371

Drew Anderson
Nebraska College of Technical Agriculture
404 East 7th St.
Curtis, NE 69025

Ms. Amy Iseneker Ricco
Mercer County Community College
102 N. Broad Street
Trenton, NJ 08608

Kelly Hennigan
Morrisville State College SUNY
P. O. Box 901
Morrisville, NY 13408

Mr. Randall Swanson
Paul Smiths College
103 Freer Science Bldg
Paul Smiths, NY 12970

Mr. Mark Deacon
Cincinnati State Technical College
3520 Central Parkway
Cincinnati, OH 45223

Dr. Susan Everett
Clark State Community College
570 East Leffel Lane
Springfield, OH 45501-0570

Ms. Theri Wasniewski
Central Lakes College
501 West College Drive
Brainerd, MN 56401

Dr. Bill Fonteno
North Carolina State University
Box 7609
Raleigh, NC 27695-7609

Mr. Darrell Kiser
Catawba Valley Community College
2550 Highway 70 S.E.
Hickory, NC 28302

Mr. George Thomas
Haywood Community College
Natural Resources Div.
Clyde, NC 28721

Mr. Matt Chagnon
University of New Hampshire - Thompson
11c Putnam Hall
Durham, NH 03824

Ms. Jan-Marie Traynor
Morris County College
214 Center Grove Rd.
Randolph, NJ 07869

Mr. Jack Ingels
SUNY Cobleskill
State Route 7
Cobleskill, NY 12043

Mr. Jonathan Lehrer
SUNY Farmingdale
2350 Broadhollow Road
Farmingdale, NY 11735

Mr. Jim Downs
Hocking Technical College
3301 Hocking Parkway
Nelsonville, OH 45764-9588

Mr. Chris Foley
Owens Community College
P.O. Box 10000
Toledo, OH 43699

Mr. Steve O'Neil
Columbus State Community College
550 East Spring Street
Columbus, OH 43216-1609

Mr. Michael Fisher
Central Oregon Community College
2600 N. W. College Way
Bend, OR 97701

Mr. Mike Dincher
Pennsylvania College of Technology
One College Ave
Williamsport, PA 17701-5799

Dr. Don Jackson
The Williamson Free School of Mech. Trades
106 South New Middletown Road
Media, PA 19063

Mr. Allen R. Gibson
Southeast Technical Institute
2320 N. Career Ave.
Sioux Falls, SD 57107

Mr. Dearl Lampley
Columbia State Community College
1665 Hampshire Pike
Columbia, TN 38401

Mr. David Scheid
Northern Virginia Community College - Loudoun
1000 Harry Flood Byrd Hwy.
Sterling, VA 20164-8699

Mr. Bob Peregoy
Spokane Community College
1810 North Greene St MS 2080
Spokane, WA 99207

Ms. Kate Fields
Gateway Technical College
3520 30th Avenue
Kenosha, WI 53143-1690

Mr. Maurice Peoples
Kent State University - Salem
2491 State Route 45 South
Salem, OH 44460

Mr. Bruce Nelson
Clackamas Community College
19600 South Molalla Ave.
Oregon City, OR 97045

Mr. Craig Houghton
Penn State Mont Alto
1 Campus Drive
Mont Alto , PA 17327

Xuri Zhang
Westmoreland County Community College
145 Pavilion Lane
Youngwood, PA 15697

Ms. Vicki Armstrong
Southwest Tennessee Community College
5983 Macon Cove
Memphis, TN 38134

Mr. Brian Keiling
Dabney Lancaster Community College
1000 Dabney Drive
Clifton Forge, VA 24422

Mr. David Seward
Sargent Reynolds Community College
Western Campus
Richmond, VA 23285-5622

Mr. Jim Beard
Fox Valley Technical College
1825 N. Bluemound Drive
Appleton, WI 54912-2277

Mr. Peter-Jon Rudquist
Mid-State Technical College
500 - 32nd Street North
Wisconsin Rapids, WI 54494

Mr. Larry Steward
Ohio State ATI
1328 Dover Rd.
Wooster, OH 44691-4000

Dr. Robert Cook
Keystone College
One College Green
LaPlume, PA 18440-0200

Ms. Eva Monheim
Temple University - Ambler
580 Meetinghouse Road
Ambler, PA 19002

Mr. Jason Bagwell
Spartanburg Community College
Horticulture Dept.
Spatanburg, SC 29305

Mr. Jim Janosky
Nashville State Community College
120 White Bridge Rd
Nashville, TN 37209

Mr. Joseph Murray
Blue Ridge Community College
PO Box 80
Weyers Cave, VA 24486

Mr. Don Marshall
Lake Washington Tech
11605 103rd Ave. NE
Kirkland, WA 98034-8506

Mr. Peter Bemis
Western Technical College
400 Seventh Street North
Lacrosse, WI 54601

Appendix C

Letter of Introduction

Monday, April 25, 2011

Dear Green Industry Educator:

A request for your participation in a study titled, *An Investigation of Tree Root Biology Curricula in Two-Year Arboriculture and Urban Forestry Post-Secondary Programs in the United States* will be sent to you via email within the next week. **Your time and the information you provide are valuable and will help make this project successful!**

You were identified as a principal source regarding knowledge about the instruction of tree biology topics at your institution. However, if you feel a colleague is more directly connected with tree biology education at your institution, would you please "REPLY" to this email and provide a name and email contact for that individual?

Participation from everyone is crucial to develop an understanding of the approaches and materials currently being used to teach tree root biology. **This is an opportunity to highlight the great efforts being done across the US to prepare the next generation of arborists and urban foresters.** A summary of the findings will be submitted to peer-reviewed arboriculture- and urban forestry-related industry journals.

Please give this effort serious consideration and your full participation. If you have any questions or require additional information about the survey, please contact me by phone at (715) 422-5429, or via email at rudquistp@uwstout.edu.

Sincerely,

Peter-Jon Rudquist, University of Wisconsin – Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

Appendix D

University of Wisconsin-Stout, Institutional Review Board Approval Letter

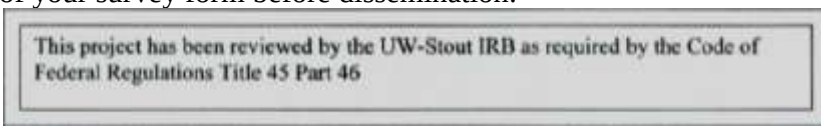
April 6, 2011

Peter-Jon Rudquist
UW-Stout

Dear Peter-Jon,

The IRB has determined your project, " *An Investigation of Tree Root Biology Curricula in Two-Year Arboriculture and Urban Forestry Post-Secondary Degree Programs in the United States"* is **Exempt** from review by the Institutional Review Board for the Protection of Human Subjects. The project is exempt under **Category 2** of the Federal Exempt Guidelines and holds for 5 years. Your project is approved from **April 5, 2011**, through **April 4, 2016**. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exemption categories you will need to reapply to the IRB for review of your modified study.

If your project involved administration of a survey, please copy and paste the following message to the top of your survey form before dissemination:



If you are conducting an **online** survey/interview, please copy and paste the following message to the top of the form:
"This research has been reviewed by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46."

Informed Consent: All UW-Stout faculty, staff, and students conducting human subjects research under an approved "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report: 1) respect for persons; 2) beneficence; and 3) justice. These three principles are best reflected in the practice of obtaining informed consent from participants.

If you have questions, please contact Research Services at 715-232-1126, or foxwells@uwstout.edu, and your question will be directed to the appropriate person. I wish you well in completing your study.

Sincerely,

Susan Foxwell

Susan Foxwell
Research Administrator and Human Protections Administrator,
UW-Stout Institutional Review Board for the Protection of Human Subjects in Research (IRB)
CC: Carol Mooney

Appendix E

Invitation to Participate in Tree Root Biology Curricula Survey Letter

Wednesday, April 27, 2011

Dear Fellow Green Industry Educator:

Your participation is requested to complete the *Tree Root Biology Curricula Survey*. This questionnaire should take less than 10 minutes to complete. Your participation is valuable and crucial to the success of this project.

This effort has the potential to provide many benefits. Previous arboriculture and urban forestry curricula studies have focused on four-year degree programs. Additionally, these studies conclude that understanding tree biology is important, yet little has been done to evaluate the extent to which the biology of tree roots is taught over the course of a student's educational career.

A primary objective of this investigation is to learn about tree root biology curricula at two-year degree programs in the United States. That is why I need your help!

This is an opportunity to highlight the great efforts being done across the US to prepare the next generation of arborists and urban foresters.

A summary of the findings will be submitted to peer-reviewed green industry journals.

I respect your right to not participate, or to maintain anonymity if you do participate. Your response will be entirely voluntary. You may choose not to participate without any adverse consequences to you. You may exit the questionnaire at any time. Once submitted, your responses cannot be withdrawn.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Please contact me for more information or if you have any questions at (715) 422-5429 or rudquistp@uwstout.edu. Also, please contact me if you are interested in receiving a printed summary of the results when it is completed later this summer.

Sincerely,
Peter-Jon Rudquist, University of Wisconsin-Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax
Follow the link to opt out of future emails:
${l://OptOutLink}

Appendix F

First Reminder to Participate in Tree Root Biology Curricula Survey Letter

Wednesday, May 4, 2011

Dear Green Industry Educator:

Your participation was recently requested to complete the questionnaire, *Tree Root Biology Curricula Survey*. **I need your help because your perspective about tree biology education is valuable!** Perhaps you have not had a chance, yet. It is not too late to provide your information anonymously by clicking on the link below.

This project has the potential to provide many benefits to the arboriculture and urban forestry industry. Did you know that …

- much of arboriculture and urban forestry curricula research work to date has focused on four-year degree programs?

-research concludes that understanding tree biology and roots is important, yet little has been done to evaluate the extent to which tree biology is taught over the course of a student's educational experience in post-secondary education?

These are just a couple of the objectives for conducting this investigation. *The questionnaire should take you less than 10 minutes to complete.* This is an opportunity to highlight the great efforts being done across the US to prepare the next generation of arborists and urban foresters. *Your assistance is of great value even if your school does not specifically offer a tree biology class.* Please give this effort serious consideration and your full participation.

Follow this link to the Survey: ${l://SurveyLink?d=Take the Survey}

Please contact Pete Rudquist for more information or if you have any questions at (715) 422-5429 or at rudquistp@uwstout.edu.

Sincerely,

Pete Rudquist, University of Wisconsin - Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

This study has been reviewed and approved by The University of Wisconsin - Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies.If you have any questions, concerns, or reports regarding your rights as a research participant, please contact the IRB Administrator, Sue Foxwell, Director, Research Services, 152 Vocational Rehabilitation Building, UW-Stout, Menomonie, WI 54751, (715) 232-2477.

Follow the link to opt out of future emails:
${l://OptOutLink}

Appendix G

Second Reminder to Participate in Tree Root Biology Curricula Survey Letter

Wednesday, May 11, 2011

Dear Green Industry Educator:

It is a busy time of year as we all wrap up another academic year. There really is no such thing as a "good time of the year" for me to ask for your help because everyone is very busy all of the time. **I still need your help to tell about all the successes of tree biology education in two-year degree programs!** Perhaps you have not had a chance to complete the TREE ROOT BIOLOGY CURRICULA SURVEY. It is not too late to provide your information anonymously by clicking on the link below.

This project has the potential to provide many benefits to the arboriculture and urban forestry industry. Did you know that …

- much of arboriculture and urban forestry curricula research work to date has ignored two-year degree programs?

-research concludes that understanding tree biology and roots is important, yet little has been done to evaluate the extent to which tree biology is taught over the course of a student's educational experience in post-secondary education?

These are just a couple of the objectives for conducting this investigation. *The questionnaire should take you less than 10 minutes to complete.*

This is an opportunity to highlight the great efforts being done in two-year degree programs across the US to prepare the next generation of arborists and urban foresters.

Your assistance is of great value even if your school does not specifically offer a tree biology class. Please give this effort serious consideration and your full participation.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Please contact Pete Rudquist for more information or if you have any questions at (715) 422-5429 or at rudquistp@uwstout.edu.

Sincerely,

Pete Rudquist, University of Wisconsin-Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

This study has been reviewed and approved by The University of Wisconsin - Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies.

If you have any questions, concerns, or reports regarding your rights as a research participant, please contact the IRB Administrator, Sue Foxwell, Director, Research Services, 152 Vocational Rehabilitation Building, UW-Stout, Menomonie, WI 54751, (715) 232-2477.

Follow the link to opt out of future emails:
${l://OptOutLink}

Appendix H

Third Reminder to Participate in Tree Root Biology Curricula Survey Letter

Wednesday, May 18, 2011

Dear Green Industry Educator:

You have a very unique perspective, and that is why your participation has been requested to complete the questionnaire, *Tree Root Biology Curricula Survey*. I hope to be able to highlight the great efforts being done across the United States to prepare the next generation of graduates for the arboriculture and urban forestry industry via the information you provide on this survey.

I am continually amazed to see the places Mid-State Technical College graduates end up working in the green industry. Perhaps you have witnessed this, too. This is one of my motives for asking you to help me with this survey. ***Your program does not have to offer a degree or coursework in arboriculture and urban forestry for the information to be valuable to this project!***

I need your help. *The questionnaire should take you less than 15 minutes to complete*. Won't you take a few minutes to do this, please? It is not too late to provide your valuable input by clicking on the link below.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Please contact Pete Rudquist for more information or if you have any questions at (715) 422-5429 or at rudquistp@uwstout.edu.

Sincerely,

Pete Rudquist, University of Wisconsin - Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

This study has been reviewed and approved by The University of Wisconsin - Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies.

If you have any questions, concerns, or reports regarding your rights as a research participant, please contact the IRB Administrator, Sue Foxwell, Director, Research Services, 152 Vocational Rehabilitation Building, UW-Stout, Menomonie, WI 54751, (715) 232-2477.

Follow the link to opt out of future emails:
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Appendix I

Fourth Reminder to Participate in Tree Root Biology Curricula Survey Letter

Tuesday, May 24, 2011

Dear Green Industry Educator:

Your participation has recently been requested to complete the questionnaire, *Tree Root Biology Curricula Survey*. Perhaps you have not had a chance, yet. It is not too late to provide your information anonymously by clicking on the link below.

This project has the potential to provide many benefits, but I cannot do it without your help. Your perspective about green industry education related to trees is very important and valuable. Very few people have tried to detail what two-year degree programs are doing to prepare the next generation for the arboriculture and urban forestry side of the green industry.

Would you help me tell this story? *The questionnaire should take you less than 10 minutes to complete.*

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Please contact Pete Rudquist for more information or if you have any questions at (715) 422-5429 or at rudquistp@uwstout.edu.

Sincerely,

Pete Rudquist, University of Wisconsin - Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

This study has been reviewed and approved by The University of Wisconsin - Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies.

If you have any questions, concerns, or reports regarding your rights as a research participant, please contact the IRB Administrator, Sue Foxwell, Director, Research Services, 152 Vocational Rehabilitation Building, UW-Stout, Menomonie, WI 54751, (715) 232-2477.

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Appendix J

Fifth Reminder to Participate in Tree Root Biology Curricula Survey Letter

Thursday, May 26, 2011

Dear Green Industry Educator:

You have a very unique perspective, and that is why your participation has been requested to complete the questionnaire, *Tree Root Biology Curricula Survey*. I hope to be able to highlight the great efforts being done across the United States to prepare the next generation of graduates for the arboriculture and urban forestry industry via the information you provide on this survey.

I am continually amazed to see the places Mid-State Technical College graduates end up working in the green industry. Perhaps you have witnessed this, too. This is one of my motives for asking you to help me with this survey. ***Your program does not have to offer a degree or coursework in arboriculture and urban forestry for the information to be valuable to this project!***

I need your help. *The questionnaire should take you less than 15 minutes to complete.* Won't you take a few minutes to do this, please? It is not too late to provide your valuable input by clicking on the link below.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Please contact Pete Rudquist for more information or if you have any questions at (715) 422-5429 or at rudquistp@uwstout.edu.

Sincerely,

Pete Rudquist, University of Wisconsin - Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

This study has been reviewed and approved by The University of Wisconsin - Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies.

If you have any questions, concerns, or reports regarding your rights as a research participant, please contact the IRB Administrator, Sue Foxwell, Director, Research Services, 152 Vocational Rehabilitation Building, UW-Stout, Menomonie, WI 54751, (715) 232-2477.

Follow the link to opt out of future emails:
${l://OptOutLink}

Appendix K

Sixth (Final) Reminder to Participate in Tree Root Biology Curricula Survey Letter

Wednesday, June 1, 2011

Dear Green Industry Educator:

Your participation has been requested a number of times to complete the *Tree Root Biology Curricula Survey*. It is not too late to provide your valuable input; but time is running short. You can still be a part of this important effort by clicking on the link below, however, the closing date of the survey is Friday, June 3, 2011.

I need your help! The questionnaire should take less than 20 minutes to complete. *This is an opportunity to highlight the great efforts being done across the United States to prepare the next generation of arborists and urban foresters.* Please give this effort serious consideration and your full participation.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Please contact me for more information or if you have any questions at (715) 422-5429 or at rudquistp@uwstout.edu.

Sincerely,

Peter-Jon Rudquist, University of Wisconsin - Stout Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

Appendix L

Thank you for Participating in the Tree Root Biology Curricula Survey Letter

Friday, June 3, 2011

Dear Green Industry Educator:

I am very grateful to you for taking time to complete the TREE ROOT BIOLOGY CURRICULA SURVEY! I have had the fortune to meet people from many aspects of the green industry throughout the country. It always impresses and humbles me to see the many ways in which folks within our industry support and help one another. Your willingness to help me with my project is another example of this. *Please accept my sincerest THANK YOU for your help!*

Thirty-seven of you responded out of the eighty-nine surveys that were distributed for a 42% response rate. The information you have provided will be tallied and summarized over the course of the summer months. Please contact me if you would like to receive a summary of the results directly from me when they are completed (anticipated completion date: August 2011).

Please contact me for more information or if you have any questions at (715) 422-5429 or at rudquistp@uwstout.edu.

Sincerely,

Peter-Jon Rudquist, University of Wisconsin – Stout, Graduate Student (Project Investigator)
c/o Mid-State Technical College
500 – 32nd Street North
Wisconsin Rapids, WI 54494
(715) 422-5429 office
(715) 422-5377 fax

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Follow the link to opt out of future emails:
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Appendix M

University of Wisconsin-Stout, Research Services, Data Analysis Plan

Peter-Jon Rudquist Research Project Report
Tree Root Biology Curricula Survey
Spring 2011
Report: 7/18/11

NOTE: statistical significance was judged using a significance level of 0.05 and 2-tailed tests (where appropriate). This means that a test statistic was deemed statistically significant if the calculated significance value was less than 0.05.

Data Analysis Conducted

Note: The question numbers are to assist the researchers when conducting statistical analyses and should be used with the survey instrument document (Tree_Root_Biology_Curricula_Surveyfinal.docx)

Research Questions –

1. How many programs offer a course with tree biology content?
   Q4: Analyze using descriptive statistics including frequencies
   Results: see output file.

2. What is the name of the principle course that has tree biology content, how many credits is it worth, and when do students encounter it in their educational career?
   Q6 (1 & 3): Analyze using descriptive statistics including frequencies
   Note: For question 6-1you will want to come up with some sort of grouping scheme for the names/titles of the courses. For example, you will have to determine if "***Arboriculture***" and "***Arboriculture 1***" belong in the same group. If so, you will want to standardize the naming convention by renaming each of the names/titles that belong in the same group the same. You will do the frequency counts based on these groupings.
   Q6-2: Analyze using descriptive statistics including frequencies, means, and standard deviations

   Note: For questions 6-2 & 3 you will want to recode the text variables into numeric values. For example, if someone responded "***4 quarter hours***" for question 6-2 you will want to recode that as simply "***4***."
   Results: researcher will conduct this analysis

3. What percent of this course is devoted to tree biology?
   Q7: Analyze using descriptive statistics including frequencies and median

   Results: see output file.

4. What percent of the tree biology content is devoted to the study of roots?
   Q8: Analyze using descriptive statistics including frequencies and median

   Results: see output file.

5. What textbooks are being used?
   Q29 (1-4): Analyze using descriptive statistics including frequencies

   Results: researcher will conduct this analysis

6. What other printed resources are being used?
   Q11: Analyze using descriptive statistics including frequencies

   You will want to come up with some sort of grouping scheme for the names/titles, and then you will do the frequency counts based on these groupings.
   Results: researcher will conduct this analysis

7. Are any electronic resources being used; if so, what are they?
   Q12-13: Analyze using descriptive statistics including frequencies

   Note: Again for question 13 you will want to come up with some sort of grouping scheme for the other electronic devices being used. For example, you will have to determine if "***ISA***" and "***ISA info***" belong in the same group. If so, you will want to standardize the naming convention by renaming each of the names/titles that belong in the same group the same.
   Results: researcher will conduct this analysis

8. How do tree biology instructors rank the list of tree biology topics?
   a. Which topics rank High, Moderate, Low, and Not Important?
      Q16-19: Analyze using descriptive statistics including frequencies, mean, median, and standard deviations
      Results: see output file.

   b. How are topics that focus on roots ranked?
      Q16-19: Analyze using descriptive statistics including frequencies, mean, median, and standard deviations
      Note: You will need to identify which particular items from questions 16-19 focus on roots for our clarification. In the attached Word doc of your survey, please highlight the root questions in yellow and send back to me. Thanks!
      Results: see output file.

   c. How does the ranking of root topics compare to the topics that cover the aboveground part of the tree?
      Q16-19: Using the averages and standard deviations from each root topic and each topic that covers the above ground part of the tree, create 95% confidence intervals (CI)

for the averages. Use the CI to determine if patterns emerge in the averages across topic type.

Results: see output file.

Note: The statistical analysis that may be performed is limited due to small sample size. Currently, these statistical analyses may not yield the information needed to address the highlighted questions below. One option is to recode the response options into two categories instead of four. For example, creating one category with the "high" ratings and another category with "moderate, low and not important" ratings may allow for additional statistical analyses and may yield more meaningful results. You may choose to group the data a different way – you could put the high and moderate together, etc.

- Before you decide about collapsing the groups, you will need to think about how you will describe/explain the results in your paper – does it make sense to you to have the moderate, low and not important responses grouped together? Will this make sense to your reader? You can always stay with the original grouping and not do the statistical analysis, but just look for trends.

Results: grouping was done using 2 groups: not important & low, moderate and high importance. Analysis run was:

- Split file of frequency of responses to matrix questions by whether or not they had a degree in arboriculture/urban forestry. Look at the results for trends.
- Crosstabs for each of the recoded matrix questions by whether or not they had a degree in arboriculture/urban forestry. Although there were no statistically significant results, you can still talk about possible trends re above bullet.

How do these numbers look for schools with degrees in arboriculture/urban forestry?

Q16-19 & 21: First recode question 21 so yes = 1 and no = 0. Then, select cases if question 21 = 1. Analyze using descriptive statistics including frequencies and medians

Results: unable to perform analysis because there were only 6 schools with degrees (we need at least 10 to calculate means)

Conversely, how do these numbers look for schools with related degrees?

Q16-19 & 23: First recode question 23 so yes = 1 and no = 0. Then, select cases if question 23 = 1. Analyze using descriptive statistics including frequencies and medians

Results: unable to perform analysis because nearly every school had related degrees

Do schools with arboriculture/urban forestry degrees place a greater ranking to root related topics than others?

Q16-19, 21, 23: First select cases if question 21 = 1. Then, select cases if new root/above ground variable (created above) = 1. Analyze using descriptive statistics including frequencies and medians

Results: unable to perform analysis because there were only 6 schools with degrees (we need at least 10 to calculate means)

d. How do schools with arboriculture/urban forestry degrees rank all topics compared to those with related degrees?
Q16-19, 21, 23: Because of the small number of schools with degrees, analyze using descriptive statistics including frequencies, median, cross-tabs and chi-square. To do the chi-square test, we will most likely need to collapse the rating scales as mentioned in the note above.

Results: unable to perform analysis because there were only 6 schools with degrees (we need at least 10 to calculate means), and nearly all had related degrees.

e. Do schools with arboriculture/urban forestry degrees rank topics similarly, or is there a wide range of options about what is important?
Q16-19, 21: Select cases if question 21 = 1. Analyze using descriptive statistics including frequencies and medians

f. How about schools that offer related degrees... do they rank topics similarly, or is there a wide range of options?
Q16-19, 23: Select cases if question 23 = 1. Analyze using descriptive statistics including frequencies, means, standard deviations, and medians – note that this was 22 out of the 24 responses, so the results will be very similar to the overall results.

9. How many two-year schools in the U.S. offer an arboriculture or urban forestry certificate or associates degree?
Q21: Analyze using descriptive statistics including frequencies

Results: see output file.

10. How many schools offer a minor/area of emphasis in study in arboriculture or urban forestry?
Q23: Analyze using descriptive statistics including frequencies

Results: see output file.

a. What major degrees are these minors/areas of emphasis in study housed under?
Q24: Analyze using descriptive statistics including frequencies

Results: see output file.

Results are in the attached output file "RP.spring2011.output.doc"
See the file "Support Document for SPSS output" for guidelines on how to read and interpret your results.

Appendix N

Complete List of Tree Biology Topics Rating in Order of Importance,

Survey Questions 11 – 14

	Not Important (0)	Low(1)	Moderate (2)	High (3)	Responses	Index Score Mean
Branch Attachment	0	2	2	20	24	2.75
Water Relations	0	0	9	15	24	2.63
Photosynthesis	1	1	4	17	23	2.61
Outside Parts of the Trunk	0	4	4	16	24	2.5
Support/Structural Roots	0	1	10	13	24	2.5
Wound Response	1	0	9	14	24	2.5
Outside Parts of a Twig	0	4	5	15	24	2.46
Water/Essential Elements Uptake	0	3	7	14	24	2.46
Structural Defects	1	0	11	12	24	2.42
Respiration	1	2	8	11	22	2.32
Mycorrhizal Associations	1	3	8	12	24	2.29
Energy Resource Allocation	1	1	13	9	24	2.25
Evapotranspiration	0	4	10	10	24	2.25
Tree Nutrition	0	6	6	12	24	2.25
Fluid Conductivity/Transport in the Phloem	2	1	10	10	23	2.22
Internal Parts in a Cross-Sectional View of Stems	0	4	11	9	24	2.21
Fine Roots	1	4	8	10	23	2.17
Lateral Root Formation	1	2	12	8	23	2.17
Fluid Conductivity/Transport in the Xylem	2	2	11	9	24	2.13
Phenology	2	5	6	11	24	2.08
Transition Zone Between Stem/Roots	3	2	11	8	24	2
Internal Parts in a Longitudinal View of a Stem	1	5	12	6	24	1.96
Outside Parts of Woody Roots	0	6	12	5	23	1.96
Photorespiration	2	6	6	9	23	1.96
Tree Associations	2	5	8	8	23	1.96
Survival	2	4	8	7	21	1.95
Energy and Stress	1	8	6	8	23	1.91
Fall Color and Leaf Senescence	2	6	11	5	24	1.79
Flower Formation/Fertilization	4	5	8	7	24	1.75
Root Cambium Zone Growth	2	8	7	6	23	1.74
Non-Woody Root Formation	2	10	5	7	24	1.71
Internal Parts in a Cross-Sectional View of Roots	2	9	6	6	23	1.7
Root Tip Meristem Growth	2	8	9	4	23	1.65
Callus Tissue and Woundwood Formation in Roots	2	8	8	4	22	1.64
Root Zone Reactionwood Formation and Self-Optimization	3	8	8	4	23	1.57
Internal Parts in a Longitudinal View of Roots	2	9	10	2	23	1.52

Root Growth in a 3-Dimensional View	5	7	7	5	24	1.5
Allelopathy	2	13	5	4	24	1.46
Bio-Mechanics	4	9	6	4	23	1.43
Pollen Development/Dispersal	7	5	9	3	24	1.33
Seed Germination	5	11	3	5	24	1.33
Mass/Energy Ratio	4	11	5	3	23	1.3
Seedling Development	4	12	5	3	24	1.29
Tree Pump Concept	4	12	4	2	22	1.18
Three Tree Concept	5	11	1	2	23	1
Core/Skin Hypothesis	6	12	2	1	21	0.9

Appendix O

Complete List of Degree Credentials Reported, Survey Question 18

	Diploma	Certificate	Associates Degree	Minor	Total	Re-Classified
Horticulture	10	16	26	1	53	Horticulture/Landscape
Landscape Management	7	11	18	1	37	Horticulture/Landscape
Natural Resources Management	4	2	12	1	19	N. R. Man./Environ. Science
Environmental Science	4	1	3	1	9	N. R. Man./Environ. Science
Other:						
Landscape Design/Build			1		1	Horticulture/Landscape
Garden Center Management			1		1	Horticulture/Landscape
Golf Course Operations			1		1	
Forestry, Wildlife, and Natural Resources		1	1		2	N. R. Man./Environ. Science
Forest Management			1		1	N. R. Man./Environ. Science
Plant Health Care		1			1	Horticulture/Landscape
Landscape Horticulture		1	1		2	Horticulture/Landscape
Parks & Recreation Operations			1		1	
Nursery Operations			1		1	Horticulture/Landscape
Horticulture		1	1		2	Horticulture/Landscape
Native Landscaping		1			1	Horticulture/Landscape
Turfgrass Management	1	1	1		3	
Plant Production		1			1	Hortiuclture/Landscape
Forest Technology			1		1	N. R. Man./Environ. Science
Agribusiness*						
Turf and Turfgrass Management*						
Sports Turf Management			1		1	
Landscape Design			1		1	Horticulture/Landscape

**No title(s) provided for degree credentials*

Appendix P

Complete List of Principle Tree Biology Courses Titles, Survey Question 3

Course Title	Credits	Semester Taken
Landscape Management 1	3	1
Arboriculture/Urban Forestry	3	2
Tree Biology	2	2
Arboriculture	3	1
Horticulture Science	5	1
Horticulture 1000	3	2
Arboriculture	3	4
Forest Ecology	3	3
Plant and Soil Science	3	3
Arboriculture	4	1
Botany	3	1
Introduction to Horticulture	3	1
Landscape Maintenance	4	1
Landscape Plants 1	3	1
Principles of Horticulture	3	1
Plant Science	3	2
Arboriculture	3	3
Arboriculture 1	4	2
Arboriculture 1	3	3
Arboriculture	2	3
Tree and Forest Biology	4	1
Plant Identification	3	1
Arboriculture	3	2
Arboriculture	3	4

Appendix Q

Tree Biology Topical Ratings – Moderate, Survey Questions 11 - 14

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Branch Attachment	0	2	2	20	24	2.75
Water Relations	0	0	9	15	24	2.63
Photosynthesis	1	1	4	17	23	2.61
Outside Parts of the Trunk	0	4	4	16	24	2.50
Support/Structural Roots	0	1	10	13	24	2.50
Wound Response	1	0	9	14	24	2.50
Outside Parts of a Twig	0	4	5	15	24	2.46
Water/Essential Elements Uptake	0	3	7	14	24	2.46
Structural Defects	1	0	11	12	24	2.42
Respiration	1	2	8	11	22	2.32
Mycorrhizal Associations	1	3	8	12	24	2.29
Energy Resource Allocation	1	1	13	9	24	2.25
Evapotranspiration	0	4	10	10	24	2.25
Tree Nutrition	0	6	6	12	24	2.25
Fluid Conductivity/Transport in the Phloem	2	1	10	10	23	2.22
Internal Parts in a Cross-Sectional View of Stems	0	4	11	9	24	2.21
Fine Roots	1	4	8	10	23	2.17
Lateral Root Formation	1	2	12	8	23	2.17
Fluid Conductivity/Transport in the Xylem	2	2	11	9	24	2.13
Phenology	2	5	6	11	24	2.08
Transition Zone Between Stem/Roots	3	2	11	8	24	2.00

Appendix R

Tree Biology Topical Ratings – Low, Survey Questions 11 - 14

	Not Important (0)	Low (1)	Moderate (2)	High (3)	Responses	Index Score Mean
Internal Parts in a Longitudinal View of a Stem	1	5	12	6	24	1.96
Outside Parts of Woody Roots	0	6	12	5	23	1.96
Photorespiration	2	6	6	9	23	1.96
Tree Associations	2	5	8	8	23	1.96
Survival	2	4	8	7	21	1.95
Energy and Stress	1	8	6	8	23	1.91
Fall Color and Leaf Senescence	2	6	11	5	24	1.79
Flower Formation/Fertilization	4	5	8	7	24	1.75
Root Cambium Zone Growth	2	8	7	6	23	1.74
Non-Woody Root Formation	2	10	5	7	24	1.71
Internal Parts in a Cross-Sectional View of Roots	2	9	6	6	23	1.70
Root Tip Meristem Growth	2	8	9	4	23	1.65
Callus Tissue and Woundwood Formation in Roots	2	8	8	4	22	1.64
Root Zone Reactionwood Formation and Self-Optimization	3	8	8	4	23	1.57
Internal Parts in a Longitudinal View of Roots	2	9	10	2	23	1.52
Root Growth in a 3-Dimensional View	5	7	7	5	24	1.50
Allelopathy	2	13	5	4	24	1.46
Bio-Mechanics	4	9	6	4	23	1.43
Pollen Development/Dispersal	7	5	9	3	24	1.33
Seed Germination	5	11	3	5	24	1.33
Mass/Energy Ratio	4	11	5	3	23	1.30
Seedling Development	4	12	5	3	24	1.29
Tree Pump Concept	4	12	4	2	22	1.18
Three Tree Concept	5	11	1	2	23	1.00
Core/Skin Hypothesis	6	12	2	1	21	0.90