THE CHALLENGES AND OPPORTUNITIES OF DIVERSIFYING PLANT SPECIES WITHIN THE URBAN LANDSCAPE

By

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of NICOLE ROSE THARPE find it satisfactory and recommend that it be accepted.

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Abstract

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A growing lack of plant species diversity in urban landscapes all across Washington State has the potential to become a major problem. Across the United States, low species diversity leads to greater incidences of environmental, insect and disease mediated plant deaths. To determine the cause of low landscape plant species diversity, wholesale nurseries were studied to identify their role in the issue. The initial hypothesis was that the problem stemmed from a lack of education in wholesale nurseries, the initial suppliers of most landscape plants. To test this hypothesis, a survey was created and distributed online. The survey results showed that most Washington wholesale nurseries had positive attitudes regarding many plant diversity issues, suggesting that they understood some aspects of diversity. However, their low level of agreement with many plant species diversity statements showed that they did not have a very strong understanding of all related issues. Survey results also showed that education is crucial to increasing positive attitudes regarding species diversity. More in-depth research is needed to substantiate these results. An interactive educational module, created with the purpose of educating students before they enter various horticulture and design-related fields, supplemented the survey. The module garnered constructive feedback, with students generally understanding the main points in addition to learning new information. This feedback was used to revise and improve the module.

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CHAPTER ONE

LITERATURE REVIEW

Introduction

Increasing the diversity of plant species in any designed landscape has many advantages including improving environmental and ecological health, increasing disease resistance, providing habitats for local fauna, and creating a unique setting for creativity in the design process (Clark, 1996; Endress, 1990; Fabos, 1979; Galvin, 1999; Knops et al., 1999; Steedman, 1994). These benefits are particularly true in urban landscapes, where higher levels of environmental stress lead to increased death and disease incidence in plants (Endress, 1990; Flemer, 1981). Thus, the need for increased species diversification becomes important for preventing urban plant deaths (Endress, 1990; Flemer, 1981).

Species diversification is a simple solution to many common landscape problems, yet the resistance to change has been tremendous. Resistance stems from increased cost to designers, contractors and clients; limited supply of more diverse plant selection; and potential for increased maintenance through legal covenants, codes and restrictions (Boston and Bettinger, 2004; Martin et al., 2003; Merhaut and Pittenger, 2005). Few individuals are willing to take responsibility for creating the current overuse of landscape materials. The problem ultimately stems from lack of supply from the wholesale nursery industry and lack of demand from landscape architects, contractors or other consumers (Endress, 1990; Flemer, 1981; Martin et al., 2003).

The objectives of this thesis were to determine the attitude of the wholesale nursery industry regarding plant genetic diversity and associated landscape issues. The survey also clarified potential associations between education level of Washington State's wholesale nursery

industry and their knowledge of plant species diversity. An educational module was also created to increase future students' overall knowledge and understanding of the importance of plant diversity in urban landscapes.

Plant species diversity in the landscape

Across Washington State, in residential areas, subdivisions, city streets and virtually any landscaped area, the same plants are planted repeatedly. Serial landscaping, or the repetitive use of the same genus and even species and cultivar, is leading to low overall landscape diversity (Clark, 1996; Galvin, 1999).

The term 'landscape' has different meanings when used in various contexts including geology, geography, biology, ecology and aesthetics (Naveh and Lieberman, 1994). For example, a geologic landscape could refer to rock placement or patterns of sedimentation, while geographic landscape simply refers to an area in terms of its placement within a larger area. Biological and ecological landscapes describe the presence and position of plants and animals within a given area as well as their interactions (Naveh and Lieberman, 1994). When referencing urban areas however, both the aesthetic and ecological definitions can best describe these landscapes: "A mosaic of heterogeneous land forms, vegetation types, and land uses [in an urban setting]" (Urban et al., 1987). A diverse, urban landscape therefore, is one that contains an extremely heterogeneous mix of vegetation types.

Since landscape diversity is a comparative term, comparisons must be made over a large enough area to easily observe the patterns in plant vegetation (Naveh and Lieberman, 1994; Urban et al., 1987). In terms of scale, the urban landscape can be as small as a neighborhood or as large as a city. It includes private homes, business districts, and industrial complexes. As

previously stated, when similar vegetation patterns continuously reappear throughout a neighborhood or town, it is a prime example of serial landscaping (Naveh and Lieberman, 1994; Urban et al., 1987).

Serial landscaping causes reduced landscape diversity and a broad range of other ecological issues, making it not strictly an aesthetic concern, but an environmental one as well (Endress, 1990; Flemer, 1981). Our society has a great deal of power and influence over environmental destruction, as well as ecological health and wellness (di Castri et al., 1990; di Castri, 1992). Thus, with careful planning, education, proper maintenance and financial assistance, landscaping can be potentially used as a tool to improve ecological health, reverse damage and prevent future ecological problems (Endress, 1990).

History of the nursery industry

The practice of changing visible land features has ancient roots. Examples of early humans' attempts to modify their landscapes for purely aesthetic reasons can be found all over Europe and Asia (Laird, 1992). Like any activity that manipulates aesthetics, landscaping has traditionally been undertaken by wealthy individuals living in affluent nations.

In the latter part of the last century, economic growth led to changes in urban settlement structures. Early societies were centered around major water sources, and city centers relied on these water sources for both income and transportation (Fabos, 1979). One side effect of dense urban clustering was reduction in personal property. Owning a yard as we know it today was a luxury that few could afford. The average citizen did not regularly practice landscaping, as it was typically reserved for the wealthy (Fabos, 1979).

The invention of the automobile and the subsequent economic boom of the Industrial Revolution changed many things including transportation, urban sprawl, and average wealth distribution (Fabos, 1979). Automobiles made water-based transportation non-vital, and newly built roads allowed urban populations to expand. Finally, average citizens became wealthier, enabling them to own more land within urban boundaries (Fabos, 1979). These three main factors led to the development of the modern urban landscape.

The urban landscape began to emerge and develop after World War II when economic growth caused an unprecedented construction boom of residential homes (Fabos, 1979; Oregon Association of Nurseries, 2007). This new construction led to a greater need for landscaping material to beautify the newly exposed ground. As a result, the popularity of nursery plants and other landscaping materials increased exponentially (Oregon Association of Nurseries, 2007). What initially began as small garden shops and local gardening enthusiasts purveying landscaping plants to a small and wealthy populace, swiftly developed into a booming industry that divided its production strategies into wholesale and retail sectors. For example, renowned wholesale rose producers Jackson and Perkins began as market gardeners who specialized in fruits, roses and hardy ornamentals. By the latter part of the 19th century, they were well known for their high quality plants including over 175,000 roses (Davidson et al., 2000).

Since its inception, the nursery industry has experienced frequent and constant change (Davidson et al., 2000). Competition between local nurseries fueled new technological discoveries and techniques, as each attempted to produce the largest variety and most unique plants. Techniques such as budding, grafting, and other forms of propagation allowed nurserymen to create variation in their plant stock and more rapidly increase the amount available for sale (Davidson et al., 2000). Nurseries rapidly expanded their local markets

nationally through technologies such as cold storage, tractors, and rail transport. Cold storage allowed growers to keep plants longer before sale, tractors increased ease and rapidity of cultivation and harvest, and rail transport let growers ship plants greater distances than ever before (Davidson et al., 2000). Introduction of the parcel post promoted the concept of mail-order plants, prompting many nurseries to create extensive catalogs for customers across the nation. Transportation improvements allowed customers greater access to plants, and growers responded by creating retail outlets where their customers could make one-stop shopping trips to purchase any garden product or plant they needed. Thus began the modern garden center industry (Davidson et al., 2000).

Today, the United States has the largest production and consumer market for nursery and greenhouse products in the world (Decoteau, 2005). The nursery industry comprises the third most profitable agricultural commodity and is the fastest growing segment of U.S. agriculture (Decoteau, 2005). In 2006, total gross sales of nursery crops totaled $4.65 billion (USDA, 2007). As demand in the United States increases for available landscaping material, nurseries compete to produce more unique specimens in an attempt to lure the American consumer. Breakthroughs in genetic breeding, in addition to new technologies that increase efficiency, ensure levels of flexibility, modernity and novel production that will allow nurseries to continue to expand their saleable palate (Oregon Association of Nurseries, 2007).

Another factor leading to the growth of the nursery industry, in addition to demand for unique species, is the prevalence of trade shows, popular literature and garden expositions. For example, the Far West show in Oregon draws the largest attendance of any trade show in the nation with over 800 exhibitors and a waiting list for the next year that generally exceeds 120 exhibitors (Oregon Association of Nurseries, 2007). Publications such as Better Homes &

Gardens, Sunset Magazine and Horticulture Magazine provide consumers with gardening advice, selection guides, and the latest trends in horticulture. These media sources enable people to emulate various landscaping styles from all over the nation and create a steady market for the nursery industry. According to a survey of wholesale nurseries in California, sales are dependent on weather, water supply and market demand while product pricing is based on production costs, market demand and product uniqueness (Merhaut and Pittenger, 2005). Utilizing popular advertising to create a market for their products allows wholesale and retail nurseries more control over sales and product pricing.

Part of creating a thriving market is responding to consumer demands and requests. As nurseries develop and change, so do their customers. Successful marketing strategies involve selling regionally appropriate plants, knowing the customer, introducing new and visually different plants and catering to trends in consumer requests (Davidson et al., 2000). Nurseries often utilize sales data to determine what customers want. While sales data explain what people prefer to buy, they do not provide a motivation. One survey describes undesirable tree features such as allergenic flowers, messy sap and fruit, and high maintenance requirements (Lohr et al., 2004). Nurseries, therefore, would likely avoid selling landscape plants with those traits. Other surveys convey the importance of quality control and standardization among plants (Horticultural Research Institute, 1967) as well as lifespan, disease and pest resistance, and plant quality in an urban environment (Clark, 1996; Iles and Vold, 2003). Thus, in order to remain profitable and competitive, nurseries must understand and predict what their future customers will want. They must also respond quickly to trends in both consumer desires and legal codes that regulate the planting of certain species.

In the United States, the Green Revolution has influenced legislation and regulation concerning natural resource policies (Steedman, 1994). State and local governments are passing meticulous environmental regulations, and cities are fortifying their urban forestry and landscape ordinances (Boston and Bettinger, 2004; Endress, 1990; Flemer, 1981; Garber, 2000). For example, the city of Wichita, Kansas passed a new landscape ordinance that regulates landscape size and type, in addition to location and placement method of newly planted vegetation (Miller, 2007). These regulations apply to homeowners and businesses who wish to install new plantings within city limits (Miller, 2007). Other cities have also been using landscape ordinances to solve and prevent problems such as environmental degradation, poor air, and water quality and low urban aesthetic attributes (Garber, 2000). These measures reflect efforts to preserve and increase biodiversity in urban landscapes that are lacking plant species diveristy.

Importance of biotic diversity in ecosystems

Although scientists have long understood many aspects of environmental function in terms of individual biotic and abiotic processes, they have only recently begun to study the landscape as a whole (Urban et al., 1987). This new field of landscape ecology studies interactions within a landscape or ecosystem, to increase understanding of ecosystem health and how to maintain it (Urban et al., 1987).

Two elements integral to ecosystem health are clean water and biotic diversity (Smith, 1993). Defining strict diversity guidelines to rate ecosystem health is virtually impossible. Health can be estimated however, by observing the ability of an ecosystem to sustain natural processes and phenomena (Smith, 1993). Processes such as nutrient cycling, water cycling, soil building, and vegetation regeneration are crucial to long-term sustainability of both human and natural

populations (Smith, 1993). Therefore, by increasing ecosystem diversity and the availability of clean water, we can ensure the sustainability of our own communities.

Under natural conditions, species diversity is a necessary element to the overall sustainability and longevity of a given site. Changes in species composition occur through a combination of biotic and abiotic ecological interactions (Baker, 1995; Neilson et al., 1992; Urban et al., 1987). For instance, a fire's devastating effect on a stand of deciduous trees could create a niche for a new stand of conifers. Numerous environmental elements are constantly interacting so that it is impossible for every species, at every age to be tolerant of these constant and natural changes. Therefore, the greater the species variety and age distribution in a site, the greater likelihood survivors will exist following a major environmental disturbance (Flemer, 1981; Hobbs, 1988).

Examples of disturbances include fires, landslides, floods, disease epidemics, or intensive herbivory. One study shows that the resiliency of an ecosystem's vegetation depends not only on diversity, but also on the scale of the disturbance (Urban et al., 1987). Areas with frequent, large-scale disturbances will typically only support hardy species while less affected areas will support a broader range of species. The species composition of an area, as determined by disturbance events, is called a disturbance regime. Large-scale ecosystems such as watersheds or parks are composed of patches of disturbance regimes, each uniquely suited to the conditions within that patch (Urban et al., 1987). Many patches may comprise an ecosystem, creating greater overall diversity.

Another study shows the importance of disturbance in promoting diversity in natural settings (Hobbs, 1988). In this case, disturbance increased overall diversity (i.e. number of different species) while *decreasing* species richness (i.e. number of individuals within each

species). Mitigating factors include the size of each patch of vegetation studied and the environmental conditions within each patch (Hobbs, 1988). These two studies demonstrate that, although overall diversity in *natural* settings can remain at a healthy rate despite disturbance events, human activity causes unnatural changes in diversity that deplete both richness and health. It is for this reason that current ecosystem diversity levels and thus ecosystem health is on the decline in urban areas (Clark, 1996; Galvin, 1999; Rajaniemi, 2002).

Quality is another important aspect of diversity and refers to the types of plant species in a site rather than numbers of species. Thus, species richness and not abundance can be more vital in some locations (Neilson et al., 1992; Ruijven et al., 2003). In a natural, healthy ecosystem, the majority of plant species present are generally either native or naturalized. Native plants are important because they are uniquely adapted to a specific habitat and are generally able to tolerate abiotic and biotic disturbances to a much higher degree than non-native species (Neilson et al., 1992; Ruijven et al., 2003). Native species also contribute to the formation of important niches and ecological interactions that ultimately determine the composition of entire ecosystems. In many areas, without the presence of native species, fundamental ecosystem processes would cease (Knops et al., 1999).

Loss of native species is generally aggravated by two sources: climatic change and disturbance events (Neilson et al., 1992). Climate changes result in abnormal temperature variations and alteration of the moisture regime. These abiotic stresses weaken native plants that are adapted to a specific climate regime, thus opening niches for non-native plants to enter and invade (Neilson et al., 1992).

Likewise, disturbance events stimulate the formation of new niches through the death and removal of species that formerly occupied a site. Such disturbances can be natural phenomena

(such as wildfire or floods) or human mediated (Neilson et al., 1992). In both instances, the general result of disturbance is increased species abundance and overall diversity. In the case of human mediated disturbance however, this increased abundance is often in the form of non-native and potentially invasive species (Allen et al., 2006). When invasive species account for a majority of a site's diversity, ecosystem functioning changes and health declines (Allen et al., 2006).

Plant species diversity in urban landscapes

The horticulture industry has introduced many exotic species for use in landscapes; some have become aggressive invaders (Allen et al., 2006; Kelley et al. 2006). Those that are invasive alter the structure and function of environments that contain rare and endangered native species all over the world (Allen et al., 2006). The ability of plants to become invasive depends on several factors including disturbance in native communities, herbivory, nutrient availablility and the overall diversity level (Espinosa-Garcia et al., 2004; Knops et al., 1999; Rajaniemi, 2002; Ruijven et al., 2003). Native diversity is particularly important in preventing invasion. Species-rich native plant communities use available resources more efficiently, leaving less for potential invaders to access (Ruijven et al., 2003). Species richness also contributes to lower disease outbreaks. Diverse communities have large numbers of plants and equally large varieties of species. Homogenous communities have many plants of the same species. Thus, if a large number of host plants exists, diversity will be low and disease incidence will be high (Knops et al., 1999).

While diversity in native communities contributes to lower invasibility and disease incidence, the same truth exists for non-native, planted landscapes. Many urban landscapes,

street plantings, in particular are extremely homogeneous. Miles of city blocks are often planted with the same species or even cultivar (Merritt, 2007). Despite aesthetic advantages, homogeneous plantings such as these are susceptible to increased pest and disease attacks. They also suffer from intense inter-specific competition for limited supplies of nutrients and water in urban areas (Endress, 1990; Flemer, 1981). Examples of recent pest and disease outbreaks include gypsy moth, tent caterpillar, Dutch elm disease, dogwood anthracnose, powdery mildew, oak wilt and sudden oak death (Flemer, 1981; Steigman, 2006).

Across the country, Dutch elm disease (*Ophiostoma ulmiand)* and the emerald ash borer (*Agrilus planipennis*) have caused epidemic rates of tree deaths. In Chicago alone, where over 19% of street trees are ash trees, entire streets planted with ash have died out completely (Makra, 2007). Although difficult to predict, the next major epidemic to affect other commonly planted genera such as cherries or plums (*Prunus* spp.*)* or maples (*Acer* spp.) seems imminent. In the city of Seattle, there are over 22,000 maples planted, over 7,000 of which are red maples (*Acer rubrum*) (Seattle Department of Transportation, 2007). If this genus were to become as severely threatened as elms, nearly 20% of the city's trees would be destroyed (Seattle Department of Transportation, 2007).

Insects and pathogens are not the only threats to monoculture street plantings. In some cases, age produces similarly devastating consequences. Seventy years ago, the city of Denver, Colorado sought to avoid the threat of Dutch elm disease by planting maples instead of elms (Merritt, 2007). Unfortunately, all of these trees were planted at the same time and are now reaching maturity simultaneously. The result is thousands of trees dying within a few short years of each other (Merritt, 2007). Thus, selecting appropriate species as well as avoiding even age stands is equally crucial to maintaining urban plant sustainability.

Plants in metropolitan areas are subjected to a vast assortment of pressures including: improper placement, pollution, soil compaction, drought, low light levels, poor nutrition and dense, monoculture plantings (Chalker-Scott, 2005; Celestain and Martin, 2005; Endress, 1990; Flemer, 1981). These environmental stresses all work to weaken plants' defense systems leaving them vulnerable to predation and disease. Diseases such as Dutch elm disease, powdery mildew, dogwood anthracnose, oak wilt, and sudden oak death have reached critical levels in cities all across North America (Steigman, 2006). Smith (1994) published the first report of the disease dogwood anthracnose (*Discula destructiva*) affecting Kousa dogwood (*Cornus kousa*), which was formerly thought to be resistant to the pathogen. He noted that, although in most landscape situations this tree would not be affected, susceptibility could be induced through water and transplanting stress; both common in urban areas (Smith, 1994).

Water stress of peach trees increased the disease severity of fungal gummosis (*Botryosphaeria dothidea*) (Pusey, 1989). Reducing or eliminating irrigation increased inoculation success and facilitated the spread and severity of the disease throughout the trees (Pusey, 1989). This shows a direct correlation between common urban stresses and potential spread of disease.

Environmental stress can also contribute to disease epidemics indirectly. Stressed trees often suffer higher rates of insect predation which in turn leads to disease vectoring through these insects and their damage. MacFarlane and Meyer (2003) showed that the emerald ash borer has more of an impact in urban areas than in rural areas due to environmental stresses weakening tree defenses. Not only are stressed trees more likely to be attacked by insects, they are also more likely to become diseased. Increased likelihood of insect predation caused by urban environmental stress is a leading factor in Dutch elm disease. The European elm bark beetle

(*Scolytus multistriatus*) and the New York native elm bark beetle (*Hylygopinus rufipes*) have been identified as the primary vectors for spreading Dutch elm disease and elm yellows (Lanier et al., 1988). The most susceptible elms are those that are under stress (Lanier et al., 1988). Urban environments are stressful for many plant systems and proper maintenance and placement can increase the lifespan of many landscape plants.

Compounding the environmental stresses on urban landscape plants are maintenance issues such as improper planting and care, poor site selection, and inadequate nutrition. Simply training landscape installers to properly select, plant and maintain landscapes can increase overall ecological health and aesthetic value of landscapes (VanDerZanden et al., 2006). For example, appropriate selection of urban species allows trees to withstand high environmental pressures such as a small growing space, low light, windy locations, and paved areas such as sidewalks and roadways (McPherson and Muchnick, 2005). Many tolerant species are available and, through proper selection, planting related deaths can be reduced.

Poor maintenance and planting techniques can cause plant deaths just as environmental pressures do. Improper plant installation techniques, such as neglecting to remove the pot or burlap wrapping, planting at an incorrect depth, planting crookedly or forgetting to water, may result in serious problems including circling roots, shoot damage or disease (Chalker-Scott, 2005). Topping, staking injury and improper fertilization techniques are responsible for landscape failures and stem from a simple ignorance of correct cultural techniques. In situations such as these, educating landscape professionals to reduce landscape damage is clearly required and should be mandatory (Chalker-Scott, 2005; VanDerZanden et al., 2006).

Efforts to train green industry professionals are receiving more support then ever. For example, Oregon State University held collaborative seminars in 2003 and 2004, to further

educate members of the landscape industry (VanDerZanden et al., 2006). The majority of the participants reported learning applicable skills in addition to obtaining a greater understanding of many issues in horticulture (VanDerZanden et al., 2006). Specialized education programs are important to students entering the horticulture profession, as well as adults wanting specific technical training to find new employment (Steward, 2003). Technical training includes seminars as well as certification and allows students and industry employees to develop into industry leaders (Steward, 2003). Furthermore, in 2007, a study on employer preferences for landscape horticulture graduates found that employers preferred graduates with greater professional development and practical field experience, in addition to technical proficiency (Berle, 2007).

The creation of more knowledgeable professionals through specific technical training also adds to the knowledge base of a company, improving its overall image and customer service capacity (Steward, 2003). Educational events are taking place all over the country and may be a valid answer to closing the gap between what people learn in the landscape industry and what is generally known in the scientific community.

Justifying landscapes

Some people believe that maintaining urban greenery wastes precious resources such as water and nutrients, and requires too much money to develop landscapes and educate those in the horticulture industry. A survey performed by Lohr et al. (2004) found that although most individuals preferred to have plants in urban areas, there was a small percentage, mainly younger, non-white males, who did not. They cited reasons such as allergies and impediment of visual elements to justify their responses (Lohr et al., 2004). Those who preferred the presence of landscape plants however, explained that trees were vital to providing shade and cooling,

reducing smog and dust and making people feel calmer (Lohr et al., 2004). This survey and others (Kuo et al., 1998; Horticultural Research Institute, 1967; Westphal, 2003), suggest that the overwhelming majority of urban populations feel trees and other landscape plants are vital to the improvement of community economy, social structure and ecological health (Kuo et al., 1998; Horticultural Research Institute, 1967; Westphal, 2003).

The contribution of landscape plants to community economies can be described in terms of aesthetics and value. Many cities implement landscape ordinances to increase the aesthetics of a community, increase tourism, and decrease crime, which are all economically positive (Garber, 2000; Miller, 2007; Snelgrove et al., 2004). Studies evaluating the relationship between urban crime and urban greenness have shown negative correlations (Snelgrove et al., 2004). Although people traditionally believed that removing vegetation reduced crime, Snelgrove et al. (2004) proved that the opposite was actually true, not only in Austin, Texas but in other cities as well. Thus, cities can improve economies, increase tourism and reduce crime, simply by increasing urban vegetation.

Landscaping can also have positive economic effects by increasing home values. In order to better predict how each adds perceived value to a home, Behe et al. (2005) studied three attributes: type of plant material, plant size, and design sophistication. Their results indicated that the most preferred and valuable landscapes were those that had large, sophisticated and colorful landscape designs (Behe et al., 2005). Adding plants to a home site had positive financial results in several instances. The Weyerhaeuser Company (1989) estimated that landscaping could increase a home's value by 15%, while a 1999 survey distributed at a flower and garden show in Detroit, suggested an increase in value of 12.7% (Hardy et al., 2000). Other reports have documented similar trends (Hardy et al., 2000). Some homeowners feel the rewards for

maintaining a landscape are not equal to the amount of work and care required. One survey suggested that in cases where people do not enjoy gardening, maintenance occurs to prevent social scorn and these individuals receive little actual satisfaction from the work (Horticultural Research Institute, 1967). Financial rewards such as increased home values therefore, tend to mitigate the work and financial costs required, thus encouraging more individuals to install landscapes (Hardy et al., 2000). However, Rachael Kaplan discovered that while tangible or financial rewards might be an initial incentive for gardening, the longer people garden, the more psychological rewards they receive (Kaplan, 1973). Thus, gardening becomes a pleasurable activity rather than a chore. Another study found that gardening evokes strong positive emotions, reduces anxiety and tension and engenders a sense of pride in one's garden creation (Lewis, 1992).

Solving the Problem

Teaching people to understand the importance of incorporating a diverse array of landscape plant species, proper maintenance techniques, and a greater appreciation for plants, may determine the future of urban landscapes. Improving plant-related education in general may be useful in promoting appropriate installation and maintenance techniques, in addition to increasing positive perceptions of landscape plants and plant diversity (Steward, 2003).

Better horticultural education is being emphasized and demanded both community and industry wide. Nurseries are beginning to hire greater numbers of trained professionals and educated students (Chandel and Chandel, 2005; VanDerZanden et al., 2006). Currently, many college-level horticulture students fail to meet industry requirements for experience and expertise, leading to labor shortages at some companies (Chandel and Chandel, 2005).

Landscape architecture firms for instance, are specifically demanding that graduates have extensive scientific training, thus enhancing the need for better horticultural education (Ryder and Swoope, 1997). Horticultural education is not only important and necessary for teaching plant diversity, it is now fortunately becoming a desirable attribute in employees industry wide (Ryder and Swoope, 1997).

Training and education are not only important at the industry professional level, but at the university level as well. For example, teaching horticulture and landscape architecture students to recognize the importance of species diversity in the landscape before they graduate might influence them to incorporate greater diversity in future designs. Such course curricula would be beneficial to emphasize sustainable practices as well as introduce students to greater interdisciplinary training (Ryder and Swoope, 1997). Teaching students to understand elements of nature and ecology on a more interdisciplinary level can have many positive impacts on future landscape designs and our present urban landscape.

As technology increases, it is easier for educators to make teaching a more interactive experience. The internet and computer models and programs are becoming extremely important learning tools for modern students (Gilbert et al, 2007; Hutchinson, 2007; Li, 2007). For example, more than 127,000 web-based, university-level courses were offered in the United States alone between 2000 and 2001 (Robinson, 2007). Introducing students to simulations and interactive case studies provides a level of hands-on experience that has previously been unavailable to many (Gilbert et al; 2007; Hutchinson, 2007; Li, 2007). Interactive computer models are particularly useful in that they are relatively simple to create and easy for students to visualize, thus accelerating absorption and comprehension of information.

Landscape plant species diversity is an important issue that many people are not aware of (Flemer, 1981; Kelley et al., 2006). Urban landscapes are frequently homogenous, suggesting that nurseries are either not aware or not willing to address this issue (Iles and Vold, 2003). Determining why many urban landscapes continue to lack species diversity may be the first step toward preventing future homogeneity and the potential environmental devastation associated with it. The wholesale nursery industry, as one of the main suppliers of ornamental plants, strongly influences landscape plant diversity (Merhaut et al., 2005). Educating future nursery personnel and landscape designers on the importance of species diversity may prevent future monoculture landscapes (VanDerZanden et al., 2006).

Objectives

The overall objectives of this project are to:

- Determine if the issue of lack of plant species diversity in urban landscapes is related to wholesale nursery producers. This will be accomplished by randomly selecting and surveying various Washington wholesale nurseries to ascertain:
    - how much they know about the issue of plant species diversity in the landscape,
    - if the nursery industry believes they could or should address the issue, and
    - where they gained knowledge of the issue.

- Create an educational module that will increase future university students' overall knowledge and understanding of the importance of plant species diversity in urban landscapes.

CHAPTER 2

DETERMINING DETERRENTS TO LANDSCAPE PLANT SPECIES DIVERSITY: A SURVEY OF THE WASHINGTON WHOLESALE NURSERY INDUSTRY

Introduction

In urban landscapes throughout Washington State, the same plant types are planted in a copious and repetitive manner. As urban areas expand, this repetitive use of the same genus and even plant species is leading to lower urban landscape plant diversity. Many United States urban landscapes, in particular street plantings, are extremely homogeneous with miles of city blocks often planted with the same species or even cultivar (Merritt, 2007). For example, in the city of Seattle there are over 22,000 maples planted, and over 7,000 of these are red maples (*Acer rubrum*) (Seattle Department of Transportation, 2007). Similarly in Chicago, over 19% of street trees are ash trees (Makra, 2007).

Homogeneous plantings are susceptible to increased pest and disease attacks. Across the United States, insects and pathogens such as Dutch elm disease and now the emerald ash borer, have caused epidemic rates of tree deaths (DuPont, 2007; Steigman, 2006). In Michigan, Indiana, Ohio, and Illinois, the emerald ash borer has destroyed over 25 million ash trees (DuPont, 2007). In these states, entire blocks of street trees containing only one or two ash species have died out completely as the emerald ash borer infected one tree after another (Flemer, 1981; Steigman, 2006). If maple trees in Seattle become as severely threatened as ash, nearly 20% of the city's trees would be destroyed (Seattle Department of Transportation, 2007). Other examples of recent pest and disease outbreaks include gypsy moth, tent caterpillar, dogwood anthracnose, powdery mildew, oak wilt and sudden oak death (Flemer, 1981; Steigman, 2006).

Disease spread is related to a lack of diversity, in both urban and natural areas (Flemer, 1981; Meyer, 1985). Knops et al. (1999) found that decreasing the diversity of various grassland ecosystems resulted in increased frequency, spread, and intensity of diseases. Meyer (1985) discussed a similar trend in urban street trees: less diverse street plantings were more at risk for insect attack and disease spread.

Natural ecosystems or communities can serve as an effective model for a healthy urban landscape since the species diversity is a necessary element for the overall sustainability and longevity of a given area (Baker, 1995; Neilson et al., 1992). In a natural ecosystem, changes in species composition occur through a combination of biotic and abiotic ecological interactions (Baker, 1995; Neilson et al., 1992; Urban et al., 1987). Numerous environmental elements are constantly interacting so that it is impossible for every species, at every age to be tolerant of these constant and natural changes. Therefore, the greater the species variety and age distribution in a site, the greater likelihood survivors will exist following a major environmental disturbance (Flemer, 1981; Hobbs, 1988).

One study showed that the resiliency of an ecosystem's vegetation depends on diversity, as well as the scale of the disturbance (Urban et al., 1987). Areas with frequent, large-scale disturbances will typically only support hardy species, while less affected areas will support a broader range of species (Urban et al., 1987). Native plants are uniquely adapted to a specific habitat and are generally able to tolerate abiotic and biotic disturbances to a much higher degree than non-native species (Neilson et al., 1992). However, when native plants are severely weakened by extreme biotic stresses, such as those resulting from climate change, niches for non-native invading plants open (Neilson et al., 1992). In many areas, without the presence of healthy native species, fundamental ecosystem processes would cease (Knops et al., 1999).

Plant diversity increases resiliency to stress and disease, and thus is crucial to the health and ability of an urban ecosystem to function. To increase urban landscape diversity, state and local governments are passing environmental regulations (such as Title 24: United States Department of Housing and Urban Development, subtitle 24, part 50: Protection and Enhancement of Environmental Quality), and cities are fortifying their urban forestry and landscape ordinances (Boston and Bettinger, 2004; Endress, 1990; Flemer, 1981; Garber, 2000). For example, the city of Wichita, Kansas passed a new landscape ordinance that regulates landscape size and species type, in addition to location and placement method of newly planted vegetation (Miller, 2007*).* Homeowners and businesses in Wichita that install new plantings within city limits are limited to plants from a more diverse "preferred species" list (Miller, 2007). This prevents them from overusing similar species commonly used across the United States. Ordinances are becoming increasingly commonplace. The University of Georgia has even created a template to help cities institute landscape ordinances, thereby making it easier for cities to promote greater urban diversity (Garber, 2000).

Determining why many urban landscapes continue to lack diversity is one step toward preventing future homogeneity. The wholesale nursery industry, as one of the main suppliers of ornamental plants, strongly influences the diversity of landscape plant choices (Merhaut et al., 2005).

A further deterrent to plant diversity is that nursery definitions of diversity are typically design-related, with "diversity" meaning anything from variety of color, variety of uses, and variety of plant sizes and shapes, to not planting too many of the same plant in an area. A review of five years of industry literature such as "Digger Magazine" reveals very few articles about species diversity per year (e.g. in 2007 these were found: Petersen, A; Petersen, B; Petersen, C;

Rafter, 2007). The article Some Like it Hot describes diverse drought-tolerant plant introductions but does not address plant species diversity (Petersen, C). The situation is similar in the "American Nurseryman" magazine. (e.g. in 2007 these were found: Benson, A; Benson, B; Bramwell, 2007; Landicho, A; Landicho, B; Roethling, 2007). For example, the article Holiday Delights describes the diverse array of new plants that have been introduced for the 2007 holiday season, but does not mention genetic species diversity (Benson, A). These and many other articles ultimately fail to describe diversity from an ecological or genetic sense. Therefore, it is easy to see why many in the nursery industry do not understand or agree that diversity is a genetic and ecological issue. Failing to understand these aspects of diversity may result in negative attitudes regarding it.

In order to determine opinions and general knowledge of landscape diversity within the wholesale nursery industry, a survey was distributed to Washington wholesale nurseries. The main objectives of the survey were to determine the knowledge level of the Washington wholesale nursery industry regarding plant species diversity and where they gained their knowledge of the issue.

Materials and Methods

The survey. This survey was approved by the WSU Institutional Review Board, IRB Number #09858-001. In fall 2007, a statewide internet survey was conducted. The online survey contained 31 questions that required respondents to provide demographic information, asked respondents to select a value or statement about the production of their plant material, where they obtain information on horticultural topics, and their attitudes about plant species diversity in the landscape (Appendix A). The final question gave them the option to provide explanatory

comments. To address each of these topics, the questions were either open-ended, categorical, or qualitative. Eight questions were open-ended, three were numerical, four were closed-ended and sixteen were categorical. The sixteen categorical questions required respondents to rate their opinions on plant diversity issues on a 6-point scale of "strongly disagree" to "strongly agree". Some of these categorical questions were written so that "agree" indicated an understanding of diversity, while others were written so that "disagree" indicated an understanding of diversity.

Survey development. Before survey questions were written, thirteen nursery professionals in Oregon were telephoned and asked sample questions regarding landscape plant diversity issues during a cold calling session. Since Oregon nurseries were not included in the final study, information received from them would not affect conclusions. Verbal responses were recorded to capture colloquial word usage, so that future survey questions would be more easily understood (Dillman, 2000). These specific word choices were used when developing the final questions for the survey. An initial draft of the survey was given to ten horticulture faculty to ensure content validity (Dillman, 2000); seven were from Washington State University, one was from The University of Idaho and two were from Oregon State University. A later draft was given to five WSU graduate and undergraduate horticulture students to further ensure that the content of the survey was easy to understand and reliable (Dillman, 2000). The final draft was placed on a survey-based web site called SurveyMonkey.com (www.surveymonkey.com).

Selection of survey participants. A list of the 718 wholesale companies with Washington nursery licenses was acquired from the Washington State Department of Agriculture in spring 2007. The list was edited to remove companies that had no nursery affiliation (such as food service and lumber companies), shortening the list to 426 nurseries. The remaining list contained companies involved with plants through design, retail sales, agriculture or wholesale production.

Each company was called to determine if they were a wholesale nursery and to obtain the name of the person who was responsible for making plant inventory decisions. A quarter of the nurseries called had either gone out of business or did not answer the phone. The final list of businesses to whom the survey was distributed, were wholesale nurseries, totaling 130 (Appendix B).

Survey respondents. Each of the 130 individuals was contacted by phone, given a brief, verbal summary of the survey, and assured that their answers to the survey would be anonymous. Their email addresses were collected and a cover letter (Appendix A) sent to each nursery explained the objective of the research, instructions for completing the survey, and contained a link to the survey website. A follow-up letter was emailed to all individuals two months later to encourage non-responding nurseries to participate in the survey (Appendix A). Of the 130 contacted wholesale nurseries, 48 participated in the survey. Data from six of the respondents were not used because five respondents only completed the beginning survey questions, and one for being a landscape architect. There were forty-two respondents in the final analysis. This is a response rate of 32%, which falls well within the acceptable range (Dixon and Turner, 2007).

Survey analysis. For the analysis, responses to demographic questions (Appendix C, Table 11) were grouped into various categories based upon response frequency, so each category had enough responses for the analysis. Responses to question 1 were divided into “owner” and “non-owner.” Responses to question 2 were divided into “East side” and “West side.” Responses to both question 3 and 4 were divided into “long” and “short.” Responses to question 5 were divided into “20-500 acres” and “0-10 acres.” Responses to question 6 was divided into “more” and “less,” while responses to questions 7 and 8 were divided into “many” and “few.” Responses to question 9 were simply recorded (Appendix D, Table 12), while question 10 responses were

also divided into categories of “more” and “less.” These questions were analyzed against other variables and no meaningful demographic relationships were found.

Respondents were also asked to identify their basis for a decision to add new and different plant species, cultivars, or varieties to their inventories (Question 28). They were allowed to select the following choices: sales and marketing information, trade shows, customer requests, ease of growth and maintenance, last year’s sales and profitability, environmental concern, overall plant preferences, production costs or other (Appendix C, Table 13).

Seven survey statements contained information about different aspects of diversity issues and asked respondents to state their opinion of these issues (Table 1). Answers to these statements were combined to create a “Diversity” measurement scale representing respondents’ overall level of understanding regarding these diversity issues. When agreeing with the statement indicated a strong overall understanding of plant species diversity, responses of “strongly disagree”, “disagree”, “slightly disagree”, “slightly agree”, “agree”, or “strongly agree” were given scores of one to six, respectively. Question 14 however, was phrased so that a respondent’s agreement would indicate a negative opinion of diversity, so the score was reversed, with “strongly disagree” being scored as six. Then the scores for all seven questions were summed, creating a “Diversity” measurement scale from seven, meaning a respondent had essentially no understanding of or an appreciation for the need for species diversity in landscapes, to forty-two, meaning a respondent had a great understanding of or an appreciation for the need for species diversity in landscapes.

Question 12 (Appendix A) was not used in the calculation of the “Diversity” scale, due to the confusing nature of the responses. Respondents’ who had previously agreed with most

questions on diversity, were split in their responses. Opinions on this question were unrelated to knowledge on species diversity issues.

The same scoring technique used to create the Diversity scale, was also used to create scales representing a respondent's opinion on landscape designs ("Design," Table 2), if they felt that diversity was the responsibility of customers and landscape designers ("Responsibility," Table 3), and if they were willing to accept responsibility for increasing landscape diversity ("Nursery role," Table 4). For each of these categories, similar survey questions were grouped and their scores were combined as previously described.

Both "Design" questions were phrased so that agreement indicated that design issues could be reasons for repetitive plantings (Table 2). Respondents with a high "Design" score therefore may have felt that design issues were more important than diversity issues. Both "Responsibility" questions were phrased so that agreement indicated that nursery customers and landscape designers were responsible for repetitive landscape plantings (Table 3). Respondents with high "Responsibility" scores did not feel responsible for diversity. Finally, "Nursery role" questions 22 and 25 were phrased so that agreement indicated that adding plants to inventories was possible, but would not protect nurseries from authoritative regulation (Table 4). Questions 21 and 26 were phrased so that agreement indicated a belief that a sufficient amount of plant material was being produced to address diversity (Table 4). Questions 21 and 26 were inverted so that respondents with high "Nursery role" scores believed that the Washington State wholesale nursery industry already played a sufficiently large role in increasing landscape species diversity.

As previously described, seven diversity statements were combined to create a "Diversity" scale to estimate a respondent's overall knowledge of various diversity topics. From

the seven statements, three were selected that best represented major diversity concepts crucial to a true understanding of landscape plant diversity (Table 5). Responses of “strongly disagree,” “disagree,” and “slightly disagree” were combined into one category of “disagree” while responses of “slightly agree,” “agree” or “strongly agree” were combined into one category of “agree”.

Respondents reporting their level of education in question 29 (Appendix A), had seven choices: four-year college, technical or community college, professional certification, industry or extension workshops or meetings, high school, internship, or other. They could select as many choices as applied to them. Responses reported in question 29 were combined into two categories, “College”, and “Non-college” in a variable called “Education level” (Table 5). If a respondent selected technical or community college or a four-year college, they were placed in the “College” category. If a respondent had not selected these, they were placed in the “Non-college” category. The percent of respondents who agreed with each Diversity question was compared to “Education level” to see if having higher education was more beneficial in increasing understanding of diversity (Table 5). The percent of respondents who agreed with each question was also compared to each specific educational response category in question (professional certification, industry or extension workshops or meetings, high school, technical or community college, university, or internship) to see if one specific level of education was more beneficial than another in increasing understanding of diversity (Table 6). These results were analyzed using ProcFreq in SAS and significant differences were determined using the Jonckheere-Terpstra test (SAS, 2002-2003).

In question 30 (Appendix A), respondents were questioned about where they had learned about issues with having many similar plant species in a landscape: government programs,

school or college classes, university outreach, trade journals and articles, professional organizations and news media, and other. They could select all that applied to them. Responses for this question were also combined into two categories, "College" and "Non-college" in a variable called "Diversity information source" (Table 7). If a respondent had selected school or college classes, or university outreach, they were placed into the "College" category. If they had not selected these choices, they were placed into the "Non-college" category. The percent of respondents who agreed with each Diversity question was compared to "Diversity information source" to see if receiving information from school or college classes or university outreach was more beneficial in increasing understanding of diversity (Table 7). The percent of respondents who agreed with each question was also compared to each specific information source (professional certification, industry or extension workshops or meetings, high school, technical or community college, university, or internship) to see if one specific source of diversity information was more beneficial than another in increasing understanding of diversity (Table 8). These results were also analyzed using ProcFreq in SAS and significant differences were determined using the Jonckheere-Terpstra test (SAS, 2002-2003).

Finally, we compared "Education level" and "Diversity information source" to the "Diversity" mean score, which was a composite diversity score created by combining responses to the 7 diversity questions (Table 9). These results were analyzed using Proc GLM in SAS (SAS, 2002-2003).

Results and Discussion

Demographic characteristics. Seventy-four percent of respondents owned their own nurseries (Appendix C, Table 11). Nursery industry employment duration ranged from one year to fifty

years, with an average employment duration of seventeen years. Seventy-one percent were experienced, having been employed in the nursery industry for ten to fifty years. Nursery production size ranged from zero to five hundred acres, with an average area of twenty-nine acres. Seventy-six percent of the nurseries surveyed had up to ten acres in wholesale production, while seventy-nine percent reported also using ten acres to produce their most abundant species. Eighty-four percent of respondents had nurseries located in western Washington, with twenty-one percent located in King County alone.

Fifty-six percent of nurseries grew 51 to more than 500 different species while forty-five percent grew fewer than 50 species (Appendix C, Table 11). Amounts of different cultivars also varied, ranging from fewer than 100 to more than 1000 different cultivars or varieties (Appendix C, Table 11). Fifty-one percent of nurseries grew fewer than 100 different cultivars or varieties of plants and forty-seven percent grew more than 1000 different cultivars or varieties. The top three determining factors why respondents added new and different plant species, cultivars, or varieties to their inventories were: customer requests (67%), overall plant preferences (55%) and ease of growth and maintenance (45%) (Appendix D, Table 13).

General knowledge of landscape plant diversity. The rate of agreement on two survey questions about attitudes and knowledge of plant species diversity issues (Questions 16 and 17), was over eighty percent (Table 1). Thus, it appears that members of the Washington wholesale nursery industry have a strong understanding of some diversity issues. Only around fifty percent of respondents however, agreed with species diversity questions 14, 15, and 20. These results show a majority of respondents having positive attitudes regarding diversity, but suggest that a majority do not show a strong understanding of many diversity issues. For example, on question 11, fifty-five percent of respondents disagreed that planting more than 10% of the same plant

species in a region greatly increases the risk of insect or disease outbreaks, while forty-five percent agreed. This could suggest that people do not understand the relationship between species diversity and disease outbreak, or perhaps they disagreed with the ten percent figure and did not think that ten percent would greatly increase risk.

The majority of respondents disagreed that planting large numbers of a single plant species in a commercial or residential landscape increases the likelihood of severe insect or disease outbreaks (Table 1, Question 13). Interestingly, more people disagreed with this question than question 11, despite the similar wording of the two questions (Table 1). Perhaps respondents thought that the word "species" was too limiting; or perhaps they disagreed that possible insect or disease problems would be "severe." Another possibility is that respondents were confused by the many different definitions of the word "diversity". Terminology confusion is a likely explanation, as similar confusion was also apparent in many of the cold calls to Oregon-based nurseries when developing the survey.

Influence of plant-related education on knowledge of landscape plant species diversity. Respondents' overall understanding of landscape plant diversity issues ("Diversity" measurement scale), was significantly related to Education level (Table 9). Since higher scores suggests better understanding of diversity, respondents who learned about plants at technical or community college or university apparently understood more about landscape diversity.

Education is not only vital to understanding complex issues like plant species diversity, it is also becoming increasingly important in many horticultural industries. Employers in these industries are hiring greater numbers of employees with higher education and more practical field experience (Berle, 2007). Many universities are striving to strike a balance in their horticultural curricula between science and technical proficiency to meet industry demands

(Berle, 2007; Davies, 2004). Employees who receive this kind of education are therefore more likely to understand and agree with many of the positive ecological and financial implications of landscape diversity.

Respondents who received plant-related education at a technical or community college or university were more likely to agree with specific survey statements on landscape diversity issues, while those having less education were less likely to agree (Table 5). When specific levels of education were analyzed, the two most significant responses included university-educated respondents who agreed with statement 13 in Table 6, and respondents with a high school education who agreed with statement 16 in Table 6. The first significant response showed that respondents with higher education are more likely to have positive opinions about diversity than those who did not receive plant-related education at institutions of higher education. The second significant response showed that those without college or university training were least likely to have positive opinions about species diversity. These results indicate that institutions of higher education are teaching students about species diversity issues including proper plant selection and environmental use (Steward ,2003).

Respondents who learned about the issues with having many similar plants in the landscape in a school or college setting were more likely to agree with the specific survey question “Planting more than 10% of the same species in a region greatly increases the risk of insect or disease outbreaks” (Table 7, Question 11). Sixty percent of those who reported learning about plant diversity issues in classes or university outreach agreed with that statement, while only 32% of those who did not learn about plant diversity issues in classes or university outreach agreed. This shows that institutions of higher education are teaching students to avoid landscape problems by planting no more than 10% of the same genus, 20% of the same species and 30% of

the same cultivar or variety of landscape plants (Cauchon, 1997; Sydnor and Struve, 2000; Santamour, 1990).

When specific sources of plant diversity information were analyzed, there were four highly significant responses (Table 8). Significant sources of diversity information that correlated with agreement about a statement included school or college classes on statement 11, trade journals or articles on statement 11, university outreach on statement 16 and professional organizations on statement 16. A significant source of diversity information that correlated to disagreement (or a very low rate of agreement) with a statement was government programs on statement 13 (Table 8). As multiple sources of information produced significant responses, it is likely that people in the nursery industry commonly get their information from several sources (Table 8). This is beneficial because the more sources of information that are available to people, the better acquainted they are likely to become with various diversity issues.

The last decade has shown increases in the numbers of professional programs, university courses, in-house company training and extension seminars available to those in the horticulture trade (Gilbert et al., 2007; Hutchinson, 2007; Robinson, 2007). Required knowledge is rising and nurseries are beginning to hire more educated students and pre-trained professionals (Chandel and Chandel, 2005; VanDerZanden et al., 2006).This trend could also account for non-college educated individuals having positive attitudes regarding plant diversity.

Washington wholesale nursery's attitudes on responsibility for landscape species diversity. "Design," "Responsibility" and "Nursery role" were not significantly related to other factors in this survey (data not shown), but responses on individual questions were meaningful. Opinions were divided regarding the implementation of plant species diversity into the landscape, with 67% of respondents agreeing with question 18 and only 27% agreeing with

question 19 (Table 2). This means that although respondents think that increasing diversity in the landscape increases maintenance, it does not detract from the overall landscape aesthetics. Responses to questions 23 and 24, regarding who is responsible for landscape species diversity were the same, with 71% of respondents agreeing that responsibility for diversity lies with customers and designers, and not wholesale nurseries (Table 3).

Most respondents also felt that the wholesale nursery industry was already doing enough to promote and increase diversity (Table 4). Although respondents indicated that the nursery industry could easily add more species to their inventories (Question 22), most felt that they currently offer an adequate range of plants for their customers to choose from (Question 21). Although most people felt that nurseries could add more diversity to their inventories (Question 22), 76% felt that voluntarily increasing inventory species variety would not allow them to avoid regulation (Question 25). Questions 21 and 26 in "Nursery role" were phrased so that agreement indicated negative attitudes regarding diversity. For both of these questions a majority of respondents agreed, indicating that they feel that wholesale nurseries are addressing the species diversity issue because they grow an adequate range of plant species and frequently add new plants. Despite wholesale nursery's belief that they are providing adequate plant diversity in their inventories, lack of species diversity continues to exist. These results seem to indicate that although nurseries feel they have the ability to increase diversity, they do not feel that voluntarily doing so would benefit them. Despite awareness that they are not doing enough to solve the problem, nurseries are unwilling to voluntarily increase diversity in their inventories.

Summary

Members of the Washington wholesale nursery industry have some understanding of overall plant diversity issues, but most lack a thorough understanding of many specific diversity problems. This may be due to variations in experience, education level and diversity information sources.

Respondents with at least two years of higher education had more knowledge and a better opinion of plant diversity in the landscape than those who did not have a higher level of education. However, even people without at least two years of higher education had some understanding of the importance of diversity. This means that education sources such as high school, government programs, extension, trade journal articles, various organizations and news media, may be distributing information to those in the nursery trade.

This study did not identify specific deterrents to diversity in the landscape. Obviously, lack of education may be a hindrance, as well as negative attitudes regarding diversity, which are also related to education. Many wholesale nurseries feel that because their industry is so consumer-driven, they have little control over diversity. Survey comments included, “Most of the choices about what to raise is based on market demands. New species and varieties are added based on demand and the ability of new species and varieties to adapt to our regional growing conditions.” Market demands and ease of maintenance are often the main reason many nurseries grow what they do. In fact, respondents reported that the top three reasons they added new and different plant species, cultivars, or varieties to their inventories were customer requests, overall plant preferences and ease of growth and maintenance (Appendix C, Table 11).

The respondents indicated that designers and customers should be responsible for diversity. Respondents indicated this through comments such as, “The nursery business tends to

dote on cultivars and the ability to replicate a marketable image. The culture of landscape architects also bears some of the responsibility, just as schools of Forestry are responsible for promulgating economic-based studies, rather than ecologically grounded programs;" and "We grow species together for ease of maintenance. Large blocks of the same species are usually installed in commercial or city situations. The area of most concern is street trees, where the problem amount of high care and replacement requirements is multiplied greatly by poor cultural care."

Part of the answer to identify why plant species diversity is lacking in many areas, may lie in the attitudes many respondents have regarding responsibility for diversity. Many do not feel personally responsible for providing and promoting greater landscape diversity and, in addition, feel that such promotion and implementation is the responsibility of others. This reflects a prevalent attitude that was encountered during initial cold calls to Oregon wholesale nurseries. When people were asked for their opinions regarding responsibility for lack of diversity in the landscape, they almost universally placed blame elsewhere. Perhaps future education, in addition to providing information about diversity issues, should inform nurseries on ways they can start increasing diversity in their own nurseries. Unless nurseries are willing to admit some responsibility for the problem, it may continue to be a problem.

Increasing plant species diversity in wholesale nurseries may also be prevented by confusion at the various definitions of diversity. These definitions are often not genetically or ecologically related (i.e. planting too many of the same plant in one area), but instead are aesthetically related (i.e. variety of color, uses, or plant shapes and sizes). Industry literature such as "Digger Magazine" and "American Nurseryman" magazine for example, have many articles about new plant introduction that discuss "diversity," but fail to describe diversity from an

ecological or genetic sense. Therefore, many in the nursery industry do not understand that diversity is genetically and ecologically related because they are receiving misleading information. This lack of understanding about of diversity may result in negative attitudes regarding it.

Ultimately, the results of this study have few implications beyond the need for higher education (from various sources) on plant species diversity in the landscape and the role of the nursery industry in contributing to the problem. Wholesale and retail nursery workers need more education about increasing plant species diversity, as do home-owners and landscape architects and designers. Strengthening our conclusions would require more in-depth study of this subject. A longer, more detailed survey might relay more conclusive information about why respondents held their specific beliefs. If we expanded our survey population to include wholesale nurseries all across the northwest, we could have gotten a higher response rate and perhaps even a more broad range of responses. Finally, perhaps administering the survey in person or over the phone versus online, might yield more complete information as respondents would be able to discuss their knowledge, ideas and opinions about plant diversity face-to-face.

There is still much information lacking about education and its specific role in nurseries, and landscape diversity in general. Only more in-depth, future studies can improve the amount of information available in this area where research is lacking. Until then, there can be no definitive recommendations on successfully addressing the problem of lack of diversity in the landscape.

Table 1. Washington wholesale nursery industry responses (percent agreement) on individual attitude statements that were combined to form a Diversity measurement scale.

Diversity attitude statement	n	% agree[1]	% disagree[2]
Statements where agreement indicates understanding of diversity			
11. Planting more than 10% of the same plant species in a region greatly increases the risk of insect or disease outbreaks.	41	45	55
13. Planting large numbers of a single plant species in a commercial or residential landscape increases the likelihood of severe insect or disease outbreaks.	41	40	60
15. In many cities where over 20% of the street trees are ash trees, Emerald ash borer (an insect pest) is a problem. Emerald ash borer would probably not be a problem if only 5% of the trees were ash.	39	54	46
16. Planting a wide range of genetically different plant species in a landscape increases the chances the landscape will remain healthy.	42	83	17
17. Increasing the number of different plant species used in an area is important for biodiversity.	42	85	15
20. Lack of plant diversity in a given region is an ecological problem.	39	56	44
Statements where disagreement indicates understanding of diversity			
14. Elm trees that have died from Dutch elm disease should be replaced with the new disease-resistant elms.	40	59	41

[1]Percent of respondents who selected “strongly agree,” “agree” or “slightly agree.”
[2]Percent of respondents who selected “strongly disagree,” “disagree” or “slightly disagree.”

Table 2. Washington wholesale nursery industry responses (percent agreement) on individual attitude statements that were combined to form a Design measurement scale.

Design attitude statement	n	% agree[1]	% disagree[2]
Statements where disagreement indicates understanding of diversity			
18. Landscapes planted with similar plants are easier to maintain than landscapes with many different species.	40	67	33
19. Landscapes planted with many different species often look disorganized or cluttered.	41	27	73

[1]Percent of respondents who selected "strongly agree," "agree" or "slightly agree."
[2]Percent of respondents who selected "strongly disagree," "disagree" or "slightly disagree."

Table 3. Washington wholesale nursery industry responses (percent agreement) on individual attitude statements that were combined to form a Responsibility measurement scale.

Responsibility attitude statement	n	% agree[1]	% disagree[2]
Statements where disagreement indicates understanding of diversity			
23. Marketing large quantities of the same popular and well-known plants will continue until customers ask for a more diverse selection of plants.	41	71	29
24. Landscape designers contribute to the lack of diversity in landscape plants because they look at plants primarily as design elements.	41	71	29

[1]Percent of respondents who selected "strongly agree," "agree" or "slightly agree."
[2]Percent of respondents who selected "strongly disagree," "disagree" or "slightly disagree."

Table 4. Washington wholesale nursery industry responses (percent agreement) on individual attitude statements that were combined to form a Nursery role measurement scale.

Nursery role attitude statement	n	% agree[1]	% disagree[2]
Statements where agreement indicates understanding of diversity			
22. The wholesale nursery industry could easily add more plant species to their inventories.	41	67	33
25. Voluntarily increasing the number of different plant species in their inventories would allow nurseries to avoid regulatory interference from state or federal authorities.	42	24	76
Statements where disagreement indicates understanding of diversity			
21. Most wholesale nurseries currently offer an adequate range of genetically different plants for their customers to choose from.	42	78	22
26. The wholesale nursery industry is already addressing the species diversity issue because they frequently introduce new plants for their customers.	41	83	17

[1]Percent of respondents who selected "strongly agree," "agree" or "slightly agree."
[2]Percent of respondents who selected "strongly disagree," "disagree" or "slightly disagree."

Table 5. Washington wholesale nursery industry responses (percent agreement) with attitude statements based on the general level of education where a respondent had received knowledge about plants (Question 29)**.**

Diversity Attitude Statement	General education level[1]	n	% agree[2]	Significance[3]
11. Planting more than 10% of the same plant species in a region greatly increases the risk of insect or disease outbreaks.	College	25	56	0.05
	Non-college	17	29	
13. Planting large numbers of a single plant species in a commercial or residential landscape increases the likelihood of severe insect or disease outbreaks.	College	25	52	0.03
	Non-college	17	24	
16. Planting a wide range of genetically different plant species in a landscape increases the chances the landscape will remain healthy	College	25	84	0.41
	Non-college	16	81	

[1]College = respondents checked “technical or community college” or “4-year college”. Non-college = respondents did not check “technical or community college” or “4-year college”.
[2]Percent of respondents who selected “strongly agree,” “agree” or “slightly agree.”
[3]Significance based on a Jonckeere-Terpstra Test.

Table 6. Washington wholesale nursery industry responses (percent agreement) with attitude statements on diversity based on the specific level of education where a respondent had received knowledge about plants (Question 29)**.**

Diversity attitude statement	Specific education level[1]	n	% agree[2]	Significance[3]
11. Planting more than 10% of the plant species in a region greatly the risk of insect or disease outbreaks	Prof. certification	12	58	0.14
	Industry/Extension	23	52	0.16
	High school	9	33	0.21
	Tech/com. college	13	54	0.23
	University	15	53	0.22
	Internship	10	30	0.14
13. Planting large numbers of a single species in a commercial or residential landscape increases the likelihood of insect or disease outbreaks.	Prof. certification	12	42	0.46
	Industry/Extension	23	39	0.42
	High school	9	56	0.15
	Tech/com. college	13	46	0.31
	University	15	60	0.03
	Internship	10	40	0.49
16. Planting a wide range of genetically different plant species in a landscape increases the chances the landscape will remain healthy	Prof. certification	12	75	0.20
	Industry/Extension	23	78	0.19
	High school	9	67	0.07
	Tech/com. college	13	77	0.25
	University	15	87	0.32
	Internship	10	80	0.39

[1]Exact wording on survey for education levels were: “Professional certification,” “Industry or extension workshops or meetings,” “High school,” “Technical or community college,” “4-year college,” and “Internship.”
[2]Percent of respondents who selected “strongly agree,” “agree” or “slightly agree.”
[3]Significance based on a Jonckeere-Terpstra Test.

Table 7. Washington wholesale nursery industry's responses (percent agreement) on individual attitude statements on diversity based on the general source where they had learned about the issues with having many similar plant species in a landscape (Question 30)**.**

Diversity attitude statement	General educational source[1]	n	% agree[2]	Significance[3]
11. Planting more than 10% of the same plant species in a region greatly increases the risk of insect or disease outbreaks.	College	20	60	0.04
	Non-college	22	32	
13. Planting large numbers of a single plant species in a commercial or residential landscape increases the likelihood of severe insect or disease outbreaks.	College	20	45	0.29
	Non-college	22	36	
16. Planting a wide range of genetically different plant species in a landscape increases the chances the landscape will remain healthy	College	20	75	0.10
	Non-college	21	90	

[1]College = respondents checked "technical or community college" or "4-year college". Non-college = respondents did not check "technical or community college" or "4-year college".
[2]Percent of respondents who selected "strongly agree," "agree" or "slightly agree."
[3]Significance based on a Jonckeere-Terpstra Test.

Table 8. Washington wholesale nursery industry's responses (percent agreement) on individual attitude statements on diversity based on the specific source where they had learned about the issues with having many similar plant species in a landscape (Question 30)**.**

Diversity attitude statement	Specific educational source[1]	n	% agree[2]	Significance[3]
11. Planting more than 10% of the same plant species in a region greatly increases the risk of insect or disease outbreaks	Government programs	15	40	0.31
	School/college classes	12	67	0.04
	University outreach	13	54	0.23
	Trade journals/articles	28	57	0.02
	Professional orgs.	17	53	0.21
	News Media	6	67	0.13
13. Planting large numbers of a single plant species in a commercial or residential landscape increases the likelihood of severe insect or disease outbreaks.	Government programs	15	20	0.02
	School/college classes	12	50	0.22
	University outreach	13	46	0.31
	Trade journals/articles	28	46	0.14
	Professional orgs.	17	47	0.24
	News Media	6	50	0.31
16. Planting a wide range of the genetically different plant species in a landscape increases chances the landscape will remain healthy	Government programs	15	87	0.32
	School/college classes	12	75	0.20
	University outreach	13	69	0.06
	Trade journals/articles	28	82	0.42
	Professional orgs.	17	71	0.04
	News Media	6	83	0.49

[1]Exact wording on survey for education sources were: "Government programs", "School or college classes", "University outreach", "Trade journals or articles", "Professional organizations", "News Media."
[2]Percent of respondents who selected "strongly agree," "agree" or "slightly agree."
[3]Significance based on a Jonckeere-Terpstra Test.

Table 9. Influence of Washington wholesale nursery industry respondent's general education level and source of information on landscape plant species diversity on their overall knowledge of landscape plant diversity issues.

	Diversity Knowledge		
General education level[1]	**n**	**Diversity mean score[2]**	**Significance[3]**
College	22	28.5	0.03
Non-college	15	23.9	
General diversity information source[4]			
College	17	28.5	.11
Non-college	20	25.1	

[1]College = respondents checked "technical or community college" or "4-year college". Non-college = respondents did not check "technical or community college" or "4-year college".
[2]Mean score was based on a scale from 7, indicating no understanding of landscape plant species diversity issues, to 42, indicating high level of understanding of landscape plant diversity issues.
[3]Significance based on Proc GLM (SAS, 2002-2003).
[4]College = respondent checked "school or college classes" or "university outreach". Non-college = respondent did not check "school or college classes" or "university outreach."

CHAPTER THREE

AN EDUCATIONAL MODULE TO TEACH LANDSCAPE PLANT SPECIES DIVERSITY TO UNDERGRADUATE HORTICULTURE AND LANDSCAPE ARCHITECTURE STUDENTS

Introduction

Many urban areas across the nation suffer from low landscape diversity, caused by the repeated use of the same plant species. Miles of city blocks are homogeneous, often planted with the same species or even cultivar of plant (Merritt, 2007). Homogeneous plantings, although aesthetically pleasing to some, are often more susceptible to pest and disease attacks. Disease incidence in urban areas is aggravated by a lack of plant species diversity (Flemer, 1981; Meyer, 1985). In addition, plants in urban areas are often exposed to a variety of cultural and environmental stresses including improper placement in the landscape, pollution, soil compaction, drought, low light levels, poor nutrition and dense, monoculture plantings (Celestian and Martin, 2005; Chalker-Scott, 2005; Endress, 1990; Flemer, 1981; Lohr et al., 2004). These urban stresses weaken the plants' defense systems, leaving them vulnerable to predation and disease.

Education about proper cultural techniques and plant selection can lead to choices that reduce stress on urban landscape plants (VanDerZanden et al., 2006). Better horticultural education is being demanded both community and industry wide (Steward, 2003). The last decade has shown increases in the numbers of professional programs, university courses, in-house company training and extension seminars available to those in the horticulture trade (Gilbert et al., 2007; Hutchinson, 2007; Robinson, 2007). Required knowledge is rising and nurseries are beginning to hire more educated students and pre-trained professionals (Chandel

and Chandel, 2005; VanDerZanden et al., 2006). However, lack of plant species diversity continues to be common in urban landscapes.

Teaching undergraduate horticulture and landscape architecture students to recognize the importance of plant species diversity in the landscape may prompt them to incorporate greater species diversity in future designs. Increasing students' understanding of elements of nature and ecology on a more interdisciplinary level may positively affect future landscape designs and change our present urban landscape (Ryder and Swoope, 1997).

Recently, teaching and learning have become more interactive through technological advances. The internet, as well as computer modules and programs are becoming particularly important e-learning tools for all ages of modern students (Gilbert et al., 2007; Hutchinson, 2007; Li, 2007; Peterson et al., 2006). In the United States alone, between 2000 and 2001, more then 127,000 web-based, university-level courses were offered (Waits and Lewis, 2003) For example, Hall and Wilson (2004) created an educational module to teach the basics of silage fermentation to extension personnel, individual dairy producers, and forage management consultants. Silage fermentation in relation to dairy cattle health is a process that can be conceptually challenging to understand. Their module used rich, visual presentations that allowed individuals to experience different management scenarios and develop a deeper understanding of the silage fermentation process (Hall and Wilson, 2004).

Introducing students to e-learning simulations and interactive case studies improves the knowledge, performance and skills of today's students compared to lecture (Gilbert et al., 2007; Hutchinson, 2007; Li, 2007). Interactive computer models offer an adequate, cost effective alternative to hands-on work for improving absorption and information comprehension (Peterson

et al., 2006). Educational gains are similar in interactive modules and hands-on learning, and both are superior compared to traditional classroom lectures (Peterson et al., 2006).

Interactive teaching tools are well suited toward educating future horticulturalists and landscape architects. Collaborative and creative skills, necessary for these types of students, can be developed and improved using computer-based applications (Li, 2007).

The goal of this project was to develop an interactive educational tool that would increase future students' overall knowledge and understanding of the importance of plant species diversity in urban landscapes.

Module description and development

The educational module. In 2007, an educational module was developed to educate horticulture and landscape architecture undergraduate students on issues related to urban landscape plant species diversity. The module, created in Microsoft's Power Point program, consisted of a series of slides and simple animations containing information on horticultural and ecological research regarding plant species diversity and its importance in our environment. The negative impacts of landscapes that lack species diversity were divided into three different learning units: insect impacts, disease impacts, and environmental impacts.

The learning unit on insect impacts described common types of insect damage and discussed how monoculture plantings increased the risk and extent of damage by insects such as the Emerald ash borer (*Agrilus planipennis*). The disease impacts unit described different modes of disease transmission such as biological and mechanical vectoring, showed that monoculture plantings are at increased risk for infection compared to diverse plantings, and discussed the transmission and spread of Dutch elm disease (*Ophiostoma novo-ulmi*) in the United States. The

unit on environmental impacts described how having plant species diversity reduces the negative impacts of common environmental stresses including wind, cold and drought.

Students progressed slide by slide through each of the learning units in the module. The module could be completed in about twenty to thirty minutes. A five-minute long, ten-question quiz at the end of the module required students to apply the information they had read. The quiz could be scored manually and repeated as many times as needed.

Educational module development. An online database of shorter, smaller educational modules on various crop technology lessons was reviewed prior to the development of this module to provide a template for content and style (Lee and Namuth, 2008). Information in each of the learning units came from numerous journal articles. Pictures and graphics originated from personal sources and the internet. During class time, a preliminary version of the module was tested on a volunteer basis in a sophomore level landscape plant materials class that contained 30 horticulture and landscape architecture students. Changes in content and style were made based on their feedback. The final version of the module was put onto a compact disc for future students to use.

Results and Discussion

Educational module use. The purpose of the educational module was to increase students' understanding of the importance of plant species diversity. The module simplified the complex idea of landscape plant species diversity and presented it in a clear and easy to visualize format.

The module and this type of e-teaching in general, has many strengths. E-teaching improves learning quality so that students are better able to absorb and apply information, it

eases and increases access to education and training, it improves cost-effectiveness, and it reduces educational costs (Gilbert et al., 2007). Similar educational modules have increased students' knowledge and acted as effective alternatives to field-based science labs (Peterson et al., 2006). For example, Raidl et al. (1995) tested a computer-assisted instruction tutorial program to teach clinical reasoning skills to undergraduate dietetics students. They found that it enhanced clinical reasoning skills, provided students with experiential learning, and could effectively supplement many other topics taught in diet therapy (Raidl et al., 1995). Module-based learning facilitates comprehension of complex information and provides specific examples that students can relate to in their own lives. The interactive, hands-on approach of modules is more intellectually stimulating than passively listening to traditional lectures, and thus may encourage more active student participation and learning (Helms and Doetkott, 2007). The module created for this study was tested without comparison to other teaching methods.

Student response and summary. Initial student feedback on this educational module was valuable toward improving the quality and content of future versions. Much of the feedback included positive response to the visual elements of the presentation. Comments included:

"The pictures help to defend what is being said."

"Graphics drew the eye."

"[The module] takes the somewhat abstract concepts of biodiversity and monoculture, and visually makes its points about them."

"The graphics are well done."

"I like the graphics and animations used throughout [the module]."

Some of the negative comments included:

“I think the [module] could have more explanation in the beginning. I was kind of confused as to what was going on.”

“I think the information sections should be backed with more sources and relevant research with citation. This would help to make the information more credible.”

“[This module] would be better for a younger age group or people with no knowledge of monocultures.”

“Some slides are too wordy.”

Some students thought that the animation was helpful. Others felt that the animation, while entertaining, failed to portray many of the discussion topics as clearly as the real pictures did. Thus, the addition of more illustrative pictures might enhance students’ learning experience. The remaining comments dealt with technical issues within the program that were subsequently repaired and did not specifically relate to content. All module content may be found in Appendix E.

Ideally, several periods of module testing, collecting student feedback and modification would make this module a more useful and student-centered educational tool. It would also be beneficial to test this module on students studying different areas of plant and soil science, as well as students of various ages to determine age efficacy. Time limitations however, restricted the number of possible modifications, and thus only one set of student feedback was collected and applied.

CHAPTER FOUR

CONCLUSIONS AND SUGGESTIONS

Conclusions and suggestions

Too many urban landscapes across the United States suffer from a lack of diversity. Due to aesthetic appeal or ease of maintenance, the same genera and species of plants are used redundantly (Clark, 1996; Galvin, 1990). This sets landscapes up for future failure due to factors like environmental stress, insect attack and disease infection (Clark, 1996; Endress, 1990; Fabos, 1979, Galvin, 1999; Knops et al., 1999; Steedman, 1994). These three factors lead to millions of plant deaths each year (Endress, 1990; Flemer 1981). Plant deaths reduce or eliminate the aesthetic appeal of urban plantings and cost cities millions of dollars to remedy (Makra, 2007; Merrit, 2007; Steigman, 2006). If diverse plantings became more widely utilized, many of these issues could be solved (Endress, 1990; Flemer 1981).

There are several commonly acknowledged reasons to explain why this phenomenon continues to exist despite widely, scientifically documented proof denouncing landscape homogeneity (Clark, 1996; Endress, 1990; Galvin, 1990; Flemer 1981). These reasons include increased cost to designers, contractors and clients; limited supply of more diverse plant selection from nurseries; and potential for increased maintenance through legal covenants, codes and restrictions, lack of education in the horticultural industry and finally (as shown by this study), individuals that are unwilling to take responsibility for lack of plant species diversity (Boston and Bettinger, 2004; Martin et al., 2003; Merhaut and Pittenger, 2005). Ultimately, lack of supply from the wholesale nursery industry and lack of demand from landscape architects,

contractors or other consumers are the main contributors to low landscape species diversity (Endress, 1990; Flemer 1981; Martin et al., 2003).

Although increased costs and maintenance may contribute to a lack of demand for diversity, the biggest hurdle is education. Landscape architects and customers fail to demand a more diverse selection because they have little or no knowledge of its importance in preventing plant death. Therefore (as shown by this study), because a more diverse selection of plant species is not requested, nurseries are not motivated to provide it. In this way, a vicious cycle develops with less diverse species being planted in landscapes, and less diverse species being grown in nurseries. This study showed that one contributing factor to this cycle is that wholesale nurseries to often do not accept responsibility for diversity. Many nurseries feel that they currently provide an adequate amount of plant species diversity. Others feel voluntarily adding more species diversity to their inventories would be difficult or impossible. Still others disagree that diversity is important because they think that it reduces landscape aesthetics and increases required maintenance. This study also showed that lack of education is also behind this refusal to take responsibility.

This study's discovery of the link between education, and how well someone is able to understand plant species diversity is crucial, because it supports other literature citing a rising necessity for education in the horticulture industry. It also supports and justifies the creation of an educational module to teach horticultural professionals about the importance of plant species diversity in the landscape, before they enter the industry.

Limitations

This thesis might have been improved with some additions or changes. The survey questions asked by the author could have been improved with the addition of a greater number of more specific questions regarding education. The fact that there were too few of these types of questions in the survey, limited the depth and scope of the conclusions that were made. In retrospect, focusing the survey specifically on education and understanding of diversity issues, and asking fewer demographic questions, could have provided stronger overall conclusions. The educational module could have been enhanced by several periods of module testing, collecting student feedback and modification. Receiving more in-depth student feedback would make this module a more useful and student-centered educational tool. It would also increase the amount of available evidence regarding potential educational benefits from its use. Ideally, it would also be beneficial to test this module on students studying different horticulture-related subjects, as well as students of various ages to determine age efficacy. Time limitations allowed only one set of student feedback to be collected and applied however, which restricted subsequent modifications and improvements.

Suggestions for further research

Some potential future research topics include studying the cumulative effects of education in the design industry, nursery industry and with consumers to see if their use of diversity increases. It would also be interesting to do a survey study similar to this one, with the survey population including homeowners or landscape designers or architects, instead of wholesale nurseries. Comparing different uses and promotion of plant species diversity between wholesale and retail nurseries could also yield interesting results. Finally, expanding the

population from Washington to the entire Northwest would yield a much larger response frequency and would allow state-by-state comparisons in terms of the amount of plant species diversity that is used.

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APPENDIX A

Washington wholesale nursery landscape plant species diversity survey, Washington State University survey subject rights and consent form, survey reminder letter to Washington State's wholesale nursery industry and WSU IRB human subjects' approval.

Thank you for agreeing to complete this survey on the Nursery Industry's Views on Plant Species Diversity. It is for my Master's thesis project and will be used to determine opinions on whether planting many plants of the same species in an area is a major problem or not.
The survey has a total of thirty questions. As we said in the letter asking you to participate in this study, your answers are completely anonymous.
If you have any questions, please call Dr. Virginia Lohr (509-335-3101) or e-mail Nicole Tharpe (tharpen@wsu.edu).

Please answer each of the following questions with the best or closest answer you can.

1. What is your position within your nursery?

2. What county is your nursery located in?

3. How long have you worked for this nursery?

4. How long have you worked in the nursery industry?

5. About how many acres of your nursery are in wholesale production?

6. About how much plant material does your nursery ship out of state each year?
A. 0% - 20%
B. 21% - 40%
C. 41% - 60%
D. 61% - 100%

7. About how many different plant SPECIES are in your nursery's inventory?
A. Fewer than 50
B. 51-100
C. 101-500
D. More than 500

8. About how many different CULTIVARS or VARIETIES are in your nursery's inventory?
A. Fewer than 100
B. 101-500
C. 501-1000
D. More than 100

9. What plant species does your nursery produce the most of?

10. About how many acres are used to grow this plant?

11. Planting more than 10% of the same plant species in a region greatly increases the risk of insect or disease outbreaks.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

12. Pest problems with mass plantings of a single species in a landscape can be adequately controlled with appropriate pest management.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

13. Planting large numbers of a single plant species in a commercial or residential landscape increases the likelihood of severe insect or disease outbreaks.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

14. Elm trees that have died from Dutch elm disease should be replaced with the new disease-resistant elms.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

15. In many cities where over 20% of the street trees are ash trees, Emerald ash borer (an insect pest) is a problem. Emerald ash borer would probably not be a problem if only 5% of the trees were ash.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

16. Planting a wide range of genetically different plant species in a landscape increases the chances the landscape will remain healthy.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

17. Increasing the number of different plant species used in an area is important for biodiversity.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

18. Landscapes planted with similar plants are easier to maintain than landscapes with many different species.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

19. Landscapes planted with many different species often look disorganized or cluttered.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

20. Lack of plant diversity in a given region is an ecological problem.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

21. Most wholesale nurseries currently offer an adequate range of genetically different plants for their customers to choose from.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

22. The wholesale nursery industry could easily add more plant species to their inventories.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

23. Marketing large quantities of the same popular and well-known plants will continue until customers ask for a more diverse selection of plants.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

24. Landscape designers contribute to the lack of diversity in landscape plants because they look at plants primarily as design elements.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

25. Voluntarily increasing the number of different plant species in their inventories would allow nurseries to avoid regulatory interference from state or federal authorities.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

26. The wholesale nursery industry is already addressing the species diversity issue because they frequently introduce new plants for their customers.
Strongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree

27. About how often does your company add new species, cultivars, or varieties of plants to your plant inventory?
A. More than once per year
B. Once per year
C. Every two years
D. Every five years
E. Other (please describe):

28. A decision to add new and different plant species, cultivars, or varieties to your inventory would be based primarily on the following (Check all that apply):
A. Sales and marketing information
B. Trade shows
C. Customer requests
D. Ease of growth and maintenance
E. Last year's sales and profitability
F. Environmental concern
G. Overall plant preferences
H. Production costs
I. Other (please describe):

29. The person(s) making plant inventory decisions at your nursery has received education about plants from which of the following (Check all that apply)?
A. Professional certification
B. Industry or extension workshops or meetings
C. High school
D. Technical or community college (2-year school)
E. 4-year College
F. Internship
G. Other (please describe briefly):

30. From which source(s) have you learned about the issues with having many similar plant species in a landscape? (Check all that apply)
A. Government programs (USDA, WSDA)
B. School or college classes

C. University outreach (researchers, field days or extension)
D. Trade journals and articles
E. Professional organizations
F. News media
G. Other (please describe):

31. Additional Comments:

WASHINGTON STATE UNIVERSITY
SURVEY SUBJECT RIGHTS AND CONSENT FORM

We are asking for your help with a survey on *The Washington State Wholesale Nursery Industry's Views on Plant Species Diversity.* You have been randomly selected to participate in this on-line survey because you work with plant inventories for a wholesale nursery within Washington.

The purpose of the survey is to determine your opinions on whether planting many plants of the same species in an area is a major problem or not. It will also show what role (if any) the nursery industry plays in this issue and who is responsible for dealing with it if it is a concern. This survey is for my M.S. thesis project.

The survey will take about 10-15 minutes to complete. Most of the questions ask you to check a box indicating your opinion on the subject of the survey. A few questions ask about the nursery where you work, such as its size and most plentiful crop, or about yourself, such as how long you have worked in the industry.

Your answers are completely anonymous. There will be no way to identify you or the nursery where you work.

You may refuse to participate in this survey or to withdraw from the study at any time. If you complete the survey, we assume that you are agreeing to participate in this survey and to let us use your answers.

If you have questions about this research or what we are asking you to do, please call Dr. Virginia Lohr (509-335-3101) or e-mail Nicole Tharpe (tharpen@wsu.edu). If you agree to participate in this survey, go to this web site www.surveymonkey.com and follow the directions.

Thank you for your time and participation.

Sincerely,

Nicole Tharpe, Graduate Student
Virginia Lohr, Professor
Teresa Koenig, Assistant Professor
Department of Horticulture and Landscape Architecture
Washington State Univeristy

CONSENT STATEMENT:
I have read the above comments and agree to participate in this study. I give my permission for you to use my answers in your master's thesis and any subsequent publications. I understand that if I have any questions regarding this project, I can contact the investigator at 509-335-3101. Furthermore, if I have questions concerning my rights as a participant in this study, I can contact the WSU Institutional Review Board at 509-335-9661.

Department of Horticulture and Landscape Architecture
Washington State University
Pullman, WA 99164-6414
509-335-3101
tharpen@wsu.edu

September 28, 2007

Dear Sir or Madame,

As part of my master's research, I sent out a survey to wholesale nurseries across Washington State. I am pleased to report that I have begun receiving responses. I would like to thank those of you who have completed this survey. Your responses are extremely helpful.

If you have not yet filled out the survey, it is not too late! This is a short survey and should only take about 10-15 minutes to complete. It is critical that I get as many responses as possible. So if you can find the time, please complete this survey.

If you have any questions about this research or what we are asking you to do, please call Dr. Virginia Lohr (509-335-3101) or e-mail Nicole Tharpe (tharpen@wsu.edu). If you agree to participate in this survey, go to this web site http://www.surveymonkey.com/s.aspx?sm=ugKTthMvL6OfP2gqLATsIw_3d_3d and follow the directions.

Thank you for your time and participation.

Sincerely,

Nicole Tharpe, Graduate Student

Virginia Lohr, Professor

Teresa Koenig, Assistant Professor

MEMORANDUM

TO: VIRGINIA LOHR FROM: Malathi Jandhyala

FROM: Kris Miller, Chair, WSU Institutional Review Board (3005)

DATE: 6/29/2007

SUBJECT: Approved Human Subjects Protocol New Protocol, IRB Number #09858-001

Your Human Subjects Review Summary Form and additional information provided for the proposal titled "The Washington State Wholesale Nursery Industry's Views on Landscape Plant Diversity," IRB File Number 09858-001 was reviewed for the protection of the subjects participating in the study. Based on the information received from you, the WSU-IRB approved your human subjects' protocol on 6/29/2007. This protocol is given Exempt review category.

IRB approval indicates that the study protocol as presented in the Human Subjects Form by the investigator, is designed to adequately protect the subjects participating in the study. This approval does not relieve the investigator from the responsibility of providing continuing attention to ethical considerations involved in the utilization of human subjects participating in the study.

This approval expires on 6/27/2008. If any significant changes are made to the study protocol you must notify the IRB before implementation. Request for modification forms are available online at http://www.irb.wsu.edu/forms.asp. In accordance with federal regulations, this approval letter and a copy of the approved protocol must be kept with any copies of signed consent forms by the principal investigator for THREE years after completion of the project.

Washington State University is covered under Human Subjects Assurance Number FWA00002946 which is on file with the Office for Human Research Protections.

If you have questions, please contact the Institutional Review Board at (509) >>335-7183. Any revised materials can be mailed to the Office of Research Assurances (Campus Zip 3005), faxed to (509) 335-6410, or in some cases by electronic mail, to irb@mail.wsu.edu.

Review Type: New Protocol
Review Category: Exempt
Date Received: 6/28/2007
OGRD No.: N/A
Agency: N/A

APPENDIX B

List of Washington State wholesale nurseries and their county location (Table 10).

Table 10. Names of Washington wholesale nurseries contacted for survey and their counties of origin.

#	Nursery Name	County
1	ALPINE FARMS	MASON
2	AMERICAN GARDENS	SNOHOMISH
3	BAILEY NURSERIES, INC.	YAKIMA
4	BAMBOO MAN	JEFFERSON
5	BEL-R GREENHOUSE, INC.	KING
6	BIRINGER NURSERY	SKAGIT
7	BLUMENGARTEN GREENHOUSE, INC.	SPOKANE
8	BRANDYWINE NURSERY, INC.	SKAGIT
9	BRIGGS NURSERY, INC.	THURSTON
10	BRIGGS NURSERY, INC.	GRAYS HARBOR
11	BUDDY'S PLANT WORLD	LEWIS
12	CAMERON NURSERY LLC	FRANKLIN
13	CANNA CABANA GARDENS	GRANT
14	CEDAR VALLEY NURSERY, INC.	LEWIS
15	CEDARGROVE NURSERY	WHATCOM
16	CHERRY VALLEY BAMBOO	KING
17	CHRISHAVEN TREES	SKAGIT
18	CHRISTMAS VALLEY TREE FARMS	STEVENS
19	CLASSICAL FARMS, LLC	THURSTON
20	CLEARVIEW PERENNIALS	SNOHOMISH
21	CLIFFSIDE GARDENS	KITSAP
22	COLBYS GREENHOUSE	SPOKANE
23	CREACH GREENHOUSE	SPOKANE
24	DANIELS NURSERY	STEVENS
25	DARKWOOD EVERGREENS	ISLAND
26	DE WILDE'S WHOLESALE NURSERIES, INC.	WHATCOM
27	DIRTY KNEES NURSERY	WHATCOM
28	DIRTY PRETTY NURSERY	KING
29	DRAGONS HOLLOW	LEWIS
30	EATONVILLE NURSERY	PIERCE
31	ELITHORP FARM AND NURSERY	PIERCE
32	EMERALD CHRISTMAS TREE COMPANY	KING
33	EMERALD GLEN NURSERY	MASON
34	ENVIRONMENT WEST, INC.	SPOKANE
35	EVERGREEN VALLEY NURSERY, INC	THURSTON
36	FAR PASTURES, INC.	SNOHOMISH
37	FOREST FLOR RECOVERY NURSERY	WHATCOM
38	FOURTH CORNER NURSERIES	WHATCOM
39	GANNON'S NURSERY	YAKIMA
40	GARDEN GATE GROWERS	STEVENS

41	GARDEN GATE NURSERY, L.L.C.	FRANKLIN
42	GIG HARBOR FLOWER FARM	PIERCE
43	GRISWOLD NURSERY	KING
44	GROWING CONCERN, INC.	SNOHOMISH
45	HANGING GARDEN NATIVE PLANT FARM	KING
46	HANSEN FAMILY FARMS	LEWIS
47	HARNDEN ENTERPRISES	SNOHOMISH
48	HASSETT FARM & GARDEN	SNOHOMISH
49	HILLVIEW GARDENS PRODUCTS	SKAMANIA
50	HOLLAND AMERICA NURSERY	SNOHOMISH
51	HOOD CANAL NURSERIES, INC.	KITSAP
52	IFA NURSERIES, INC.	LEWIS
53	INLAND DESERT NURSERY	SKAMANIA
54	JASON'S GREENHOUSE	THURSTON
55	JASON'S GREENHOUSE, INC.	THURSTON
56	JUDD CREEK WETLAND & NATIVE PLANT NURSERY	KING
57	JULIUS ROSSO NURSERY / PRODUCE	KING
58	KENT NURSERY, INC.	PIERCE
59	KIRVAN'S NATIVE NURSERY & CONSTRUCTION INC.	MASON
60	KLEM'S GREENHOUSE, INC.	KING
61	LATAH CREEK NURSERY	SPOKANE
62	LAWYER NURSERY, INC.	FRANKLIN
63	LAWYER NURSERY, INC.	THURSTON
64	LEE FARM AND NURSERY	KING
65	LIMA GREENHOUSES INC.	SPOKANE
66	LIVING ART NURSERY	GRAYS HARBOR
67	LOVEJOY NURSERY	SNOHOMISH
68	MACKENZIE FARMS, LLC	YAKIMA
69	MARIAH GARDENS	KITTITAS
70	MARTINS BLUES SPRUCE & MORE	SPOKANE
71	MCMAHAN NURSERY, INC.	YAKIMA
72	METHON NATIVES	OKANOGAN
73	MEYERS CONSERVATORY	KITSAP
74	MILESTONE SERVICES/MILESTONE NURSERY	KLICKITAT
75	MOLLGAARD FLORAL	SNOHOMISH
76	MOUNTAINVIEW GREENHOUSE	KING
77	NATIVES NORTHWEST COMPANY	LEWIS
78	NISQUALLY NURSERY	THURSTON
79	NORTH CASCADE NATIVE PLANTS AND TREES	SKAGIT
80	NORTHSTAR PERENNIALS AND GROUND COVERS	WHATCOM
81	NORTHWEST HORTICULTURE	SKAGIT
82	NORTHWEST HORTICULTURE	YAKIMA
83	OHASHI SPECIMEN TREES	KING

84	PACIFIC FLORAL WHOLESALE	KING
85	PACIFIC GROWERS, INC.	WHATCOM
86	PACIFIC NATIVES & ORNAMENTALS	KING
87	PERENNIAL PLEASURES	SKAGIT
88	PILCHUCK GARDENS	SNOHOMISH
89	PUGET SOUND NURSERY SERVICES	SNOHOMISH
90	PUGET SOUND PLANTS	THURSTON
91	PUTERBAUGH FARMS, INC.	YAKIMA
92	QUALITY NURSERY	YAKIMA
93	QUARTZITE MOUNTAIN SOD AND NURSERY STOCK, INC.	STEVENS
94	RAINIER NURSERY LLC	KING
95	RIDGEWAY GARDENS	KING
96	ROBINWOOD NURSERY	KING
97	ROSSO GARDENS, LLC	KING
98	SEEDS, INC./PLANTS OF THE WILD WILLARD FIELD	WHITMAN
99	SHADY LANE HOSTAS	WHATCOM
100	SHEA'S NURSERY	KING
101	SKAGIT GARDENS, INC.	SKAGIT
102	SKIYOU NURSERY	SKAGIT
103	SMITTY'S GREENHOUSE	SPOKANE
104	SMUGGLERS COVE RHODODENDRONS	ISLAND
105	SMYTH'S GARDENVILLE GREENHOUSE, INC.	PIERCE
106	SNO-VALLEY FARMS, LLC	SNOHOMISH
107	SOUND NATIVE PLANTS	THURSTON
108	SOUTHBAY GREENHOUSES	THURSTON
109	ST. GEORGE FARM	YAKIMA
110	SUNBREAK NURSERY COMPANY	WHATCOM
111	SUNDANCE GARDENS	KING
112	SUNDQUIST NURSERY, INC.	KITSAP
113	TALL GRASSES BAMBOO	SNOHOMISH
114	THE LILY PAD	THURSTON
115	THE PLANTER BOX	PACIFIC
116	THOMPSON WHOLESALE NURSERY LLC	SPOKANE
117	TISSUES & LINERS, INC.	KING
118	TOM DE SANTO GREENHOUSES	KING
119	UPRIVER GREENHOUSE, INC.	SPOKANE
120	URBAN FOREST NURSERY	SKAGIT
121	VAN KLAVEREN'S NURSERY, LLC	SNOHOMISH
122	VAN WINGERDEN GREENHOUSE & SONS	YAKIMA
123	VIBRANT PLANTS, INC.	KING
124	VINLAND LANDSCAPE & NURSERY	JEFFERSON
125	WALKER MOUNTAIN MEADOWS NURSERY	JEFFERSON
126	WALLA WALLA NURSERY COMPANY	WALLA WALLA

127	WELLS NURSERY, LLC	SKAGIT
128	WINDY MEADOW NURSERY	WHATCOM
129	ZARD'S NURSERY	KITSAP
130	ZENITH HOLLAND GARDENS	KING

APPENDIX C

Demographic characteristics of Washington State wholesale nursery respondents (Table 11).

Table 11. Specific demographic characteristics of Washington's wholesale nursery industry survey respondents.

Demographic characteristic	n	Percent
Ownership status (Q1)		
Owner	31	74
Non-owner	11	26
State county location (Q2)		
West side	31	84
East side	6	16
Employment duration in current nursery (Q3)		
1-10 years	12	29
11-15 years	9	22
16-30 years	15	37
31-70 years	5	12
Employment duration in nursery industry (Q4)		
1-10 years	11	26
11-14 years	2	5
15-30 years	21	50
31-70 years	8	19
Acres in wholesale production (Q5)		
0-5 acres	28	67
6-10 acres	4	9.5
11-50 acres	6	14
51-500 acres	4	9.5
Plant material shipped out of state each year (Q6)		
0% - 20%	31	78
21% - 40%	4	10
41% - 60%	1	3
61% - 100%	4	10
Different plant species in nursery's inventory (Q7)		
Fewer than 50	18	45
51 – 100	9	23
101- 500	9	23
More than 500	4	10
Different cultivars or varieties in nursery's inventory (Q8)		
Fewer than 100	21	51
101 – 500	13	32
501 - 1000	6	15
Acres used to grow most frequently produced plant (Q10)		
0-5 acres	29	76
6-10 acres	3	8
11-500 acres	6	16

APPENDIX D

Ten most frequently produced plants (Table 12) and Washington State wholesale nursery responses on select plant species (Table 13).

Table 12. Most frequently produced plant species or type by the Washington wholesale nursery industry survey respondents (Question 9).

Plant Type	Number of nurseries
Acer spp.	5
Rhododendron spp.	3
Fern Species	3
Cornus spp.	3
Thuja spp.	2
Succulent spp.	2
Gaultheria spp.	2
Petunia spp.	2
Native Species	2
Malus spp.	2

Table 13. Primary deciding factors for the Washington wholesale nursery industry respondents to add new and different plant species, cultivars or varieties to their inventories (Question 28).

Plant inventory decision factors	n	Percent
Customer requests	28	67
Overall plant preferences	23	55
Ease of growth and maintenance	19	45
Sales and marketing info	18	43
Last year's sales and profitability	14	33
Production costs	14	33
Environmental concern	9	21
Trade shows	7	17

APPENDIX E

Complete content transcript for the education module and picture credits for educational module slides.

TRANSCRIPT FOR THE EDUCATIONAL MODULE

- In many urban landscapes, the same types of plants are planted over, and over, and over again!
- <Animation of identical flower clusters>
- <Picture of three hawthorns of the same species in the same neighborhood>
- Repetitive planting reduces diversity!
- Although repetitive planting can be aesthetically pleasing, it often results in negative insect, disease and environmental impacts.
- Decreased diversity increases problems! An example from nature: In grassland ecosystems, when many of the same species are abundant, diseases spread more rapidly (Knops et. al., 1999).
- Why does repetitive planting happen in *urban* landscapes?
    - A few plants are often widely advertised (especially if they are new varieties!).
    - Many people buy these popular plants and put them in their yards.
- This results in millions of people, across the country, having the same plants in their yard.
    - For example, flowering dogwoods. <Picture of three flowering dogwoods>
- Another reason . . .
    - As cities grew in both population and area, urban sprawl led to more residential lots.
    - More lots increase the need for landscaping.
- Where are all of these plants coming from?
    - <Picture of a wholesale nursery's field of maples in production>
    - All the cultivated plants in this field are maple trees!
- Who is buying all of these plants?
    - Home owners, cities, general merchants, re-wholesalers, garden centers and landscape contractors (in order of smallest to largest purchasers).
- Conclusion?
    - Millions of landscape plants come from relatively few nurseries, are sold by a few places and are the same species or variety!
- Learn about Landscape Diversity
    - <Button: Insect Impacts>
    - <Button: Disease Impacts>
    - <Button: Environmental Impacts>
    - <Button: Summary Slides>
- Insect Impacts
    - Certain insects are attracted to specific plants. These are called <u>host plants.</u>
    - When a large number of host plants are present in a small area, there is a lot more food for insects, and their populations increase. This increases the probability that plants will be damaged through insect activity.
    - By feeding or living on plants, insects can damage plants in two ways:
        - 1. Kill Plant
        - 2. Weaken Plant
        - <Animation that shows a beetle chewing a leaf and causing plant death>
        - Insect damage can cause plant to die.

- If many host plants are planted in close proximity to each other, they are all likely to become damaged or die if an insect attacks one of them.
    - <Picture of a house with an aggregation of plants of the same species>
- A real life example . . .
    - <Picture of the Emerald ash borer (*Agrilus planipennis*)
- Emerald ash borer damage
    - <Two pictures depicting trees damaged by emerald ash borer>
- When ash trees are used as street trees, planted all in a row . . . the insects can attack each tree until the entire row is dead.
    - <Picture of a street lined by healthy, dying and dead ash trees>
- But in a mixed planting one tree may die while others remain intact.
    - <Picture of dead and dying ash trees surrounded by healthy trees of other species>
- Increased plant diversity reduces insect impacts!

- Disease Impacts
    - Diseases spread from one susceptible plant to another. If enough of the same susceptible plants are repeatedly grown in the same region, the entire region can become infected.
    - Modes of disease transfer
        - One way diseases may be transmitted to plants is by <u>vectors.</u>
        - Types of vectors include:
            - <u>Biological</u>: animals, insects, fungi, nematodes and protozoa
            - <u>Mechanical</u>: tools such as pruners, shovels, trowels, etc.
        - Pruning shears can transmit rose crown gall to a healthy plant if first used on a diseased plant without disinfection.
        - <u>Vector Example</u>: The elm bark beetle is a vector for Dutch elm disease.
            - <Picture of an elm bark beetle (*Scolytus multistriatus)*>
    - Dutch elm disease
        - Caused by a fungus and spread by elm bark beetles.
        - When large elms are planted within 25 to 50 feet of each other (such as in a street planting), the roots of both trees often naturally cross each other in the soil and eventually graft together.
        - The fungus can move from infected trees to adjacent trees through these grafted roots.
        - Spread of Dutch elm disease through root grafting is a significant cause of tree death in urban areas *where elms are closely spaced.*
            - <Animation showing diseased fluids passing tree to tree via root grafts>
            - <Animation showing insect vectored Dutch elm disease killing a homogeneous street planting of elm trees>
        - Increased street tree diversity reduces the impact of Dutch elm disease.
            - <Animation showing how fewer trees are killed by Dutch elm disease in a diverse street planting>
        - Landscape diversity mitigates the negative effects of both insect and disease damage!

- Environmental Impacts
    - Plants are subjected to a wide range of environmental stresses.
    - Common environmental stresses include: wind, cold and drought.
    - Increasing plant diversity ensures that the landscape as a whole can tolerate a wider range of stresses.
    - Cold tolerance
        - Different plants handle environmental stress differently.
        - Some plants can adapt to and withstand extreme cold.
        - These are called cold hardy plants.
            - <Picture showing a plant with cold injury only on the exposed side. The protected side next to the wall was undamaged>
            - <Picture showing a normally hardy plant whose *new* growth is the only part injured by frost>
        - If a landscape has many tender plants, they may all be injured in a frost. The aesthetic impact will be devastating as most of the landscape will either become severely injured or die.
            - <Animation of a cloud precipitating frost on a planting and tender plants dying as a result>
        - Most of this landscape has died as a result of frost damage!
        - However, if a landscape contains a mix of tender and cold hardy plants, only the tender plants will be affected by frost.
        - The aesthetic impact will be minimal since only a few plants in the entire landscape are injured or die.
            - <Animation of a cloud precipitating frost on a planting and causing some tender plants to die, while most of the hardy plants live>
        - Impact on landscape is minimal since only one tree died.
        - Therefore, choosing a diverse array of plants, including both tender and cold hardy, will ensure longevity of the landscape as well as improved aesthetic value.
    - Drought tolerance
        - All plants require water to carry nutrients from the soil to the shoots.
            - <Animation of water uptake by plant roots>
        - Plants have different levels of tolerance or resistance to drought. Some may completely lack the ability to withstand drought.
            - <Picture showing plants in drought conditions: hardy plants are healthy, non-hardy plants are dying>
            - <Picture of the plant on the left suffering from drought, but the hardier plant on the right is not>
            - <Picture showing a row of plants during a drought; some are hardy and healthy, some are brown and dying>
        - What would happen if all of these plants were the same species? Imagine how this landscape would look if the whole row was damaged!
        - Incorporating drought tolerant plants into the landscape reduces the negative aesthetic impact if a number of plants are injured or killed during a drought.

- Sometimes diseases, insects or environmental damage can occur so rapidly that it is impossible to replace damaged plants before an entire planting is injured or killed.
    - Example 1: Insects
        - Trees attacked by emerald ash borer will lose 30 – 50% of the canopy in one year, and the entire tree will be killed in 2-3 years.
    - Example 2: Diseases
        - Crown gall causes abnormally rapid cell division and enlargement of stem or root tissue in host plants, appearing after the plant has been growing for just one or more seasons.
    - Example 3: Environment
        - Unexpected weather conditions such as severe drought, cold or wind can cause unforeseen, widespread damage in just hours.
    - Therefore, it is better to have a genetically diverse array of plants in the landscape to begin with.
- Summary
    - Landscape diversity is a simple concept and is important for many reasons: A greater variety of plants in the landscape results in increased resistance to insect damage, disease transfer, cold injury and drought damage.
    - Greater variety also gives people more plants to choose from and prevents nation-wide epidemics of insect infestation and disease. Thus, fewer plants will die and have to be replaced. This saves money!
    - People are *already* increasing diversity nationwide.
    - Many cities have ordinances to prevent an area from being planted with more then: 10% of one cultivar or variety, 20% of one species, 30% of one genus.
    - Many cities are planting city blocks with a large mixture of trees *within* the same block (as opposed to long rows of the same tree species for many consecutive blocks).
    - Some cities believe planting different species within the same block is less aesthetically pleasing. As an alternative, they plant only *one* species per block, but vary the species block to block.
    - Diversity is an important issue in our urban landscapes, and it is easy to implement in our own yards as well as citywide. Understanding diversity and making it a key element in the design of a landscape is the best way to prevent potential problems, now and in the future.
- Quiz
    - Question 1: What increases the probability of insect damage?
        - Large numbers of host plants in one area
        - A large food supply that increases insect populations
        - A wide range of plant species in one area
        - Both A and B
    - Question 2: What is the aesthetic impact of insect damage in a planting with many different species?
        - Low impact because damage occurs to fewer plants
        - Low impact because damage doesn't occur in diverse plantings
        - High impact because insects favor diverse food sources
        - High impact because damage in diverse plantings is more visible

- Question 3: How does Dutch elm disease impact mixed street plantings?
  - Only some elm trees are likely to be affected
  - Only trees other than elms are affected
  - Only very young trees are likely to be affected
  - None of the above
- Question 4: How does disease incidence differ in diverse plantings versus non-diverse plantings?
  - Plants in diverse plantings attract diseases
  - Plants in diverse plantings attract vectors (insects)
  - More plants are infected in non-diverse plantings
  - More plants are infected in diverse plantings
- Question 5: Why is genetic diversity in landscape plantings important?
  - Diversity reduces disease impacts on entire planting
  - Diverse plantings can be aesthetically pleasing
  - People like to have lots of choices in plants
  - All of the above
- Question 6: How does cold damage aesthetically impact a diverse planting?
  - Damage is not as obvious in diverse plantings
  - Fewer plants overall are injured
  - Tender plants are damaged by cold
  - All of the above
- Question 7: How is the landscape improved by using a diverse array of drought tolerant plants?
  - Diversity reduces drought's impacts on overall landscape
  - Diverse plantings are never injured by drought
  - Drought tolerance is increased in a diverse planting
  - Diversity does not impact drought damage in the landscape
- Question 8: Why is it important to have a genetically diverse landscape to begin with?
  - A genetically uniform landscape is a more attractive alternative to planting only one species
  - A genetically uniform landscape can be killed in a short period of time
  - Cities can enact landscape ordinances against you
  - Cities in and of themselves tend to attract more vectors
- Question 9: How have many cities incorporated genetic diversity into their landscapes?
  - Using different tree species between blocks
  - Using different tree species on either side of the street
  - Varying the amount of one species used city-wide
  - All of the above
- Question 10: What benefit is derived from having a genetically diverse array of plants in the landscape?
  - Overall resistance to insect damage is increased
  - Cold injury is reduced and occurs more sporadically
  - Drought damage is reduced and occurs more sporadically
  - All of the above

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