2006

Effect of nursery media particle size distribution on container-grown woody ornamental production

Michael Paul Richard
Louisiana State University and Agricultural and Mechanical College

EFFECT OF NURSERY MEDIA PARTICLE SIZE DISTRIBUTION ON CONTAINER-GROWN WOODY ORNAMENTAL PRODUCTION

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Horticulture

by
Michael Paul Richard
B.S., Louisiana State University, 2004
May 2006

ACKNOWLEDGMENTS

It is my pleasure to thank first and foremost Dr. Ed Bush, my major professor, for his guidance and wisdom throughout my endeavor. If there was ever a problem I could count on him to patiently help me through it. I would also like to thank my committee members Dr. Allen Owings, Dr. Paul Wilson, and Dr. Charles Johnson for their expert advice and encouragement. Special thanks go out to Ms. Ann Gray and Mr. Anthony Witcher for all of their help in the back breaking portions of my thesis. The both of you have been exceptionally considerate and helpful through the past two years. I would also like to thank everyone at the Burden Research Facility especially Mr. Allen Broyles for their generosity. I would also like to give a sincere thanks to Mrs. Gloria McClure for advising on key components of my work. Last, but definitely not least I want to thank my fellow graduate students Ms. Angelina Lopez and Mr. Sergio Sosa for the large part they have played in my success.

Absolutely none of my successes throughout my college career would have been possible if not for my family. Mom, Dad, and Kelly, I thank you, from the bottom of my heart, for all of your love and caring over the last seven years of my life. I could always count on you, mom and dad, to be there for me when I needed you the most. Your encouragement over the past two years has been wonderful. I would also like to thank all my friends and family for there love and understanding throughout this entire journey.

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ABSTRACT

Bark is a renewable resource with limited availability as a medium used by the nursery industry. Previous research has indicated that pinebark and hardwood bark can be used as a substrate in nursery production. The objective of this study is to determine the effect of bark source (pinebark and hardwood bark), particle size distribution, and irrigation frequency on the growth and quality of azalea (*Rhododendron indicum* 'Red Ruffle'), Indian hawthorn (*Rhapeolepis indica* 'Snow'), and ligustrum (*Ligustrum japonicum*). Treatments were arranged in a factorial 6x2x2 plot design, with six soil mixes, two barks, two irrigation frequencies, and six blocks totaling 144 replicates. Treatments were arranged using a randomized complete block design.

Pinebark and hardwood bark sources were sieved into four different categories using sieves 3.35mm (#6), 1.4mm (#14), 710µm (#25), and < 710µm (<#25) to establish uniform physical characteristics. Six treatments were established to provide media mixes of small, medium, and large particle size distributions. Irrigation treatments were based on the effluent collected after irrigation. Treatment 1 maintained an effluent level of 20 to 40%, while Treatment 2 maintained an effluent level of 10 to 20%.

Results indicate that hardwood bark pH and EC were significantly greater than pinebark, although differences were minor (0.3 and 0.1 increase, respectively). Quality ratings of azalea, Indian hawthorn, and ligustrum were significantly greater in pinebark compared to hardwood bark (32%, 17%, and 33% increase, respectively). Also, growth index and shoot weights for azalea, Indian hawthorn, and ligustrum were significantly greater in pinebark compared to hardwood bark. Growth indexes increased 25%, 13%, 39%, respectively, and shoot weights increased 58%, 27%, 72%, respectively. Media

treatment 3 (3.35mm, 710µm, < 710µm) produced the greatest shoot weights and growth index for azalea in pinebark. Media treatment 2 (3.35mm, 1.4mm, < 710µm) produced the greatest shoot weights, growth index, and quality ratings for Indian hawthorn and ligustrum. Hardwood bark particle size distribution had no significant effect on shoot weights, growth index, or quality ratings. Irrigation treatment 2 (low volume) significantly increased the values of EC and pH for all three plants.

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

The greenhouse and nursery industry has experienced dramatic growth over the past four decades. According to Brooker et al. (2000), this industry has increased economically from $661 million in 1960 to $12.11 billion 1998. In a survey conducted by Johnson (1999), Louisiana grower's cash receipts were at an estimated $35.4 million, which correlated into about 0.3% of the U.S share. Over 40% of the growers in this statistic were established in the 1990's. Nursery production has become a competitive industry and a stable contributor to the Louisiana economy during the past ten to fifteen years. This competitiveness has caused increased research efforts into cultural practices such as irrigation, fertility, and media influence on production. One aspect that has been researched is the soilless media that container crops are produced. The primary media for nursery production is a mix of pine and bark substrates. Choosing the correct substrates are important to obtain optimal growing conditions. There is a demand in the industry to find a media with the correct combination of particle sizes to optimize plant growth. The growth of woody ornamentals is dependent on the physical and chemical characteristics of the medium. This study looks at the effects of particle size distribution of pinebark and hardwood bark on the overall growth and quality of three woody ornamentals in a one gallon (trade) nursery production setting.

Three of the most commonly used shrubs in Louisiana landscape settings are azalea (*Rhododendron indicum* 'Red Ruffle'), Indian hawthorn (*Rhapheolepis indica* 'Snow'), and ligustrum (*Ligustrum japonicum*). These three plant species were chosen based on their water requirements found in the Best Management Practices Manuel

(1997). The low, medium, and high water requiring plant is Indian hawthorn, ligustrum, and azalea, respectively.

Azaleas come in a large number of varieties with around 10,000 different plant types. This large number of plants provides growers with a variety of habits, sizes, colors and bloom types. Azaleas grow best in USDA hardiness zones 6-8. Best growth can be established in partial shade with well drained, moist soils at a pH of 5 to 5.6 (Azalea Society of America, 1999). Indian hawthorn is part of the *Rosaceae* family and grows best in USDA hardiness zone 8-11. Its plant type is ground cover that reaches a mature height of three to seven feet and can spread from six to ten feet. Indian hawthorn is a slow growing plant that grows best is slightly alkaline soils that are well drained and can tolerate moderate drought conditions. Flowers bloom in the spring and can range from white to dark pink (Gilman, 1999). Ligustrum is characterized as a relatively large tree or shrub that stands about six to twelve feet tall, but can reach heights of twenty feet. It is known for its dark green foliage and fragrant flowers that bloom in the spring. Ligustrum's grows best in USDA hardiness zones 8-10. Ligustrum is a fairly durable plant that can withstand a variety of soil conditions and prefers sun to partial shade (Anonymous, 1996).

Container Production

Container production is the most widely used practice for growing woody ornamentals. The shift of container production away from field production was noticeable in the 1970s (Furuta, 1974) and has steadily increased (Hahn et al., 1979). The most common containers used for nursery production of woody ornamentals are one to five gallons (3.8L to 19L), but larger container production (≥15 gallons) has increased over the last few decades (Tilt, 1993). Container production offers advantages to field production, but the disadvantages can have a pronounced effect on plant growth. Volume is restricted by the container's walls and can cause a confined root system, while heavy applications of fertilizer and water are needed to maintain proper plant growth.

Scientist have studied the effects of container size on plant growth in vegetables (Bar-Tal et al., 1995; Carmi and Heuer, 1981; NeSmith, 1993; Peterson et al., 1991; Ruff et al., 1987), woody ornamentals (Dubik et al., 1990; Tilt et al., 1987), trees (Biran and Eliassaf, 1979; Gilliam et al., 1984; Hanson et al., 1987; Ismail and Noor, 1996) and bedding plants (Latimer, 1991; van Iersel, 1997). The restriction of roots can have a negative effect on root and shoot growth. The consensus is that as container size increases plant growth, leaf area, and shoot dry weight are increased. Oddiraju et al. (1994), using image analysis, stated that early root development affected coarse: fine root ratio with less coarse roots in 2 L pots than in 3 L pots. Proper aeration of the media substrates is critical to successful plant growth in pots. Growing plants in the confined space of pots and the depth of the media will have significant effects on aeration and moisture properties (Bugbee, 1986). A perched water table exists at the bottom of the pots after irrigation causing root problems. Many physiological factors can be attributed to growth differences for various container sizes. Hahn et al. (1974) stated that as container size increased production costs increased. Growers must make the final decision on growing a more quality plant in larger containers or using smaller pots for more volume.

Irrigation Management

Overhead irrigation is the most commonly use method of watering container-grown woody ornamentals (Beeson and Knox, 1991). Overhead irrigation is applied by sprinkler nozzles with a wide range of availability depending on the output volume and spray width required (Thomson, 1989). Overhead irrigation applies large volumes of water relatively inefficient, especially as pot spacing increases. Fare et al. (1991) reported that overhead irrigation applies approximately 40,000 gallons of water per acre daily, with 40 to 90% losses from evaporation and runoff. Other studies have suggested that only 12 to 50% of water actually reaches the soil surface (Beeson and Knoz, 1991; Weatherspoon and Harrell, 1980). This can be attributed to plant canopy, pot spacing, and container size. "Jamming" pots together has been suggested to increase efficiency, but plant quality can be compromised (Beeson and Knox, 1991).

Proper irrigation management involves the water dispersal to plants to supply moisture to the root zone, while decreasing irrigation volume to prevent excessive leaching and runoff. Proper irrigation management can reduce production costs. Raither and Frink (1989) stated that nurseries used an estimated 9.9 million L of water for one acre of plants per growing season. Recent concerns over water conservation and environmental contamination by nutrient and pesticide runoff from nurseries have become very important. With efficient irrigation management these concerns can be controlled (Weatherspoon and Harrell, 1980). Irrigation application efficiency is the process of reducing effluent volume by increasing irrigation frequency and decreasing volume while maintaining optimum plant growth (Groves et al., 1995). Many states have implemented water usage regulations on nurseries; so many growers must consider irrigation techniques that improve irrigation application efficiency (Parsons, 2000). Other irrigation techniques, besides overhead, that have been shown to improve efficiency are micro-irrigation and cyclic or pulse irrigation.

Micro-irrigation (MI) is an alternative form of irrigation that has produced more efficient results than overhead irrigation (Martin et al., 1989). MI is a term adapted by the American Society of Agricultural Engineers that refers to the frequent application of water, in small quantities, at or below the soil surface. With proper management this technique can maintain adequate soil moisture levels comparable to field capacity throughout the growing season (Haman and Izuno, 1989). MI encompasses drip, stake, and trickle irrigation. Drip or trickle irrigation applies water, slowly, through emitters that are on the soil surface. The application of water directly to the soil surface not only increases efficiency, but reduces disease infestation from the lack of splashing. Drip or trickle irrigation can often cause non-uniform wetting throughout the soil profile. Stake or spray stick irrigation applies a greater percentage of water across the soil surface via stakes that are positioned in individual pots. Drip and stake irrigation are found primarily in containers >20 liters with limited use in smaller containers (Beeson and Knox, 1991). These two systems have been found to increase efficiency between 44 and 72% over overhead irrigation (Lamack and Niemiera, 1993).

Cyclic irrigation can be described as dividing the daily water amounts into smaller more frequent applications. Karmeli and Peri (1974) stated that cyclic irrigation consisted of cycles with an operating phase and resting phase. Cyclic irrigation has been proven to reduce runoff and nutrient leaching and improve the quality of plant when compared to other irrigation techniques (Beeson, 1998; Beeson and Haydu, 1995; Fare et al., 1994, 1996; Gray et al., 1998; Karam and Niemiera, 1994; Lamack and Niemiera, 1993; Ruter, 1997; Tyler et al., 1996; Witmer et al., 1998). These reports indicated a water reduction by as much as 77% and decreased runoff by as much as 90%.

Fertilizer Management

The supply of nutrients to plants grown in containers is a key component to proper management practices. The ultimate aim of any fertilizer program is to maintain a optimum level of nutrients in the soil throughout the growing season. There are two types of fertilizers available for nursery use, natural (organic) and synthetic. Synthetic fertilizers are mainly used for container production because their nutrients are immediately available for plant uptake. Many of the soilless media used in container production are believed to be of low fertility and do not release or fix any plant nutrients (Baker, 1957). The low cation exchange capacity of these soils often requires large amounts of fertilizer to supply proper nutrition, which in turn can cause waste and runoff. To overcome this problem, many nurseries have gone to the use of controlled release fertilizers (CRF).

CRF efficiently utilize all applied nutrients by slowly releasing nutrients over a specified period of time. This process in performed by coating the fertilizer material which breaks down over time. The slow release reduces application frequency and waste from leaching. Several factors such as irrigation, temperature, growing media, and method of application have an influence on the rate and availability of nutrients for plant uptake. One mechanism of breakdown is the diffusion of water through the coating and into the granules (Oertli and Lunt, 1962) rendering nutrients to solution. The irrigation system (Stamps, 2000) and duration used will influence plant growth and substrate nutrient accumulation (Karam et al., 1994). Excessive irrigation water could flush the nutrient solution out of the pot. In a study performed by Miller et al. (1980), the most cost effective solution was to combine 10.8 g of fertilizer and 19.3 liters of water per 15 cm diameter of container (over 6 months). Temperature, in the atmosphere and soil, controls the rate of release of fertilizers into the soil water. Lamont et al. (1987) reported that two fertilizer sources subjected to increased temperatures released nutrients at faster rates than normal. If temperatures exceed 35°C for long periods of time after planting, plant damage could occur. Fertilizers can be supplied to the soil by dribble, incorporation, or top-dressing. Each method will affect the rate and availability of nutrients to the plant (Eakes et al., 1990; Fuller and Meadows, 1986). Yeager et al. (1989) stated that blends of potassium nitrate or potassium silicate top-dressed produced greater dry shoot weights over incorporation. In the same study, Osmocote® incorporated performed better than top-dressed. At seven days, potassium and nitrate nitrogen leachate levels were higher in incorporated fertilizer compared to surface applied. Production costs are always a major concern for growers. The type of product used can greatly reduce costs by providing more efficient nutrition. Osmocote® produced better results over many other fertilizer products in several studies (Gouin and Link, 1973; Poole and Conover, 1977; Rosenbaum et al., 1979; Smith and Treaster,). Osmocote® is a resin-coated fertilizer whose rate of nutrient diffusion across the semi-permeable membrane is influenced directly by soil temperature (Sartain and Ingram). It has been investigated in foliage plants, floriculture crops, and woody ornamentals.

Media

Most of the mixes used in container production of vegetables, greenhouse crops, and woody ornamentals do not contain mineral soils; these mixes are termed 'soilless', 'lightweight', or 'artificial' media (Bunt, 1986). These soilless media provide the proper physical and chemical properties for quality plant growth as compared to mineral soils. The most widely used soilless media is peat moss or peat-based mixes. Peat is formed from the decomposition of sphagnum moss or other mosses and sedges. With the increased cost of acquiring imported peats, growers have searched for other materials for production. Researchers have investigated the use of volcanic material with tree fern waste (Criley and Wantanabe, 1974), city refuge with primary sludge (Poole and Waters, 1972), coconut coir dust (Evans and Stamps, 1996; Meerow, 1994); sawdust (Goh and Haynes, 1977), crumb rubber (Bush et al., 2001), biosolids and yard compost (Wilson et al., 2002), and other material for a suitable substitute. Many of these substitute products are used based on geographic location and availability. The most commonly used substitute for peat-based medium in the U.S. is bark. Formerly used as a waste product for burning, bark is a lightweight product that has shown great results on a variety of plant material (Pokorny and Gugino, 1967; Pokorny and Thruman, 1965). The two types of barks available for production are softwood and hardwood.

Softwood bark, mostly pine bark species, is used for production in southern U.S., while hardwood bark is used in the northern U.S. The types of cultural practices that can be applied to each media in a container production setting vary greatly. Gartner et al. (1971 and 1973) reported that hardwood bark needed a larger amount of N than pine bark because of the rapid decomposition of hardwood. The rapid decomposition can also influence the amount of irrigation applied during the growing process by altering particle size. They also stated that a mix with at least 2/3 hardwood caused a pH increase to 8.5. The initial pH of pine bark ranges from 4.0 to 5.0 and doesn't rise substantially with aging, but hardwood bark pH can rise above 7.0 (Bunt, 1988). Pine bark and hardwood bark react differently to the addition of lime to the pre-plant mixture. Lime raises the pH of pine to a suitable range, but can cause a rapid increase in hardwood bark pH.

Regardless of bark type, if bark is used in the fresh state some phytotoxicity may occur. The degree of phytotoxicity will vary according to several factors such as species of the tree, age of the bark, the season in which it was removed, and the region it was grown (Bunt, 1988). To retard the phytotoxic nature of bark composting is necessary for all bark types. Composting is described as the biological decomposition of organic constituents under controlled conditions (Hoitink, 1980). It consists of three phases: 1) an initial phase of 1-2 days in which easily degradable soluble compounds are decomposed, 2) a thermophilic phase where temperatures increase (40 to 80°C) and cellulose is degraded, 3) a stabilization phase where temperatures return to normal and various organisms recolonize (Hoitink, 1980). Hardwood bark decomposes as much as four times faster than pine bark because of its high cellulose content (Allison and Murphy, 1963). The decomposition rate within each bark type will vary depending on the type of tree used for production. Composting can be controlled by factors such as pH, moisture, aeration, and fertilizer additions. Another beneficial aspect of composting is that soil born pathogens can be suppressed by the high heat of decomposition (Malek and Gartner, 1975; Hoitink, 1980). They found that hardwood bark suppressed many different types of pathogens compared to softwood bark.

Physical Properties

Researchers have tried to provide the perfect growth media for nursery production by characterizing the physical properties of different media. The physical quality of these mixes is dependent on the substrates ability to store and supply air and water. The physical components that are important to quality media include: pore size, pore tortuousity, water-holding capacity, hydraulic conductivity, aeration porosity, and bulk density. Bulk density is an important factor to consider in interpreting the physical and chemical properties of media on a volume basis. Bulk density of soilless media are low, therefore additions of sand are usually added to increase weight (Brown and Pokorny, 1975; Fonteno et al., 1981; Hanan, 1981). Increasing bulk density provides support to the plant in lightweight containers. Fonteno et al. (1981) also found that shrinkage and settling in a pot will increase bulk density. Total porosity (TP) can be estimated from bulk density because they are inversely related (Beardsell et al., 1979; Hanan, 1981). Total porosity is defined as the total volume of pore space in a substrate. The total porosity of a media controls the movement of water through the soil profile. Hanan (1981) found that mixtures in excess of $0.70 cm^3/cm^3$ total porosity increased percolation rates and subsequently increased water needs to control salinity. Water-holding capacity and aeration porosity are two very important physical properties. They directly influence the amount of available air and water to plant roots. The drier the media, the less available water exists and a plant uses more energy to get water (De Boot and De Waele, 1968). Verdonck et al. (1983) suggested that any media should consist of 20% air and 20 to 30% available water by volume. Adjusting particle size to accommodate these percentages has been a largely debatable topic by many scientists (Bilderback et al., 1982; Bugbee and Frink, 1986; Nkongolo and Caron, 1999; Reisch, 1967). Their studies give conflicting results on the addition or subtraction of large and small particles and how they affect both properties. Regardless of media mix or type, there must be a continuous link of air pores to roots for gas diffusion. Gas diffusion is largely controlled by the amount of water contained in the media.

Chemical Properties

Special attention must be given to media chemical properties because they have a major influence on plant quality. Chemical properties directly affect nutrient solubility and retention, thus availability for plant uptake. Suspensions, saturated media extracts, and displaced soil solutions are three methods used to analyze the chemical properties of soils (Bunt, 1988). Three of the main components that contribute to a media's chemical make-up are pH, cation exchange capacity (CEC), and electrical conductivity (EC). Multiple factors influence a media's pH including: lime concentration and activity, plant uptake of nutrients, plant species, fertilizer, and water alkalinity. Lucas and Davis (1961) constructed a chart that showed the availability of 12 nutrients across the pH range of 4.0-9.0 for organic soils. They concluded that a pH of 1-1.5 units' less than mineral soils is more desirable. Most organic soils initially have a low pH. A common practice for growers is to add pre-plant lime applications to the growing media to increase pH. Rosenbaum and Sartain (1982) found that peat or bark based media required 3.5 lbs/yd^3 of dolomite to increase pH to levels of 5.2 to 5.9. In a study on hollies, azaleas, and juniper increasing lime rates decreased shoot weight, root weight, root ball diameter, and N, P, K levels in leaves (Chrustic and Wright, 1983). The same results were conveyed in Hipp and Morgan's (1980) study on *Nephrolepis exaltata* (L.) Schott 'Rooseveltii'.

Lucas and Davis (1961) stated that lime applications to organic soils with pH above 5.8 are objectionable because of reduced P, Mn, B, and Zn availability. The pH of irrigation water can have a significant effect on media pH. Kramer and Peterson (1990) irrigated *Chrysanthemum morifolium* with five levels of alkaline water. Results showed that levels above 250 mg/L altered the nutrient availability of the growing medium and plant tissue because of a high pH. The addition of various acidic fertilizers was found to decrease pH and reverse all deleterious effects (Bishko and Fisher, 2003; Kramer and Peterson, 1990).

Plant nutrients are normally applied as salts which have a positive charge called cations. CEC is defined as the total of exchangeable cations that a substrate can absorb per weight (Bunt, 1988). Clay or organic particles have negative charges which attract positive charges of fertilizers. CEC provides a reservoir of nutrients for plant uptake. pH is known to affect the CEC of various soils (Helling et al., 1964), organic matter the greatest. In their study, it was found that as pH levels increased the CEC also increased in a linear fashion. The exchange capacity of an organic soil increased by 140 meq/100g from pH 3.5 to 8 compared to mineral soils that only increased by 18 meq $100g^{-1}$.

EC is the measure of salt content of water based on the flow of electrical current. Organic medium supply low amounts of available nutrition to plants so growers are forced to apply large amounts of fertilizers. As stated previously, fertilizers are salt based and can cause damage if not regulated. The main source of damage is reduced supply of water to roots. Acceptable media EC levels are 1.0 to 2.0 dS/m for seedlings and plugs and 2.0 to 3.0 dS/m for established plants (Lang, 1996). The main method for regulating EC in soils is by leaching. Leaching is applying large amounts of water to the medium, which displace salt ions into solution, and flushing the soil water out of the pot.

Stratification, the movement of nutrient salts to the upper 1 cm of the medium, can occur through evaporation from the medium (Argo and Biernbaum, 1994, 1995).

Particle Size Distribution

The debarking process is the removal of large pieces of bark from logs used for lumber. Too large for use, this material is hammer-milled and screened to reduce particle size suitable for plant growth. One problem that exists is that not all barks have the same particle size distribution (PSD). An ideal media would provide all varieties of plants with adequate amounts of water and equal amounts of porosity, to diffuse oxygen and other gases to the roots, with the same PSD. There has been conflicting evidence on ideal particle size distribution within a growing media. De Boot and Verdonk (1972) and Pokorny (1982) found that particles with 100% or 75% large particles and no small particles compromised an ideal media. Waters et al. (1970) reported that media with large variances in particle size and shape caused up to 22.8% shrinkage in pots. Pokorny (1979) tested six different pine barks and all varied in PSD and physical properties. His results were similar to Gartner et al. (1973) that pine bark with 70 to 80% particles within 1/40 to 3/8 inch in diameter and 20 to 30% particles smaller than 1/40 inch in diameter produced a satisfactory production media.

Bilderback and Lorscheider (1995) compared the use of double processed pine bark (DPPB) to single component pine bark (1/4 and 1/2 inch), pine bark: sand, pine bark: peat, peat: sand, peat: perlite, Metro Mix 360®, and Fafard #3 mix® for growth of woody ornamentals. DPPB is a screened and finely ground hammer milled pine bark with minimal amounts of wood or cambium. The DPPB had the most uniform particle range with less smaller particles than the other mixes. Sieve openings of 6.3, 4.0, 2.8, 2.0, 1.4, 1.0, 0.7, 0.5 mm had the same dry weight. The DPPB also had less variation between small and large particles. The DPPB produced the best growth of all the plants grown. The uniform particle distribution resulted in the greatest total porosity and volume of water held after drainage.

Richards and Beardsell (1986) found that the exclusion of large particles (>2mm diameter), which constituted 30 to 40% by volume of all mix, would be beneficial in increasing water-holding capacity and not reducing aeration. Tilt et al. (1987) compared a coarse media to a finer media and found that total porosity was the same. This indicates that removing the finer particles would not affect total porosity. Other factors have been identified that influence water supply besides bark particles. Airhart (1978) reported that the internal structure of bark particles can absorb substantial amounts of water. Hammer-milling the bark to reduce particle size will only open up more internal structures from bark fracturing. Internal pore space constitutes about 43% of the total bark particle (Pokorny and Wetzstein, 1984). They found that roots can anchor on the exterior and interior of the media particle, but only roots that develop within the particle can absorb water and nutrients.

CHAPTER 2

EVALUATION OF BARK SOURCE, PARTICLE SIZE DISTRIBUTION, AND IRRIGATION EFFECTS ON GROWTH OF CONTAINER PRODUCED AZALEA (*RHODODENDRON INDICUM* 'RED RUFFLE')

Introduction

Pinebark is the most common growing media used in Louisiana and southern United States. In contrast, hardwood bark is used across the north, midwest, and western coast. This difference is primarily because of the availability of each bark species to the geographic region. Pokorny et al. (1965) investigated pinebark as a suitable substitute for peat based growing media and found that it contains the same beneficial characteristics. Bark media have been successful in growing woody ornamentals (Gartner et al., 1971; Pokorny, 1965), herbaceous pot plants (Pokorny, 1966), and vegetables (Allaire, 2004). Composted pine bark and hardwood bark have been found to control soil-borne diseases dependent on bark species (Hoitnik, 1980). Use of hardwood bark has been somewhat limited because it is believed to cause phytotoxicity in plants. Gartner et al., (1973) proposed aging the bark for 30 days while keeping it wet with distilled water and turning every day to overcome any deleterious affects to plants. Reese et al. (1979) found that azalea growth in hardwood bark was diminished when compared to a peat-perlite mix, because pH was increased in hardwood bark. Pinebark and hardwood bark pH range from 4.0 to 5.0 and 5.0 to 8.0, respectively. Overall both bark types are used extensively in nursery production for growth in woody ornamentals.

Many of the media used for nursery production vary in their physical and chemical properties. These physical and chemical properties control aeration, water, and nutrient supply to plants, while also providing support. Because growing media are volume based, bulk density is an important physical factor in determining the physical and chemical characteristics of a medium. For optimal growth conditions, Verdonck et al. (1983) stated that aeration porosity should range from 20 to 25% with 20 to 30%

easily available water. Nkongolo and Caron (1999) stated that media physical properties should not be constrained to just measurements of air-filled porosity, water-holding capacity, and bulk density, but included gas exchange characteristics. Their study showed that increasing particle size from 2-4mm to 8-25mm did not change air-filled porosity, but increased pore tortuosity by 1.3 times and decreased gas relative diffusivity.

Particle size distribution has a direct effect on the physical and chemical properties of any medium. Chemically, the smaller the particles the more exchange sites exist for reaction. Daniels and Wright (1988), stated that, unexpectedly, pinebark particles decreasing from <2.38 to <0.05mm only slightly increased CEC, but CEC increased at 20 meq/100 g per pH unit increase. Gartner et al. (1973), established parameters for the percent of particle sizes, based on diameter, allowable in a mix. Their ideal media include: 35% (<1/32 inch), 10% (>1/8 inch), and the rest between and 1/8 and 1/32 of an inch. Different crops require different amounts of water and air for growth, therefore changing the distribution of particles in nursery media per crop is a common occurrence. Richards et al. (1986) found that tomato and *Boronia* required a media with more particles below 10mm and none above 4.75 mm, while just the opposite was true for *Peperomia*. Azalea (*Rhododendron spp.*), *Photinia*, and *Illicium* showed increased rooting and root ball diameter in a double processed pine bark when compared to other pine bark substrates (Bilderback and Lorscheider, 1995). The double processed pinebark had up to 22% less fine particles than the other substrates. Tilt et al. (1987) found that Leyland cypress, azalea, and holly growth were greater when smaller particles were present in the media. They also stated that container size has a large affect on shoot and root growth.

Growers have become increasingly interested in the quality of the media in which their crops are grown. The lack of consistency and uniformity in nursery production media has caused problems in crop quality. Nursery media directly influence both physical and chemical properties. This experiment was designed to investigate the effects of bark source (pine or hardwood), particle size distribution (six treatments), and irrigation frequency (high and low) on the growth and quality of azalea. Pinebark and hardwood bark were sieved in order to separate particles into ranges of small, medium, and large. Four ranges were used to establish six media treatments. Overhead irrigation was applied at two different amounts for plant uptake. The objective of this study was to determine which bark source, media particle size treatment, and irrigation duration would produce the best plant.

Materials and Methods

A one gallon (trade) container production study was conducted at Burden Center in Baton Rouge, LA over a twelve month period. Burden Center is located at latitude 30^{o} 24' 27", longitude 91^{o} 08' 45", and in the USDA hardiness zone 8b. Azaleas (*Rhododendron indicum* 'Red Ruffle') were grown for seven months from December 2004 to July 2005. Azaleas were started as 4 inch liners.

Media Characteristics and Evaluation

The two different media types, pinebark and hardwood bark, were obtained from Phillips Bark Processing, Brookhaven, MS. Four particle size categorical ranges were chosen for this experiment based on Drzal and Fonteno's (1999) chart of bark particle size distribution. These ranges represent a proportionate distribution of small, medium,

and large particles. The four categories include 3.35mm (#6 sieve), 1.4mm (#14 sieve), 710µm (#25 sieve), and less than 710µm (<#25 sieve).

The sieves were placed in descending order on a Ro-Tap® sieve shaker and bark was placed in the upper sieve. The sieve shaker agitated the bark for five minutes to properly separate all the particles. The sieves were separated and its contents poured into a separated container. Media treatments were established by excluding one category from each of the first four mixes. A fifth media treatment was established by combining all four categories. The commercially available mix is an even combination of 5/8 inch and 3/8 inch sieved bark. All six media treatments can be found in Appendix 1. To ensure proper uniformity all mixes were prepared in a commercial soil mixer for fifteen minutes.

Particle Ranges

Each of the four categories (3.35mm, 1.4mm, 710µm, <710µm) were sieved to determine individual particle ranges (Appendixes 2-5). The following sieves were used to determine particle ranges for each category: 25mm (1 in.), 19mm (3/4 in.), 12.5mm (1/2 in.), 6.3mm (1/4 in.), 4.0mm (#5), 3.35mm (#6), 2.8mm (#7), 1.4mm (#14), 1.0mm (#18), 710µm (#25), 500µm (#35), 355µm (#45), 250µm (#60), 180µm (#80), 125µm (#120). One hundred grams of each category were sieved according to the previous section.

Physical Properties

Bulk Density

Bulk density, the weight of dry substrate per unit volume of substrate, was measured for each categorical range and treatment (Appendixes 6-8). Media, pine and hardwood bark, was dried in a convection oven (VWR-1660) at 60°C for twelve hours. After drying a 200 ml sample was weighed and recorded. Bulk density was calculated by dividing the weight (g) by 200ml.

Water-Holding Capacity, Total Porosity, and Aeration Porosity

All water-holding capacity, total porosity, and aeration porosity measurements were calculated from techniques described by Spomer (1997). Measurements were taken for each categorical range and treatment (Appendixes 6-8).

Fertility

Both media types and all mixes were given the same fertility treatment. Osmocote® 15 N-9 P_2O_5-12 K_2O (12-14 months) was the main source of nutrition for plant consumption applied at 16.8 lb/yd^3. Dolomitic limestone was applied at a rate of 4.0 lbs/yd^3. Epsom salt ($MgSO_4$) and gypsum ($CaSO_4$) were applied at rates of 1.3 lbs/yd^3 at three month intervals. The above amendments were incorporated into the media by mixing in a commercial soil mixer for fifteen minutes. At months three and six Epsom salt and gypsum were topdressed.

Irrigation

All containerized plants received supplemental irrigation on a daily basis during the seven month growing period. During winter months, when plants were not actively growing, supplemental irrigation was applied every other day. All supplemental irrigation was applied with over-head impact sprinklers on six foot risers. Irrigation cycles or frequencies were scheduled by a Sterling 18 controller and operated by a 24 V solenoid valve. The irrigation frequency consisted of water dispersal twice daily, 6:30am and 4:30pm, respectively. Two irrigation treatments were derived with accordance to

Best Management Practices Manuel (BMP), 1997. Optimum watering duration was maintained at an effluent volume of 20 to 40%. Sub-optimum watering duration was maintained at an effluent volume of 10 to 20%. Irrigation volumes were maintained by checking effluent amounts on a bi-weekly basis. Effluent was calculated by dividing the effluent volume by the total irrigation applied. The effluent and irrigation amounts were collected in closed-capture irrigation effluent containers (Appendix 9).

Leachate Collection

At the termination of the study, leachates, solution that drains from container substrate during and after irrigation and may contain nutrients and pesticides from the substrate solution, were collected via a modified Virginia Tech Extraction Method (Wright 1984, 1986). Pots were allowed to drain for one hour after irrigation. After the one hour interval, 300ml of deionized water was poured onto the soil surface flushing the soil water from the pot. This water was collected in a closed-capture irrigation effluent system (Appendix 9), poured into 4 oz. plastic bottles and refrigerated. Leachates were filtered using folded 11cm paper filters (Schleicher & Schuell, Inc., Keene, NH) and analyzed for pH and EC with a dual meter (Model 5800-00, Cole-Palmer Instrument Co., Chicago, IL).

Plant Evaluation

<u>Growth Index</u>

Throughout the seven months of the study, data for growth of each plant were collected to determine how each treatment would affect them. Plant growth was determined by calculating a growth index for each plant throughout the study. Growth measurements were taken on 3 January 2005, 13 April 2005, and 15 July 2005. With a metric ruler, height (measured from soil surface to apical meristem) and two widths (perpendicular to each other) were taken to get an overall growth index of the plant. Growth Index was calculated by the following equation: [height (cm) x width (cm) x width (cm)]/ 3.

Quality Ratings

Quality Ratings were taken on 24 March 2005 and 5 July 2005 by three separate individuals. The same individuals performed both ratings. Quality ratings are based on a scale of one to five (1=dead, 3=commercially acceptable, 5=superior).

Shoot Dry Weights

When the study was terminated shoots of each plant were cut at the soil surface and placed into brown paper bags. Shoots and leaves were then dried in a convection oven (VWR-1660) at 60^{o}C for 48 hours. After drying, shoot and leaves were weighed on a Mettler PC 440 scale for a dry weight.

Tissue Analysis

After shoots were weighed some plants were randomly selected for tissue analysis. Leaves of the plants were ground using a 30 mesh sieve and analyzed by the Agricultural Chemistry Department, Baton Rouge, LA for the nutrients P, K, Ca, Mg, S, Fe, Mn, B, Zn, Cu, and Na. These elements were analyzed with the EPA3052 test by microwave assisted acid digestion.

Pest Control

The use of pesticides were limited throughout the study and used on an as needed basis. The application of Mancozeb®, 0.25 oz/gal., was used to control *Cercospora spp.*, leaf spot. The applications of Green Light Neem Concentrate, 1 oz/gal., and Merit®, 0.125 tsp/gal., were used to control aphids.

Experimental Design and Statistical Analysis of Data

Treatments were arranged in a factorial 6x2x2 plot design, with six mixes, two barks, two irrigation frequencies, and six blocks totaling 144 replicates. Treatments were arranged using a randomized complete block design. Growth index, quality ratings, foliar nutrient data, pH, EC, and shoot weights were analyzed using SAS Systems for Windows 9.0 via Proc GLM and Proc Means. Means were separated using the Duncan's Multiple Range Test to compare all pair-wise differences in treatments. For all analysis, a p-value ≤ 0.05 level indicated significance.

Results and Discussion

Plant Growth

Growth index was significantly affected by the bark source and particle size distribution of the growing media. Plants grown in pinebark had a significantly higher growth index compared to hardwood bark (Figure 1). Pinebark media increased plant growth by 25% over hardwood bark media by the end of the study. Growth index was also affected by particle size distribution in pinebark (Figure 2). Media treatment 3 (3.35mm, 1.4mm, and <710µm) increased growth by 11% over the other five media treatments. Media treatment six, commercially available mix, yielded the lowest index for plant growth in pinebark. Particle size distribution had no significant effect on plant growth in hardwood bark (data not shown). This may be attributed to the overall poor growth of plants in hardwood bark source.

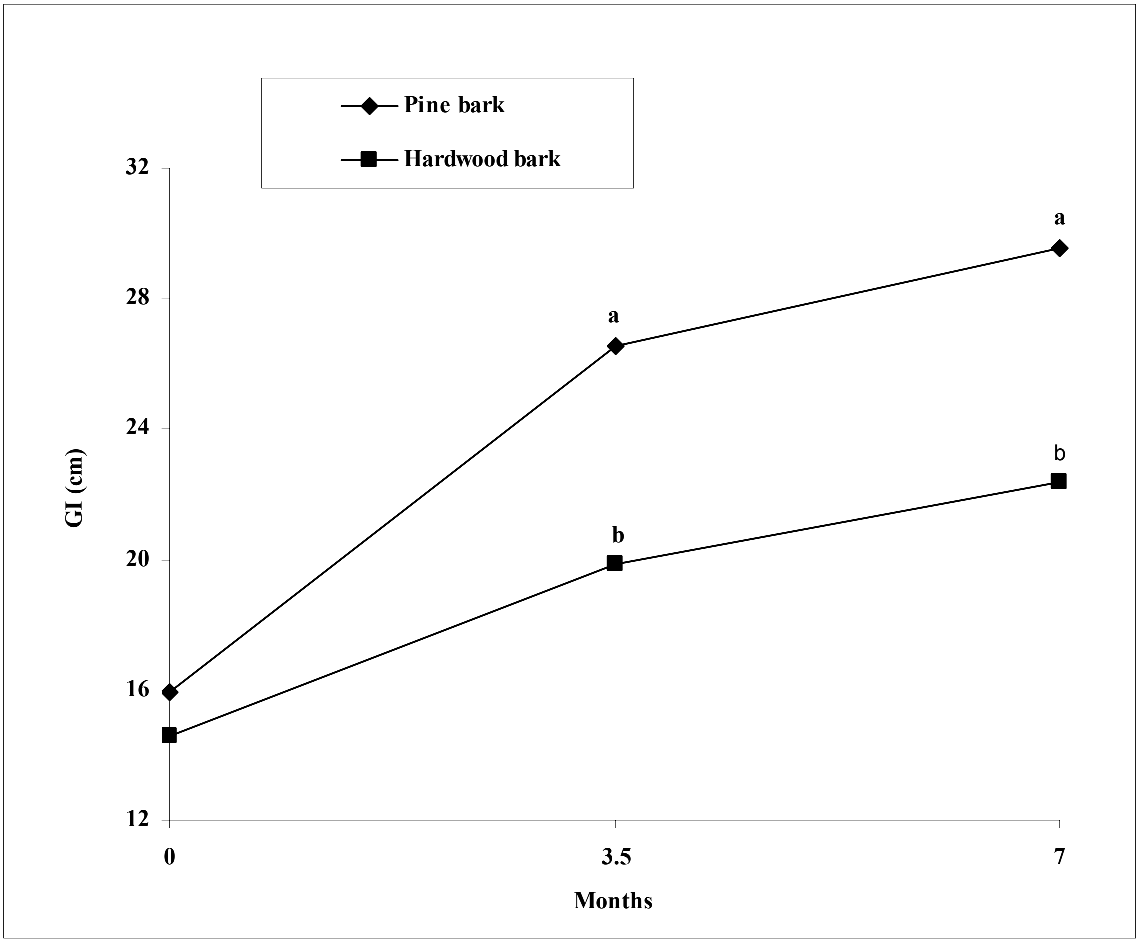

Figure 1. Comparison of pinebark and hardwood bark on growth index (GI) of container grown azalea over a seven month period.
GI= (height+width+width)/3.
Means with the same letters are not significantly different at ≤0.05 level.

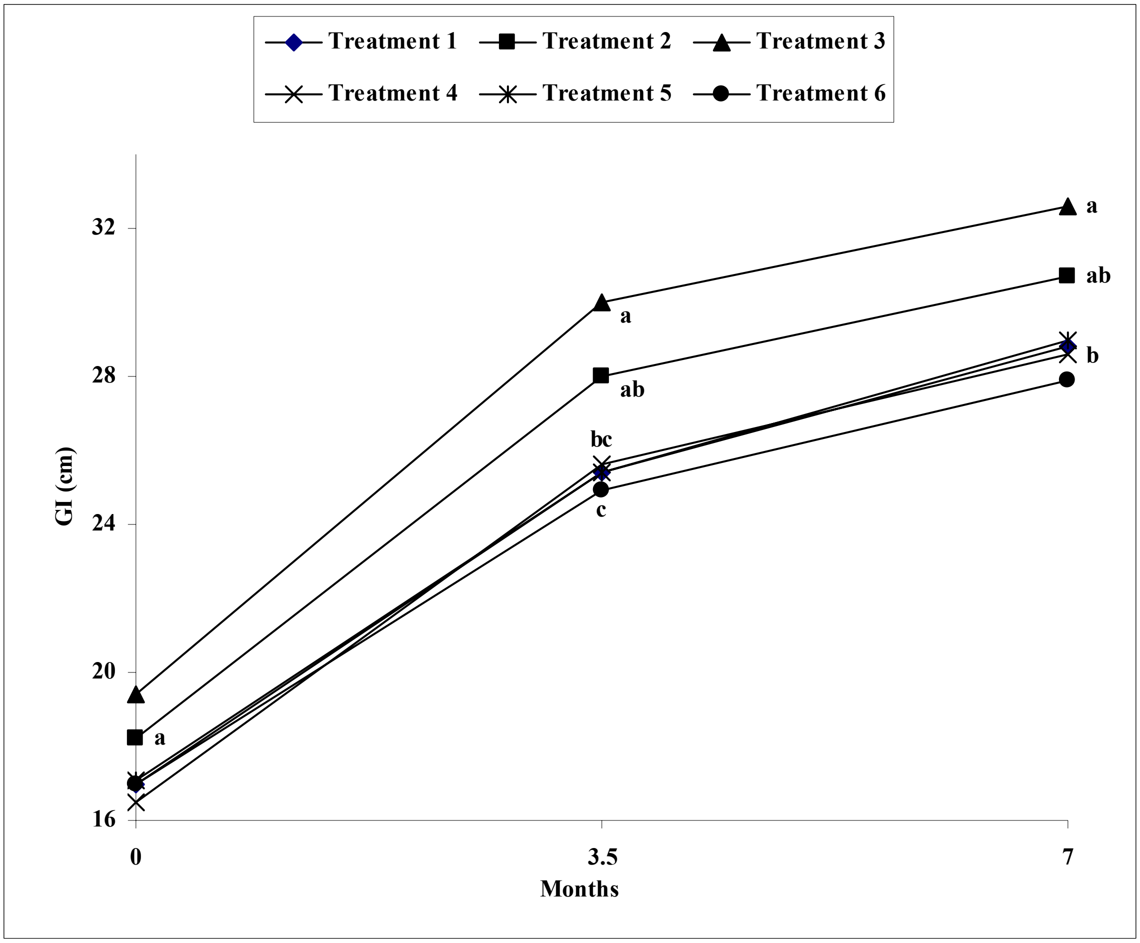

Figure 2. Comparison of media treatments on growth index (GI) of container grown azalea in pine bark over a seven month period.
GI= (height+width+width)/3.
Means with the same letters are not significantly different at ≤0.05 level.
Treatment 1= Sieve #14, 25, <25.
Treatment 2= Sieve #6, 25, <25.
Treatment 3= Sieve #6, 14, <25.
Treatment 4= Sieve #6, 14, 25.
Treatment 5= Sieve #6, 14, 25, <25.
Treatment 6= Commercial available.

Quality Ratings

For quality ratings, bark source and irrigation treatment exhibited a highly significant difference in plant quality. Plants grown in pinebark media produced a higher quality plant than hardwood bark media (Table 1). Pinebark increased quality by over 31% compared to hardwood bark. The visual ratings for hardwood bark were below the commercially acceptable range. Overall plant quality was increased by over 5% in the lower irrigation duration (Table 2). This data is surprising because azaleas are high water requiring plants.

EC and pH

Bark source had a highly significant effect on both pH and EC levels (Table 3). The pH level in hardwood bark was greater than pinebark. EC levels in hardwood bark were 18% higher than pinebark. Irrigation levels were highly significant in affecting EC, but not pH (Table 4). The low irrigation frequency had an EC level that was 48% higher in salts. The EC level in the low irrigation was one and a half times higher than the allowable limit for healthy plant growth. BMP 1997, states that EC levels, for substrates with controlled release fertilizer, should range from 0.2 to 0.5mmhos/cm. Hardwood bark and low irrigation EC levels exceed the upper limit.

Shoot Weights

Bark source had a highly significant effect on shoot dry weight (Table 5). Shoot weights were greater in pinebark than in hardwood bark. Shoot weights were 58% higher for azalea grown in pinebark compared to hardwood bark. Particle size distribution had a significant effect on azalea shoot weights for plants grown in pinebark (Figure 3). Shoot dry weights in media treatment 3 (#6, 14, <25) were 23% greater than

Table 1. Influence of bark source on quality ratings of container grown azalea at the midpoint and termination of the study.

Bark Source	3/24/05	7/5/05
Pine	3.5	3.6
Hardwood	2.4	2.4
Significance	***	***
SE ±	0.05	0.06

Quality rating: 1=dead, 3=commercially acceptable, 5=superior.
Means with *** are very highly significant at the 0.001 level.

Table 2. Influence of irrigation duration on quality ratings of container grown azalea at the midpoint and termination of the study.

Irrigation	3/24/05	7/5/05
High	2.8	2.9
Low	3.1	3.1
Significance	***	**
SE ±	0.05	0.06

Quality rating: 1=dead, 3=commercially acceptable, 5=superior.
Means with ** are highly significant at the 0.01 level.
Means with *** are very highly significant at the 0.001 level.

Table 3. EC and pH for azalea leachate analysis as influenced by bark source.

Bark Source	EC (µmos/cm)	pH
Pine bark	0.45	7.3
Hardwood bark	0.55	7.6
Significance	***	***
SE ±	0.03	0.03

Means with *** are very highly significant at the 0.001 level.

Table 4. EC and pH for azalea leachate analysis as influenced by irrigation treatment.

Irrigation	EC (µmos/cm)	pH
High	0.34	7.5
Low	0.66	7.4
Significance	***	NS
SE ±	0.03	0.03

Means with *** are very highly significant at the 0.001 level.
Means with NS are not significant.

all other media treatments. There was no significant effect in hardwood bark (data not shown). This may be attributed to the overall poor growth of azalea in hardwood bark.

Nutrition

<u>Bark Source</u>

Elemental concentrations indicated significant treatment differences for bark source (Table 6). Pine bark increased the elemental concentrations of P, S, Fe, Mn, Cu, Zn, and Na. Hardwood bark increased the concentrations of Ca and Mg 39 and 35% higher than pine bark, respectively. Bunt (1988), reported that hardwood bark has more Ca than pine bark (about 4%, compared with 0.4% in pine bark). B, Na, and Cu levels were of no significance. The levels of P, Mg, S, Fe, Cu, and Zn fell below the sufficiency range for both media (Mills, 1996). Sodium levels were unavailable for the variety of azalea grown in this study, but comparing to other azaleas Na would most probably have been considered high.

<u>Irrigation</u>

Treatment one, high irrigation, significantly impacted the levels of S, Fe, and Mn in foliar nutrient levels (Table 7). The concentration of S, Fe, and Mn were 13%, 16%, and 20% greater than treatment two, respectively. Magnesium levels were 13% greater in treatment two (lower duration). The levels of S, Mg, and Fe were below the sufficiency level for both irrigation treatments (Mills, 1996).

Table 5. Influence of bark source on the shoot dry weights of azalea at the termination of the study.

Bark Source	Weight (g)
Pine	26.2
Hardwood	11.0
Significance	***
SE ±	1.0

Shoot and leaves were dried at 60ºC for 48 hrs before weighing.
Means with *** are very highly significant at the 0.001 level.

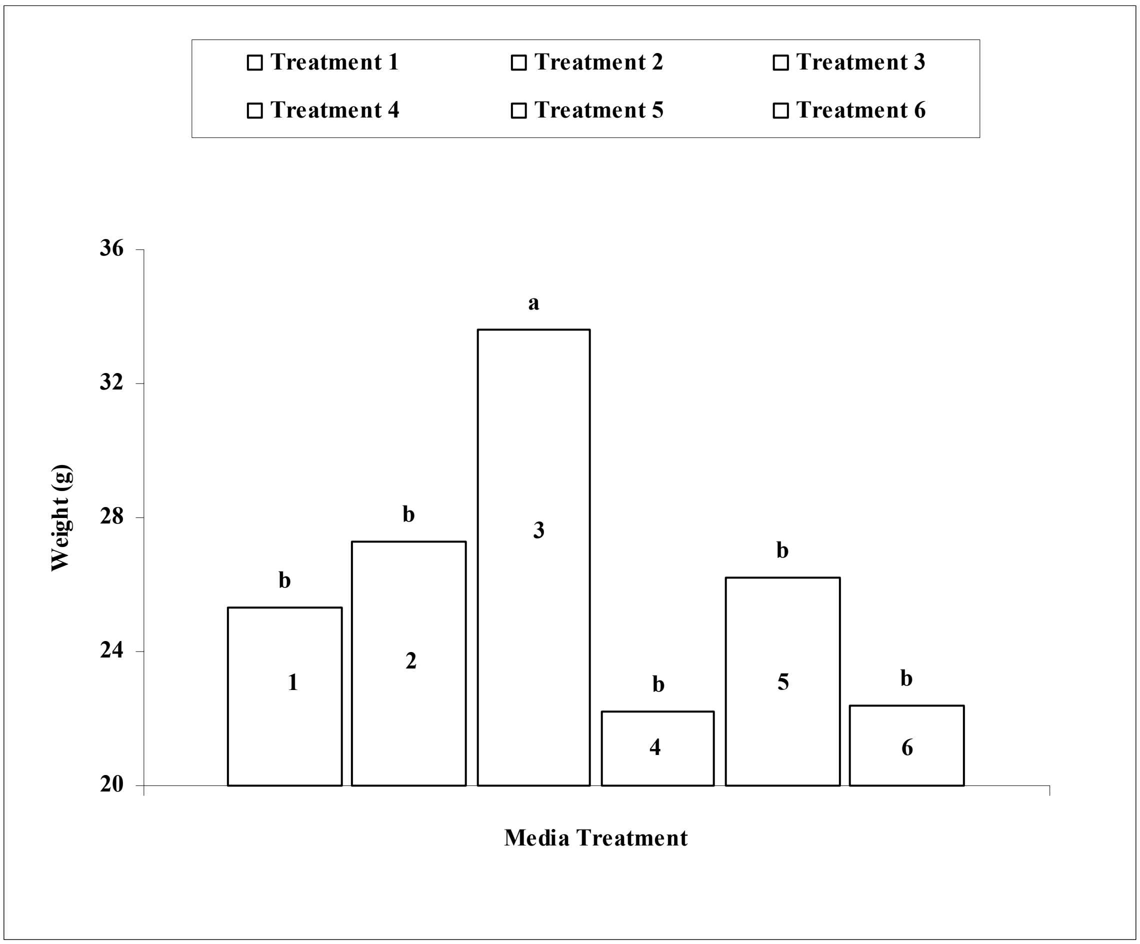

Figure 3. Comparison of media treatments on the shoot dry weights of container grown azalea in pine bark over a seven month period.
Means with the same letters are not significantly different at ≤0.05 level.
Treatment 1= Sieve #14, 25, <25.
Treatment 2= Sieve #6, 25, <25.
Treatment 3= Sieve #6, 14, <25.
Treatment 4= Sieve #6, 14, 25.
Treatment 5= Sieve #6, 14, 25, <25.
Treatment 6= Commercial available.

Table 6. Influence of growing media on azalea foliar nutrient concentrations.

	P	K	Ca	Mg	S	Fe	Mn	B	Cu	Zn	Na
Bark source	······dwt %······					······dwt (ppm)······					
Pine	0.15	1.50	0.42	0.11	0.15	46.87	89.59	83.78	4.34	17.40	7301
Hardwood	0.13	0.99	0.69	0.17	0.13	34.88	49.29	101.1	4.05	11.70	6104
Significance	***	NS	***	***	***	***	***	NS	NS	***	***
SE ±	.003	0.26	0.02	.005	.003	1.6	3.9	5.7	1.0	0.59	161

Means with *** are very highly significant at the 0.001 level.
Means with NS are not significant.

Table 7. Influence of irrigation duration on azalea foliar nutrient concentrations.

	Mg	S	Fe	Mn
Irrigation	(% dwt)		dwt (ppm)	
High	0.13	0.15	44.01	76.19
Low	0.15	0.13	36.85	60.76
Significance	*	**	*	*
SE ±	.005	.003	1.6	3.9

Means with * are significant at the 0.05 level.
Means with ** are highly significant at the 0.01 level.

CHAPTER 3

EVALUATION OF BARK SOURCE, PARTICLE SIZE DISTRIBUTION, AND IRRIGATION EFFECTS ON GROWTH OF CONTAINER PRODUCED INDIAN HAWTHORN (*RHAPEOLEPIS INDICA* 'SNOW')

Introduction

Pinebark is the most common growing media used in Louisiana and southern United States. In contrast, hardwood bark is used across the north, midwest, and western coast. This difference is primarily because of the availability of each bark species to the geographic region. Pokorny et al. (1965) investigated pinebark as a suitable substitute for peat based growing media and found that it contains the same beneficial characteristics. Bark media have been successful in growing woody ornamentals (Gartner et al., 1971; Pokorny, 1965), herbaceous pot plants (Pokorny, 1966), and vegetables (Allaire, 2004). Composted pine bark and hardwood bark have been found to control soil-borne diseases dependent on bark species (Hoitnik, 1980). Use of hardwood bark has been somewhat limited because it is believed to cause phytotoxicity in plants. Gartner et al., (1973) proposed aging the bark for 30 days while keeping it wet with distilled water and turning every day to overcome any deleterious affects to plants. Reese et al. (1979) found that azalea growth in hardwood bark was diminished when compared to a peat-perlite mix, because pH was increased in hardwood bark. Pinebark and hardwood bark pH range from 4.0 to 5.0 and 5.0 to 8.0, respectively. Overall both bark types are used extensively in nursery production for growth in woody ornamentals.

Many of the media used for nursery production vary in their physical and chemical properties. These physical and chemical properties control aeration, water, and nutrient supply to plants, while also providing support. Because growing media are volume based, bulk density is an important physical factor in determining the physical and chemical characteristics of a medium. For optimal growth conditions, Verdonck et al. (1983) stated that aeration porosity should range from 20 to 25% with 20 to 30%

easily available water. Nkongolo and Caron (1999) stated that media physical properties should not be constrained to just measurements of air-filled porosity, water-holding capacity, and bulk density, but included gas exchange characteristics. Their study showed that increasing particle size from 2-4mm to 8-25mm did not change air-filled porosity, but increased pore tortuosity by 1.3 times and decreased gas relative diffusivity.

Particle size distribution has a direct effect on the physical and chemical properties of any medium. Chemically, the smaller the particles the more exchange sites exist for reaction. Daniels and Wright (1988), stated that, unexpectedly, pinebark particles decreasing from <2.38 to <0.05mm only slightly increased CEC, but CEC increased at 20 meq/100 g per pH unit increase. Gartner et al. (1973), established parameters for the percent of particle sizes, based on diameter, allowable in a mix. Their ideal media include: 35% (<1/32 inch), 10% (>1/8 inch), and the rest between and 1/8 and 1/32 of an inch. Different crops require different amounts of water and air for growth, therefore changing the distribution of particles in nursery media per crop is a common occurrence. Richards et al. (1986) found that tomato and *Boronia* required a media with more particles below 10mm and none above 4.75 mm, while just the opposite was true for *Peperomia*. Azalea (*Rhododendron spp.*), *Photinia*, and *Illicium* showed increased rooting and root ball diameter in a double processed pinebark when compared to other pine bark substrates (Bilderback and Lorscheider, 1995). The double processed pine bark had up to 22% less fine particles than the other substrates. Tilt et al. (1987) found that Leyland cypress, azalea, and holly growth were greater when smaller particles were present in the media. They also stated that container size has a large affect on shoot and root growth.

Growers have become increasingly interested in the quality of the media in which their crops are grown. The lack of consistency and uniformity in nursery production media has caused problems in crop quality. Nursery media directly influence both physical and chemical properties. This experiment was designed to investigate the effects of bark source (pine or hardwood), particle size distribution (six treatments), and irrigation frequency (high and low) on the growth and quality of azalea. Pinebark and hardwood bark were sieved in order to separate particles into ranges of small, medium, and large. Four ranges were used to establish six media treatments. Overhead irrigation was applied at two different amounts for plant uptake. The objective of this study was to determine which bark source, media particle size treatment, and irrigation duration would produce the best plant.

Materials and Methods

A one gallon (trade) container production study was conducted at Burden Center in Baton Rouge, LA over a twelve month period. Burden Center is located at latitude 30° 24' 27", longitude 91° 08' 45", and in the USDA Hardiness Zone 8b. Indian hawthorn (*Rhapeolepis indica* 'Snow') plants were grown for nine months from October 2004 to July 2005. Indian hawthorns were started as 3 inch liners.

Media Characteristics and Evaluation

The two different media types, pinebark and hardwood bark, were obtained from Phillips Bark Processing, Brookhaven, MS. Four particle size categorical ranges were chosen for this experiment based on Drzal and Fonteno's (1999) chart of bark particle size distribution. These ranges represent a proportionate distribution of small, medium,

and large particles. The four categories include 3.35mm (#6 sieve), 1.4mm (#14 sieve), 710µm (#25 sieve), and less than 710µm (<#25 sieve).

The sieves were place in descending order on a Ro-Tap® sieve shaker and bark was placed in the upper sieve. The sieve shaker agitated the bark for five minutes to properly separate all the particles. The sieves were separated and its contents poured into a separated container. Media treatments were established by excluding one category from each of the first four mixes. A fifth media treatment was established by combining all four categories. The commercially available mix is an even combination of 5/8 inch and 3/8 inch sieved bark. See Appendix 1 for all media treatments. To ensure proper uniformity all mixes were prepared in a commercial soil mixer for fifteen minutes.

<u>Particle Ranges</u>

Each of the four categories (3.35mm, 1.4mm, 710µm, <710µm) were sieved to determine individual particle ranges (Appendixes 2-5). The following sieves were used to determine particle ranges for each category: 25mm (1 in.), 19mm (3/4 in.), 12.5mm (1/2 in.), 6.3mm (1/4 in.), 4.0mm (#5), 3.35mm (#6), 2.8mm (#7), 1.4mm (#14), 1.0mm (#18), 710µm (#25), 500µm (#35), 355µm (#45), 250µm (#60), 180µm (#80), 125µm (#120). One hundred grams of each category were sieved according to the previous section.

Physical Properties

<u>Bulk Density</u>

Bulk density, the weight of dry substrate per unit volume of substrate, was measured for each categorical range and treatment (Appendixes 6-8). Media, pine and hardwood bark, was dried in a convection oven (VWR-1660) at 60°C for twelve hours.

After drying a 200 ml sample was weighed and recorded. Bulk density was calculated by dividing the weight (g) by 200ml.

Water-Holding Capacity, Total Porosity, and Aeration Porosity

All water-holding capacity, total porosity, and aeration porosity measurements were calculated from techniques described by Spomer (1997). Measurements were taken for each categorical range and treatment (Appendixes 6-8).

Fertility

Both media types and all mixes were given the same fertility treatment. Osmocote® 15 N-9 P_2O_5-12 K_2O (12-14 months) was the main source of nutrition for plant consumption applied at 16.8 lb/yd^3. Dolomitic limestone was applied at a rate of 8.0 lbs/yd^3. The above amendments were incorporated into the media by mixing in a commercial soil mixer for fifteen minutes.

Irrigation

All containerized plants received supplemental irrigation on a daily basis during the nine month growing period. During winter months, when plants were not actively growing, supplemental irrigation was applied every other day. All supplemental irrigation was applied with over-head impact sprinklers on six foot risers. Irrigation cycles or frequencies were scheduled by a Sterling 18 controller and operated by a 24 V solenoid valve. The irrigation frequency consisted of water dispersal twice daily, 6:30am and 4:30pm, respectively. Two irrigation treatments were derived with accordance to Best Management Practices Manuel (BMP), 1997. Optimum watering duration was maintained at an effluent volume of 20 to 40%. Sub-optimum watering duration was maintained at an effluent volume of 10 to 20%. Irrigation volumes were maintained by checking effluent amounts on a bi-weekly basis. Effluent was calculated by dividing the effluent volume by the total irrigation applied. The effluent and irrigation amounts were collected in closed-capture irrigation effluent containers (Appendix 9).

Leachate Collection

At the termination of the study, leachates, solution that drains from container substrate during and after irrigation and may contain nutrients and pesticides from the substrate solution, were collected via a modified Virginia Tech Extraction Method (Wright 1984, 1986). Pots were allowed to drain for one hour after irrigation. After the one hour interval, 300ml of deionized water was poured onto the soil surface flushing the soil water from the pot. This water was collected in a closed-capture irrigation effluent system (Appendix 9), poured into 4 oz. plastic bottles and refrigerated. Leachates were filtered using folded 11cm paper filters (Schleicher & Schuell, Inc., Keene, NH) and analyzed for pH and EC with a dual meter (Model 5800-00, Cole-Palmer Instrument Co., Chicago, IL).

Plant Evaluation

<u>Growth Index</u>

Throughout the nine months of the study, data for growth of each plant were collected to determine how each treatment would affect them. Plant growth was determined by calculating a growth index for each plant throughout the study. Growth measurements were taken on 27 October 2004, 21 January 2005, 13 April 2005, and 15 July 2005. With a metric ruler, height (measured from soil surface to apical meristem) and two widths (perpendicular to each other) were taken to get an overall growth index of the plant. Growth Index was calculated by the following equation: [height (cm) x width (cm) x width (cm)]/ 3.

Quality Ratings

Quality Ratings were taken on 24 March 2005 and 5 July 2005 by three separate individuals. The same individuals performed both ratings. Quality ratings are based on a scale of one to five (1=dead, 3=commercially acceptable, 5=superior).

Shoot Dry Weights

When the study was terminated shoots of each plant were cut at the soil surface and placed into brown paper bags. Shoots and leaves were then dried in a convection oven (VWR-1660) at 60°C for 48 hours. After drying, shoot and leaves were weighed on a Mettler PC 440 scale for a dry weight.

Tissue Analysis

After shoots were weighed some plants were randomly selected for tissue analysis. Leaves of the plants were ground using a 30 mesh sieve and analyzed by the Agricultural Chemistry Department, Baton Rouge, LA for the nutrients P, K, Ca, Mg, S, Fe, Mn, B, Zn, Cu, and Na. These elements were analyzed with the EPA3052 test by microwave assisted acid digestion.

Pest Control

The use of pesticides were limited throughout the study and used on an as needed basis. The application of Mancozeb®, 0.25 oz/gal., was used to control *Cercospora spp.*, leaf spot. The applications of Green Light Neem Concentrate, 1 oz/gal., and Merit®, 0.125 tsp/gal., were used to control aphids.

Experimental Design and Statistical Analysis of Data

Treatments were arranged in a factorial 6x2x2 plot design, with six mixes, two barks, two irrigation frequencies, and six blocks totaling 144 replicates. Treatments were arranged using a randomized complete block design. Growth index, quality ratings, foliar nutrient data, pH, EC, and shoot weights were analyzed using SAS Systems for Windows 9.0 via Proc GLM and Proc Means. Means were separated using the Duncan's Multiple Range Test to compare all pair-wise differences in treatments. For all analysis, a p-value ≤ 0.05 level indicated significance.

Results and Discussion

Plant Growth

Growth index was significantly affected by the bark source and particle size distribution of the growing media. Plants grown in pinebark had a significantly higher growth index compared to hardwood bark (Figure 3). Pinebark media increased plant growth by 11%, 12%, and 13% over hardwood bark media, for the second, third, and final measurement, respectively. Growth index was also significantly affected by particle size distribution in pinebark (Figure 4). Duncan's Multiple Range Test indicated that media treatments 1, 2, 3, and 5, had equal means. These four media treatments increased growth index by 14% over the commercially available mix by the end of the study. The commercially available mix yielded the lowest index for plant growth in pinebark. Particle size distribution had no significant effect on plant growth in hardwood bark (data not shown). This may be attributed to the overall poor growth of plants in the hardwood bark source.

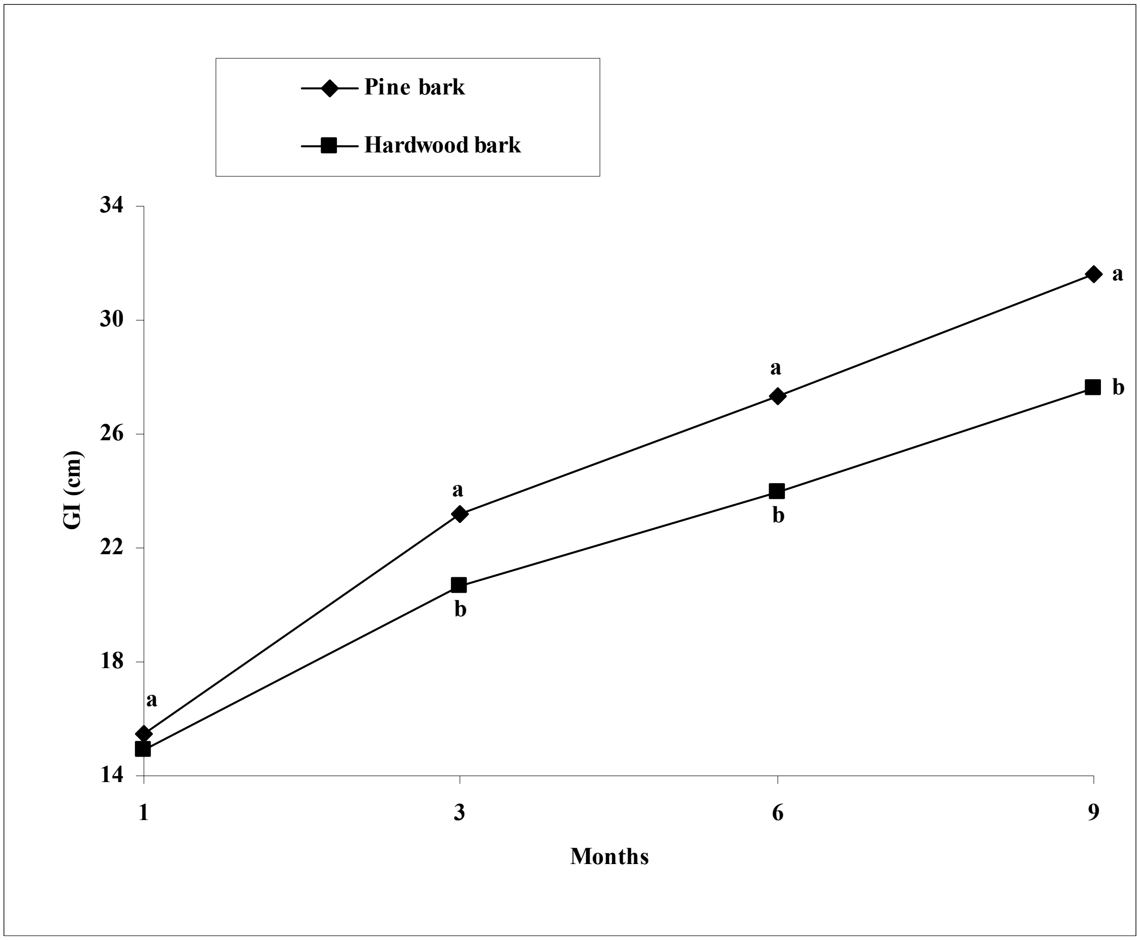

Figure 4. Comparison of pinebark and hardwood bark on growth index (GI) of container grown Indian hawthorn over a nine month period.
GI= (height+width+width)/3.
Means with the same letters are not significantly different at ≤0.05 level.

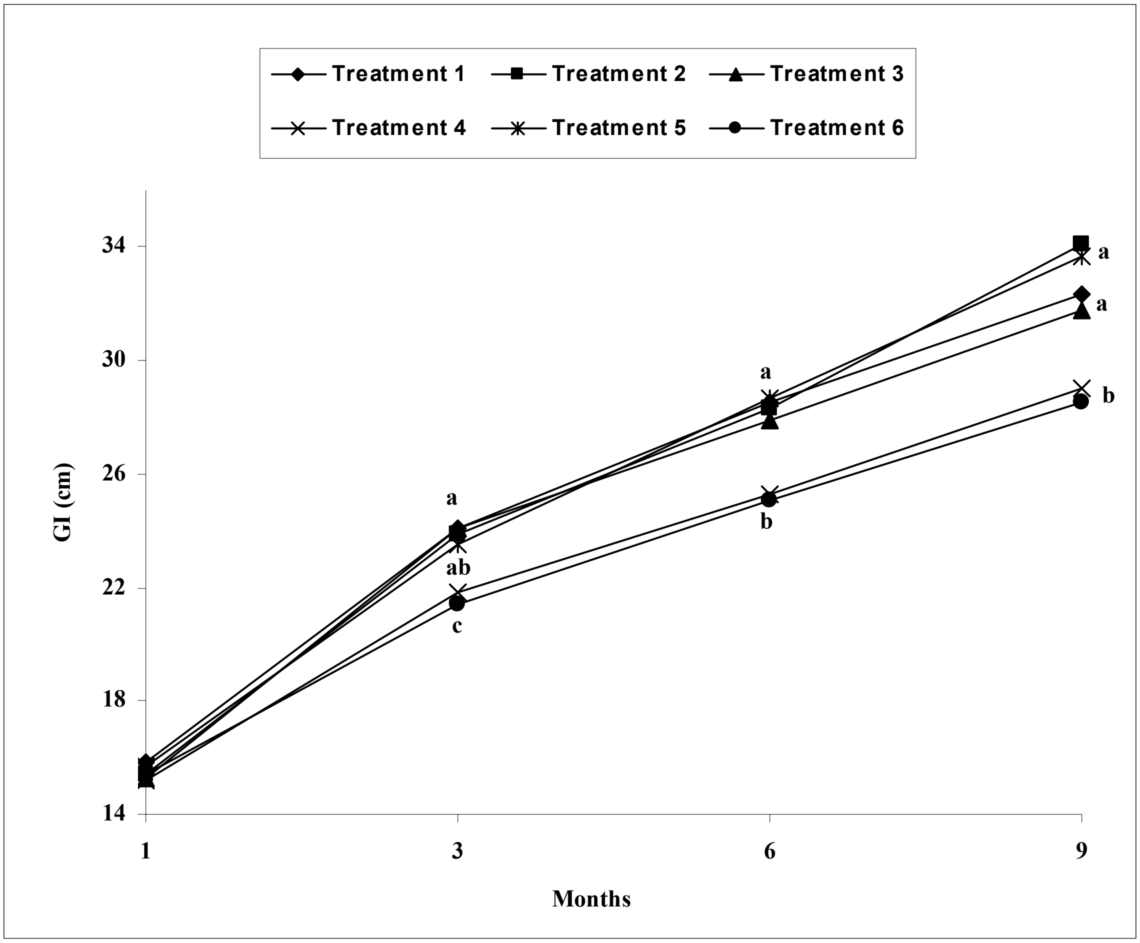

Figure 5. Comparison of media treatments on growth index (GI) of container grown Indian hawthorn in pinebark over a nine month period.
GI= (height+width+width)/3.
Means with the same letters are not significantly different at ≤0.05 level.
Treatment 1= Sieve #14, 25, <25.
Treatment 2= Sieve #6, 25, <25.
Treatment 3= Sieve #6, 14, <25.
Treatment 4= Sieve #6, 14, 25.
Treatment 5= Sieve #6, 14, 25, <25.
Treatment 6= Commercial available.

Quality Ratings

For quality ratings, bark source and particle size distribution exhibited a highly significant difference in plant quality. Plants grown in pinebark media produced a higher quality plant than hardwood bark media (Table 8). Plant quality was above the commercially acceptable range for both bark sources. Particle size distribution had a significant effect on quality ratings (Table 9). The Duncan's Multiple Range test indicates that media treatments 1, 2, 3, and 5 were statistically similar. As previously noticed in growth index, the commercially available media treatment rated the poorest.

EC and pH

Bark source had a highly significant effect on both pH and EC levels (Table 10). The pH level in hardwood bark was greater than pinebark. EC levels in hardwood bark were 16% higher than pinebark. Irrigation levels were highly significant in affecting pH and EC levels (Table 11). The low irrigation duration had an EC level that was 18% higher in salts. The high irrigation duration produced lower pH levels than the low irrigation duration. EC levels, for bark and irrigation, were in the acceptable range set forth by BMP (1997).

Shoot Weights

Bark source had a highly significant effect on shoot dry weight. Shoot weights were greater in pinebark than in hardwood bark (Table 12). Shoot weights were 27% higher for Indian hawthorn grown in pinebark compared to hardwood bark. Particle size distribution had a significant effect on Indian hawthorn shoot dry weights for plants grown in pinebark (Figure 5). Shoot dry weights in media treatment 2 (#6, 25, <25) were 24% greater than all other media treatments. There was no significant effect in hardwood

Table 8. Influence of bark source on quality ratings of container grown Indian hawthorn at the midpoint and termination of the study.

Bark Source	3/24/05	7/5/05
Pine	3.5	3.7
Hardwood	3.0	3.0
Significance	***	***
SE ±	0.04	0.05

Quality rating: 1=dead, 3=commercially acceptable, 5=superior.
Means with *** are very highly significant at the 0.001 level.

Table 9. Influence of media treatment on quality ratings of container grown Indian hawthorn at the midpoint and termination of the study.

Treatment	3/24/05	7/5/05
(#14, 25, <25)	3.5ab	3.7a
(#6, 25, <25)	3.7a	4.0a
(#6, 14, <25)	3.7a	3.9a
(#6, 14, 25)	3.2b	3.3b
Control (all sieve size)	3.6a	3.9a
Commercially available	3.2b	3.2b
Significance	*	***
SE ±	0.04	0.05

Quality rating: 1=dead, 3=commercially acceptable, 5=superior.
Means with * are significant at the 0.05 level.
Means with *** are very highly significant at the 0.001 level.

Table 10. EC and pH for Indian hawthorn leachate analysis as influenced by bark source.

Bark Source	EC (μmos/cm)	pH
Pine	0.37	7.4
Hardwood	0.44	7.6
Significance	***	***
SE ±	0.02	0.02

Means with *** are very highly significant at the 0.001 level.

Table 11. EC and pH for Indian hawthorn leachate analysis as influenced by irrigation treatment.

Irrigation	EC (μmos/cm)	pH
High	0.37	7.4
Low	0.45	7.6
Significance	*	***
SE ±	0.02	0.02

Means with * are significant at the 0.05 level.
Means with *** are very highly significant at the 0.001 level.

bark (data not shown). This may be attributed to the overall poor growth of Indian hawthorn in hardwood bark.

Nutrition

Bark Source

Elemental concentrations indicated a significant treatment differences for bark source (Table 13). Pine bark increased elemental concentrations of S, Fe, Mn, Cu, Zn, and Na. Hardwood bark produced levels of Ca and B that were 33 and 42% higher than pine bark, respectively. Bunt (1988) reported that hardwood bark has more Ca than pine bark (about 4%, compared with 0.4% in pine bark). P, K, and Mg levels were of no significance. The concentration levels of Ca and Mn were below the survey average for both media (Mills, 1996). Sodium levels were 26.5 and 23.5 times higher than the survey average for pine bark and hardwood bark, respectively (Mills, 1996).

Irrigation

Several of the element's concentrations were significantly impacted by the irrigation treatment applied (Table 14). Treatment one, high irrigation, increased elemental levels as high as 39% in Mn and as low as 4% in Mg over hardwood bark. The levels of B and Na were greater in irrigation treatment two, low irrigation. Na levels were extremely high, especially in irrigation treatment two. This may suggest that the low irrigation volume did not leach enough salts out of solution.

Table 12. Influence of bark source on the shoot dry weights of Indian hawthorn at the termination of the study.

Bark Source	Weight (g)
Pine	67.1
Hardwood	49.1
Significance	***
SE ±	1.8

Shoot and leaves were dried at 60ºC for 48 hrs before weighing.
Means with *** are very highly significant at the 0.001 level.

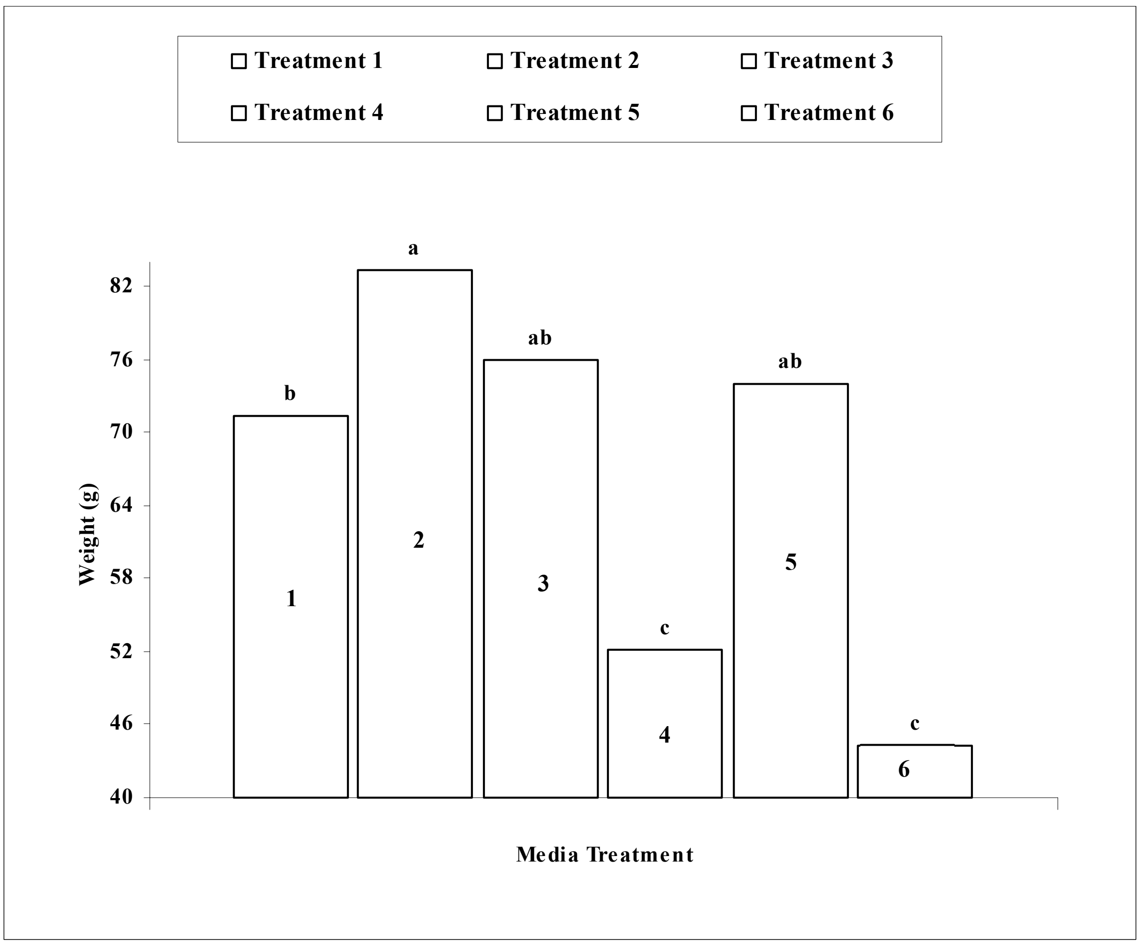

Figure 6. Comparison of media treatments on the shoot dry weights of container grown Indian hawthorn in pinebark over a nine month period.
Means with the same letters are not significantly different at ≤0.05 level.
Treatment 1= Sieve #14, 25, <25.
Treatment 2= Sieve #6, 25, <25.
Treatment 3= Sieve #6, 14, <25.
Treatment 4= Sieve #6, 14, 25.
Treatment 5= Sieve #6, 14, 25, <25.
Treatment 6= Commercial available.

Table 13. Influence of growing media on Indian hawthorn foliar nutrient concentrations.

	P	K	Ca	Mg	S	Fe	Mn	B	Cu	Zn	Na
Bark source	······················% dwt·······················					·······························dwt (ppm)···························					
Pine	0.21	1.32	1.00	0.23	0.12	47.47	77.03	51.99	6.38	49.51	4241
Hardwood	0.20	1.16	1.50	0.21	0.11	30.42	40.26	91.65	4.99	39.00	2736
Significance	NS	NS	***	NS	***	***	***	**	***	**	***
SE ±	.006	0.05	0.05	.004	.002	2.0	4.8	6.2	0.19	1.8	189

Means with ** are highly significant at the 0.01 level.
Means with *** are very highly significant at the 0.001 level.
Means with NS are not significant.

Table 14. Influence of irrigation duration on Indian hawthorn foliar nutrient concentrations.

	P	K	Ca	Mg	S	Fe	Mn	B	Cu	Zn	Na
Irrigation	······················% dwt·······················					·······························dwt (ppm)···························					
High	0.22	1.40	1.30	2.31	0.12	45.60	76.40	67.10	6.01	49.60	2867
Low	0.19	1.10	1.20	2.22	0.11	34.52	46.40	73.90	5.50	40.60	4025
Significance	***	**	NS	NS	***	***	***	NS	NS	*	***
SE ±	.006	0.05	0.05	.004	.002	2.0	4.8	6.2	0.19	1.8	189

Means with * are significant at the 0.05 level.
Means with ** are highly significant at the 0.01 level.
Means with *** are very highly significant at the 0.001 level.
Means with NS are not significant.

CHAPTER 4

EVALUATION OF BARK SOURCE, PARTICLE SIZE DISTRIBUTION, AND IRRIGATION EFFECTS ON GROWTH OF CONTAINER PRODUCED LIGUSTRUM (*LIGUSTRUM JAPONICUM*)

Introduction

Pinebark is the most common growing media used in Louisiana and southern United States. In contrast, hardwood bark is used across the north, midwest, and western coast. This difference is primarily because of the availability of each bark species to the geographic region. Pokorny et al. (1965) investigated pinebark as a suitable substitute for peat based growing media and found that it contains the same beneficial characteristics. Bark media have been successful in growing woody ornamentals (Gartner et al., 1971; Pokorny, 1965), herbaceous pot plants (Pokorny, 1966), and vegetables (Allaire, 2004). Composted pine bark and hardwood bark have been found to control soil-borne diseases dependent on bark species (Hoitnik, 1980). Use of hardwood bark has been somewhat limited because it is believed to cause phytotoxicity in plants. Gartner et al., (1973) proposed aging the bark for 30 days while keeping it wet with distilled water and turning every day to overcome any deleterious affects to plants. Reese et al. (1979) found that azalea growth in hardwood bark was diminished when compared to a peat-perlite mix, because pH was increased in hardwood bark. Pinebark and hardwood bark pH range from 4.0 to 5.0 and 5.0 to 8.0, respectively. Overall both bark types are used extensively in nursery production for growth in woody ornamentals.

Many of the media used for nursery production vary in their physical and chemical properties. These physical and chemical properties control aeration, water, and nutrient supply to plants, while also providing support. Because growing media are volume based, bulk density is an important physical factor in determining the physical and chemical characteristics of a medium. For optimal growth conditions, Verdonck et al. (1983) stated that aeration porosity should range from 20 to 25% with 20 to 30%

easily available water. Nkongolo and Caron (1999) stated that media physical properties should not be constrained to just measurements of air-filled porosity, water-holding capacity, and bulk density, but included gas exchange characteristics. Their study showed that increasing particle size from 2-4mm to 8-25mm did not change air-filled porosity, but increased pore tortuosity by 1.3 times and decreased gas relative diffusivity.

Particle size distribution has a direct effect on the physical and chemical properties of any medium. Chemically, the smaller the particles the more exchange sites exist for reaction. Daniels and Wright (1988), stated that, unexpectedly, pinebark particles decreasing from <2.38 to <0.05mm only slightly increased CEC, but CEC increased at 20 meq/100 g per pH unit increase. Gartner et al. (1973), established parameters for the percent of particle sizes, based on diameter, allowable in a mix. Their ideal media include: 35% (<1/32 inch), 10% (>1/8 inch), and the rest between and 1/8 and 1/32 of an inch. Different crops require different amounts of water and air for growth, therefore changing the distribution of particles in nursery media per crop is a common occurrence. Richards et al. (1986) found that tomato and *Boronia* required a media with more particles below 10mm and none above 4.75 mm, while just the opposite was true for *Peperomia*. Azalea (*Rhododendron spp.*), *Photinia*, and *Illicium* showed increased rooting and root ball diameter in a double processed pinebark when compared to other pine bark substrates (Bilderback and Lorscheider, 1995). The double processed pine bark had up to 22% less fine particles than the other substrates. Tilt et al. (1987) found that Leyland cypress, azalea, and holly growth were greater when smaller particles were present in the media. They also stated that container size has a large affect on shoot and root growth.

Growers have become increasingly interested in the quality of the media in which their crops are grown. The lack of consistency and uniformity in nursery production media has caused problems in crop quality. Nursery media directly influence both physical and chemical properties. This experiment was designed to investigate the effects of bark source (pine or hardwood), particle size distribution (six treatments), and irrigation frequency (high and low) on the growth and quality of azalea. Pinebark and hardwood bark were sieved in order to separate particles into ranges of small, medium, and large. Four ranges were used to establish six media treatments. Overhead irrigation was applied at two different amounts for plant uptake. The objective of this study was to determine which bark source, media particle size treatment, and irrigation duration would produce the best plant.

Materials and Methods

A one gallon (trade) container production study was conducted at Burden Center in Baton Rouge, LA over a twelve month period. Burden Center is located at latitude 30° 24' 27", longitude 91° 08' 45", and in the USDA hardiness zone 8b. Ligustrum (*Ligustrum japonicum*) plants were grown for nine months from October 2004 to July 2005. Ligustrum were started as 3 inch liners.

Media Characteristics and Evaluation

The two different media types, pinebark and hardwood bark, were obtained from Phillips Bark Processing, Brookhaven, MS. Four particle size categorical ranges were chosen for this experiment based on Drzal and Fonteno's (1999) chart of bark particle size distribution. These ranges represent a proportionate distribution of small, medium,

and large particles. The four categories include 3.35mm (#6 sieve), 1.4mm (#14 sieve), 710µm (#25 sieve), and less than 710µm (<#25 sieve).

The sieves were place in descending order on a Ro-Tap® sieve shaker and bark was placed in the upper sieve. The sieve shaker agitated the bark for five minutes to properly separate all the particles. The sieves were separated and its contents poured into a separated container. Media treatments were established by excluding one category from each of the first four mixes. A fifth media treatment was established by combining all four categories. The commercially acceptable mix is an even combination of 5/8 inch and 3/8 inch sieved bark. See Appendix 1 for all media treatments. To ensure proper uniformity all mixes were prepared in a commercial soil mixer for fifteen minutes.

<u>Particle Ranges</u>

Each of the four categories (3.35mm, 1.4mm, 710µm, <710µm) were sieved to determine individual particle ranges (Appendix 2-5). The following sieves were used to determine particle ranges for each category: 25mm (1 in.), 19mm (3/4 in.), 12.5mm (1/2 in.), 6.3mm (1/4 in.), 4.0mm (#5), 3.35mm (#6), 2.8mm (#7), 1.4mm (#14), 1.0mm (#18), 710µm (#25), 500µm (#35), 355µm (#45), 250µm (#60), 180µm (#80), 125µm (#120). One hundred grams of each category were sieved according to the previous section.

Physical Properties

<u>Bulk Density</u>

Bulk density, the weight of dry substrate per unit volume of substrate, was measured for each categorical range and treatment (Appendixes 6-8). Media, pine and hardwood bark, was dried in a convection oven (VWR-1660) at 60^{o}C for twelve hours.

After drying a 200 ml sample was weighed and recorded. Bulk density was calculated by dividing the weight (g) by 200ml.

Water-Holding Capacity, Total Porosity, and Aeration Porosity

All water-holding capacity, total porosity, and aeration porosity measurements were calculated from techniques described by Spomer (1997). Measurements were taken for each categorical range and treatment (Appendix 6-8).

Fertility

Both media types and all mixes were given the same fertility treatment. Osmocote® 15 N-9 P_2O_5-12 K_2O (12-14 months) was the main source of nutrition for plant consumption applied at 16.8 lbs/yd^3. Dolomitic limestone was applied at a rate of 8.0 lbs/yd^3. The above amendments were incorporated into the media by mixing in a commercial soil mixer for fifteen minutes.

Irrigation

All containerized plants received supplemental irrigation on a daily basis during the nine month growing period. During winter months, when plants were not actively growing, supplemental irrigation was applied every other day. All supplemental irrigation was applied with over-head impact sprinklers on six foot risers. Irrigation cycles or frequencies were scheduled by a Sterling 18 controller and operated by a 24 V solenoid valve. The irrigation frequency consisted of water dispersal twice daily, 6:30am and 4:30pm, respectively. Two irrigation treatments were derived with accordance to Best Management Practices Manuel (BMP), 1997. Optimum watering duration was maintained at an effluent volume of 20 to 40%. Sub-optimum watering duration was maintained at an effluent volume of 10 to 20%. Irrigation volumes were maintained by checking effluent amounts on a bi-weekly basis. Effluent was calculated by dividing the effluent volume by the total irrigation applied. The effluent and irrigation amounts were collected in closed-capture irrigation effluent containers (Appendix 9).

Leachate Collection

At the termination of the study, leachates, solution that drains from container substrate during and after irrigation and may contain nutrients and pesticides from the substrate solution, were collected via a modified Virginia Tech Extraction Method (Wright 1984, 1986). Pots were allowed to drain for one hour after irrigation. After the one hour interval, 300ml of deionized water was poured onto the soil surface flushing the soil water from the pot. This water was collected in a closed-capture irrigation effluent system (Appendix 9), poured into 4 oz. plastic bottles and refrigerated. Leachates were filtered using folded 11cm paper filters (Schleicher & Schuell, Inc., Keene, NH) and analyzed for pH and EC with a dual meter (Model 5800-00, Cole-Palmer Instrument Co., Chicago, IL).

Plant Evaluation

<u>Growth Index</u>

Throughout the nine months of the study, data for growth of each plant were collected to determine how each treatment would affect them. Plant growth was determined by calculating a growth index for each plant throughout the study. Growth measurements were taken on 27 October 2004, 21 January 2005, 13 April 2005, and 15 July 2005. With a metric ruler, height (measured from soil surface to apical meristem) and two widths (perpendicular to each other) were taken to get an overall growth index of the plant. Growth Index is calculated by the following equation: [height (cm) x width (cm) x width (cm)]/ 3.

<u>Quality Ratings</u>

Quality Ratings were taken on 24 March 2005 and 5 July 2005 by three separate individuals. The same individuals performed both ratings. Quality ratings are based on a scale of one to five (1=dead, 3=commercially acceptable, 5=superior).

<u>Shoot Dry Weights</u>

When the study was terminated shoots of each plant were cut at the soil surface and placed into brown paper bags. Shoots and leaves were then dried in a convection oven (VWR-1660) at $60^{o}C$ for 48 hours. After drying, shoot and leaves were weighed on a Mettler PC 440 scale for a dry weight.

<u>Tissue Analysis</u>

After shoots were weighed some plants were randomly selected for tissue analysis. Leaves of the plants were ground using a 30 mesh sieve and analyzed by the Agricultural Chemistry Department, Baton Rouge, LA for the nutrients P, K, Ca, Mg, S, Fe, Mn, B, Zn, Cu, and Na. These elements were analyzed with the EPA3052 test by microwave assisted acid digestion.

Pest Control

The use of pesticides were limited throughout the study and used on an as needed basis. The application of Mancozeb®, 0.25 oz/gal., was used to control *Cercospora spp.*, leaf spot. The applications of Green Light Neem Concentrate, 1 oz/gal., and Merit®, 0.125 tsp/gal., were used to control aphids.

Experimental Design and Statistical Analysis of Data

Treatments were arranged in a factorial 6x2x2 plot design, with six mixes, two barks, two irrigation frequencies, and six blocks totaling 144 replicates. Treatments were arranged using a randomized complete block design. Growth index, quality ratings, foliar nutrient data, pH, EC, and shoot weights were analyzed using SAS Systems for Windows 9.0 via Proc GLM and Proc Means. Means were separated using the Duncan's Multiple Range Test to compare all pair-wise differences in treatments. For all analysis, a p-value ≤ 0.05 level indicated significance.

Results and Discussion

Plant Growth

Growth index was significantly affected by the bark source and particle size distribution of the growing media. Plants grown in pinebark had a significantly higher growth index compared to hardwood bark (Figure 5). Pinebark media increased plant growth by 16%, 31%, and 39% over hardwood bark media, for the second, third, and final measurement, respectively. Growth index was also affected by particle size distribution in pinebark (Figure 6). Media treatment 2 (#6, 25, <25) yielded the greatest growth index over all other treatments by the end of the study. Media treatment six, commercially acceptable, had the lowest mean index for plant growth in pinebark. Particle size distribution had no significant effect on plant growth in hardwood bark (data not shown). This may be attributed to the overall poor growth of plants in hardwood bark source.

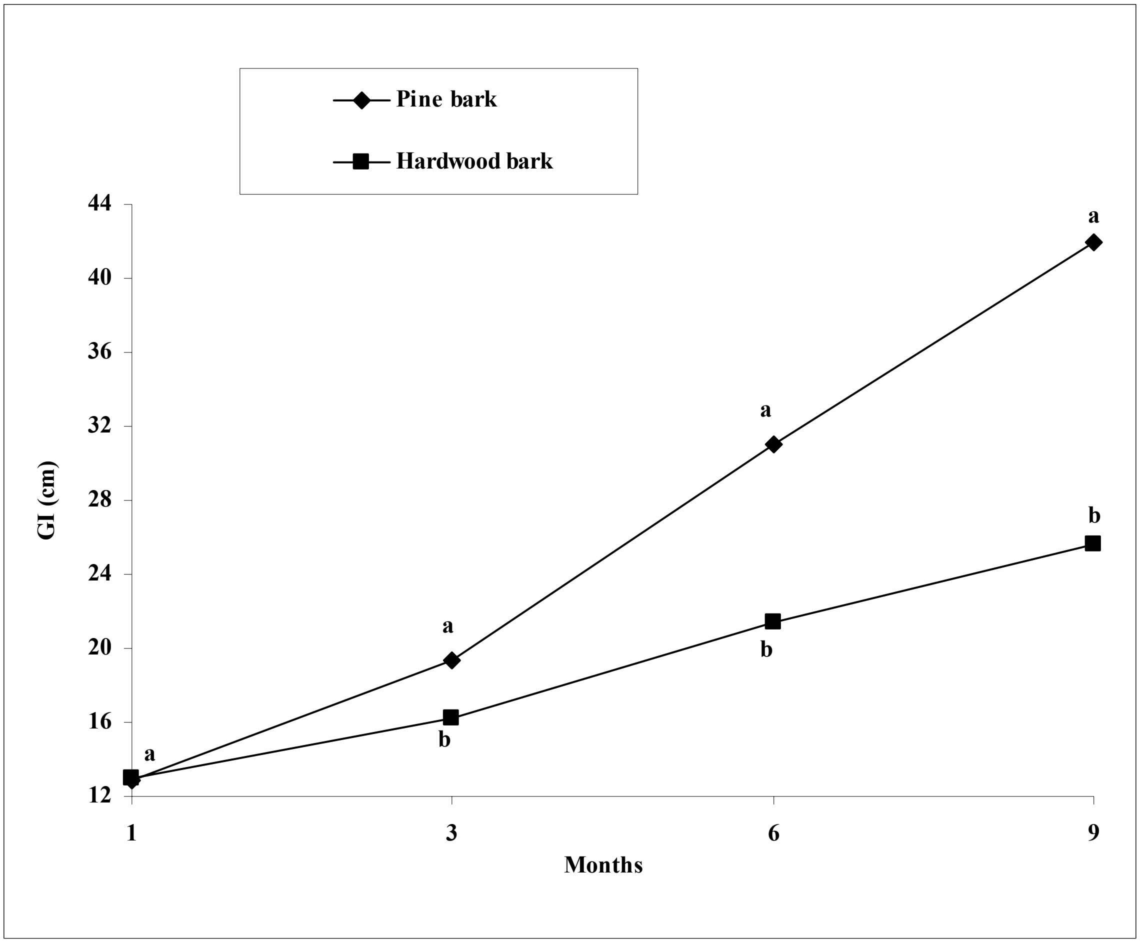

Figure 7. Comparison of bark media on growth index (GI) of container grown ligustrum over nine months.
GI= (height+width+width)/3.
Means with the same letters are not significantly different at ≤0.05 level.

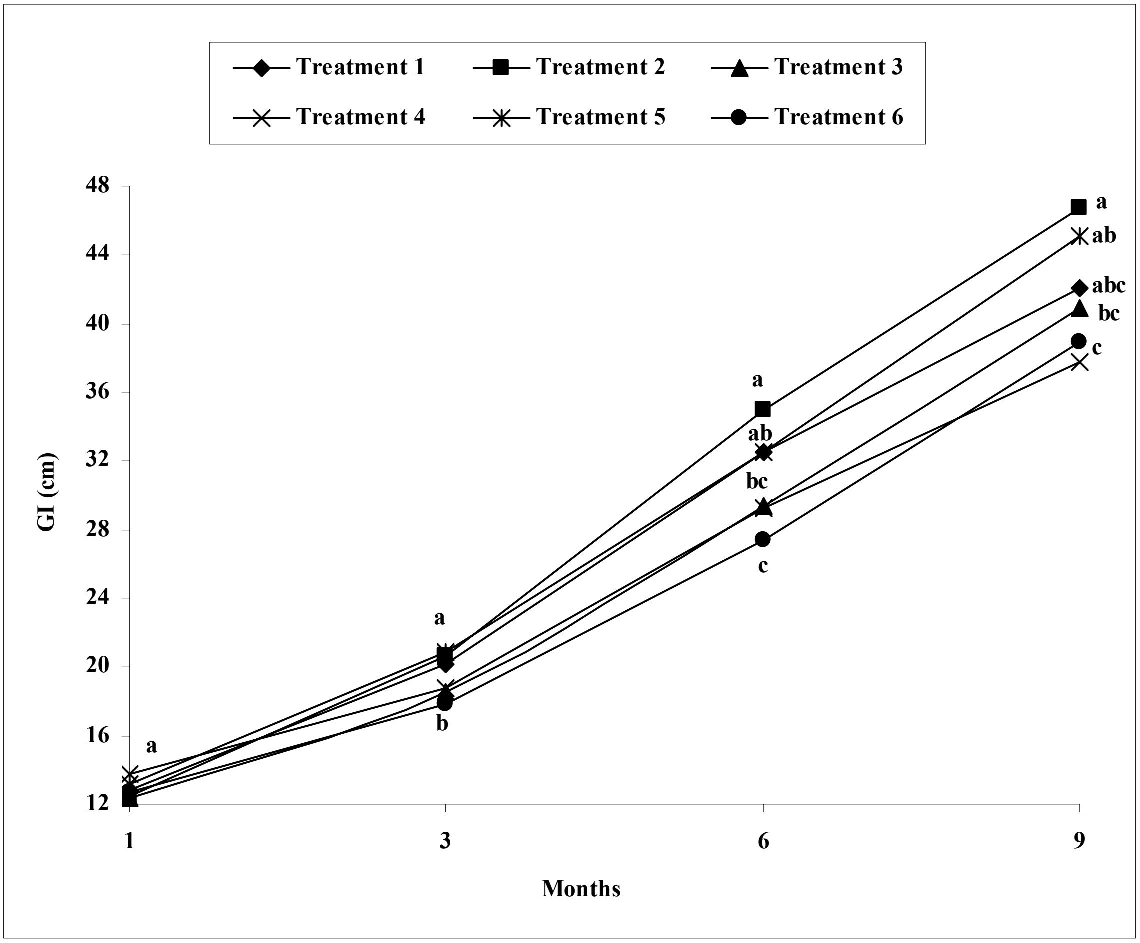

Figure 8. Comparison of media treatments on growth index (GI) of container grown ligustrum in pine bark over seven months.
GI= (height+width+width)/3.
Means with the same letters are not significantly different at ≤0.05 level.
Treatment 1= Sieve #14, 25, <25.
Treatment 2= Sieve #6, 25, <25.
Treatment 3= Sieve #6, 14, <25.
Treatment 4= Sieve #6, 14, 25.
Treatment 5= Sieve #6, 14, 25, <25.
Treatment 6= Commercial available.

Quality Ratings

For quality ratings, bark source exhibited a highly significant difference in plant quality. Plants grown in pinebark media produced a higher quality plant than hardwood bark media (Table 15). Pinebark increased plant quality by over 33% compared to hardwood bark. Hardwood bark ratings were below the commercially acceptable range.

EC and pH

Bark source had a highly significant effect on both pH and EC levels (Table 16). The pH level in hardwood bark was greater than pinebark. EC levels in hardwood bark were 14% higher than pine bark. Irrigation levels were shown to be highly significant in affecting pH and EC levels (Table 17). The low irrigation duration had an EC level that was 18% higher in salts. The high irrigation duration produced lower pH levels than the low irrigation duration. EC levels, for bark and irrigation, were in the acceptable range set forth by BMP (1997).

Shoot Weights

Bark source had a highly significant effect on shoot dry weight. Shoot weights were greater in pinebark than in hardwood bark (Table 18). Shoot weights were 3.5 times greater for Ligustrum grown in pinebark compared to hardwood bark. Particle size distribution had a significant effect on Ligustrum shoot weights for plants grown in pinebark (Figure 9). Shoot dry weights in media treatment 2 (#6, 25, <25) were 12% greater than all other media treatments. There was no significant effect in hardwood bark (data not shown). This may be attributed to the overall poor growth of ligustrum in hardwood bark.

Table 15. Influence of bark source on quality ratings of container grown ligustrum at the midpoint and termination of the study.

Bark Source	3/24/05	7/5/05
Pine	3.5	3.7
Hardwood	2.4	2.4
Significance	***	***
SE ±	0.06	0.07

Quality rating: 1=dead, 3=commercially acceptable, 5=superior.
Means with *** are very highly significant at the 0.001 level.

Table 16. EC and pH for ligustrum leachate analysis as influenced by bark source.

Bark Source	EC (µmos/cm)	pH
Pine	0.37	7.4
Hardwood	0.44	7.6
Significance	***	***
SE ±	0.02	0.02

Means with *** are very highly significant at the 0.001 level.

Table 17. EC and pH for ligustrum leachate analysis as influenced by irrigation treatment.

Irrigation	EC (µmos/cm)	pH
High	0.37	7.4
Low	0.45	7.6
Significance	*	***
SE ±	0.02	0.02

Means with * are significant at the 0.05 level.
Means with *** are very highly significant at the 0.001 level.

Table 18. Influence of bark source on the shoot dry weights of ligustrum at the termination of the study.

Bark Source	Weight (g)
Pine	56.0
Hardwood	15.7
Significance	***
SE ±	2.3

Shoot and leaves were dried at 60ºC for 48 hrs before weighing.
Means with *** are very highly significant at the 0.001 level.

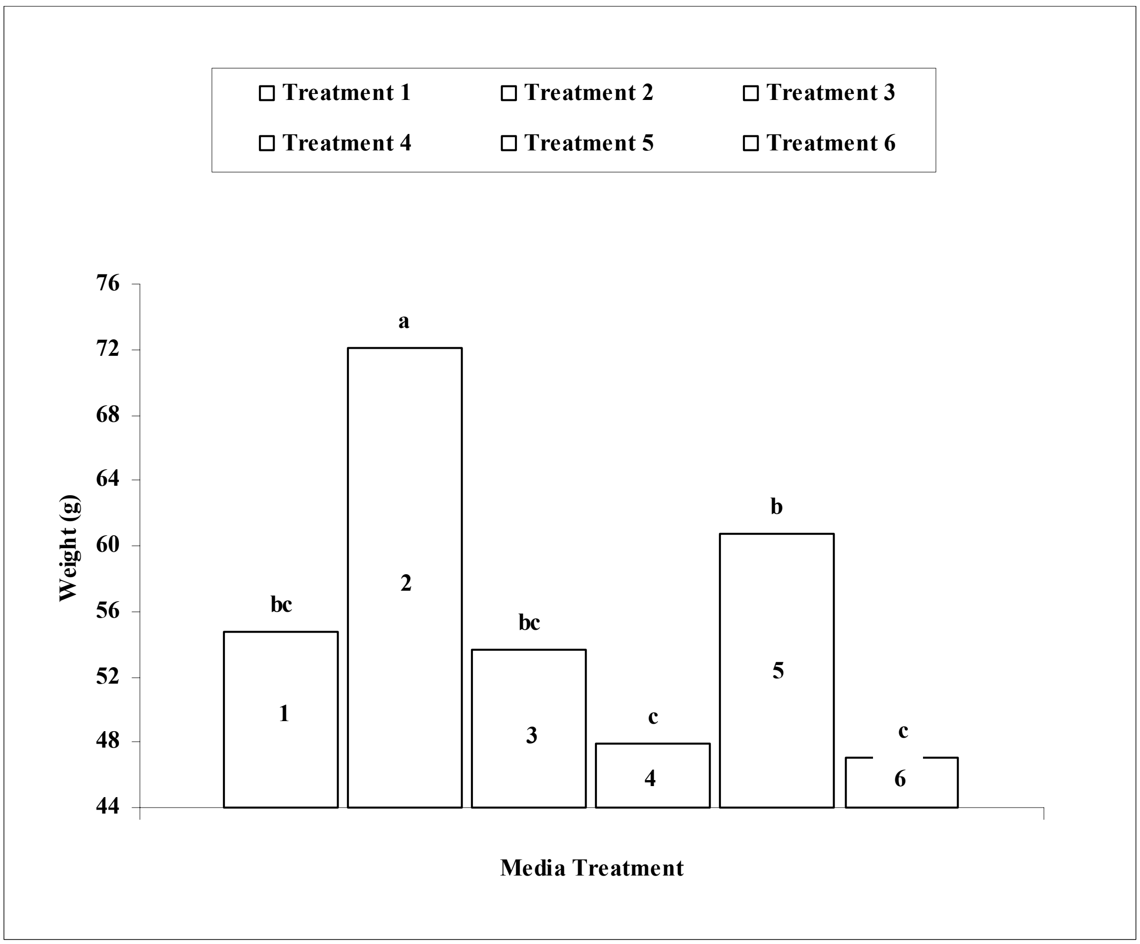

Figure 9. Comparison of media treatments on the shoot dry weights of container grown ligustrum in pinebark over a nine month period.
Means with the same letters are not significantly different at ≤0.05 level.
Treatment 1= Sieve #14, 25, <25.
Treatment 2= Sieve #6, 25, <25.
Treatment 3= Sieve #6, 14, <25.
Treatment 4= Sieve #6, 14, 25.
Treatment 5= Sieve #6, 14, 25, <25.
Treatment 6= Commercial available.

Nutrition

Elemental concentrations indicated a significant treatment difference for bark source (Table 19). Hardwood bark increased elemental concentrations of P, Ca, Mg, S, B, Zn, and Na. Pinebark produced Mn concentrations that were 25% higher than hardwood bark. K, Fe, and Cu levels were of no significance. The levels of Mg and S were slightly below the survey average, while Fe was extremely deficient in both media. Mn levels were below the survey average for hardwood bark (Mills, 1996). Sodium levels were 14 and 18 times greater than the upper limit of the survey range for pinebark and hardwood bark.

Table 19. Influence of growing media on Ligustrum foliar nutrient levels.

	P	K	Ca	Mg	S	Fe	Mn	B	Cu	Zn	Na
Bark source	·····················% dwt·······················					······························dwt (ppm)····························					
Pine	0.13	1.40	0.37	0.07	0.09	32.71	106.4	35.84	4.42	30.10	3875
Hardwood	0.24	1.78	0.86	0.10	0.13	26.06	80.22	84.95	4.43	36.03	4801
Significance	***	NS	***	**	***	NS	*	***	NS	*	**
SE ±	0.01	0.19	0.04	.004	.003	1.7	5.9	6.2	0.22	1.4	154

Means with * are significant at 0.05 level.
Means with ** are highly significant at 0.01 level.
Means with *** are very highly significant at 0.001 level.
Means with NS are not significant.

CHAPTER 5

CONCLUSIONS

Bark source, particle size distribution, and irrigation frequency play an integral part in the overall success of plant growth in containerized nursery production. These factors directly control air, water, and nutrient availability. Our study suggested that bark source and particle size distribution effected the growth and quality of three woody ornamental shrub species. Irrigation frequency affected the EC and pH values of each growing medium.

In azalea production, pinebark yielded superior results. Pinebark increased plant growth index and quality ratings, while producing greater shoot dry weights when compared to hardwood bark. Pinebark also lowered the EC and pH values compared to hardwood bark. Particle size distribution significantly affected the growth of container-grown azaleas. Media treatment 3 (#6, 14, <25) produced the highest growth index and shoot dry weights for azaleas. This would suggest that azaleas may grow best without certain medium to small particles. Irrigation treatment 2 (low) produced EC and pH units above the acceptable limit for proper growth. Nutrient analysis indicated that pinebark increased elemental levels in all nutrients other than Ca and Mg.

In Indian hawthorn production, pinebark yielded superior results. Pinebark increased plant growth index and quality ratings, while producing greater shoot dry weights when compared to hardwood bark. Pinebark lowered EC and pH values when compared to hardwood bark. Particle size distribution significantly affected plant growth. Indian hawthorns growth index and quality ratings were higher in media treatments 1, 2, 3, and 5. Shoot dry weights were greatest in media treatment 2 (#6, 25, <25). Irrigation treatment 2 (low) produced EC and pH levels that were higher than treatment 1 (high). Nutrient analysis indicated that pinebark increased elemental levels in all nutrients other than Ca and B.

In ligustrum production, pinebark yielded superior results. Pinebark increased plant growth index and quality ratings, while producing greater shoot dry weights when compared to hardwood bark. Pinebark produced lower EC and pH values compared to hardwood bark. Particle size distribution significantly affected plant growth. Media treatment 2 (#6, 25, <25) produced the greatest growth index and shoot weights for containerized ligustrums. This would suggest that ligustrum plants may grow best in media without large-medium particles. Irrigation treatment 2 (low) produced EC and pH levels that were higher than treatment 1 (high). Nutrient analysis indicated that hardwood bark increased elemental levels in all nutrients besides Mn.

Overall, pinebark is the preferred medium for growing crops in a container nursery setting compared to hardwood bark. Soil EC and pH values were greater in medium amended with hardwood bark than pinebark. Growth index, shoot weights, and quality ratings were significantly higher in crops grown in pinebark.

Particle size distribution effected the overall growth of all plants. Media treatment success was based on the type of plant grown. Each plant species responded differently to each treatment. Regardless of plant type, the commercially acceptable media mix produced plants with the lowest growth index and shoot weights throughout the study. This study suggests that particle size distribution is important to plant growth and quality, but on individual plant needs. Further research is needed to determine why plant growth is diminished in hardwood bark and to further determine the effects of particle size distribution in media on a wide range of ornamental species.

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APPENDIX

BARK, WEATHER, AND NUTRIENT DATA

Appendix 1. Potting medium treatments for pine bark and hardwood substrates.

Treatment	Sieve #6	Sieve #14	Sieve #25	Sieve #<25
	……………%	………………	………………	…………
1	0	33	33	33
2	33	0	33	33
3	33	33	0	33
4	33	33	33	0
5	25	25	25	25
6	Commercially Available Mix			

Commercially Available Mix= 50/50 mix of bark sieved through a 5/8 in. sieve (16mm) and a 3/8 in. sieve (9.4mm)

Appendix 2. Distribution of particles within category 3.35mm (#6 sieve).

Sieve Opening	Sieve#	Pine bark	Hardwood bark
		……………%	………………
12.5mm	½ in.	5.2	5.2
6.3mm	¼ in.	31.2	30.5
4.0mm	5	37.2	33.2
3.35mm	6	11.2	9.2

100 gram sample. n=3.

Appendix 3. Distribution of particles within category 1.4mm (#14 sieve).

Sieve Opening	Sieve#	Pine bark	Hardwood bark
		……………%	………………
2.8mm	7	12.5	15.2
1.4mm	14	75.5	74.0

100 gram sample. n=3.

Appendix 4. Distribution of particles within category 710µm (#25 sieve).

Sieve Opening	Sieve#	Pine bark	Hardwood bark
		……………%	………………
1.0mm	18	36.5	57.2
710µm	25	44.5	41.2

100 gram sample. n=3.

Appendix 5. Distribution of particles within category <710µm (<#25 sieve).

Sieve Opening	Sieve#	Pine bark	Hardwood bark
		·········%·········	
500µm	35	28.0	34.0
355µm	45	25.2	28.0
250µm	60	16.0	14.0
180µm	80	10.0	8.0
125µm	120	7.2	6.0
<125µm	Pan	11.2	8.0

100 gram sample. n=3.

Appendix 6. Preliminary pinebark physical properties.

Bark Source	Sieve #	Bulk Density	WHC	TP	AP
		·······g/cm^3······	·········%·········		
PB	#6	0.22	13.15	58.17	45.02
PB	#14	0.26	28.85	66.40	37.55
PB	#25	0.34	50.40	71.43	21.03
PB	#<25	0.50	69.00	76.97	7.97

PB= pinebark. WHC= water-holding capacity. TP= total porosity. AP= aeration porosity. n=2.

Appendix 7. Preliminary hardwood bark physical properties.

Bark Source	Sieve #	Bulk Density	WHC	TP	AP
		·······g/cm^3······	·········%·········		
HW	#6	0.14	14.74	67.73	52.99
HW	#14	0.17	23.72	67.59	43.87
HW	#25	0.45	31.75	65.48	33.73
HW	#<25	0.57	52.76	59.45	6.69

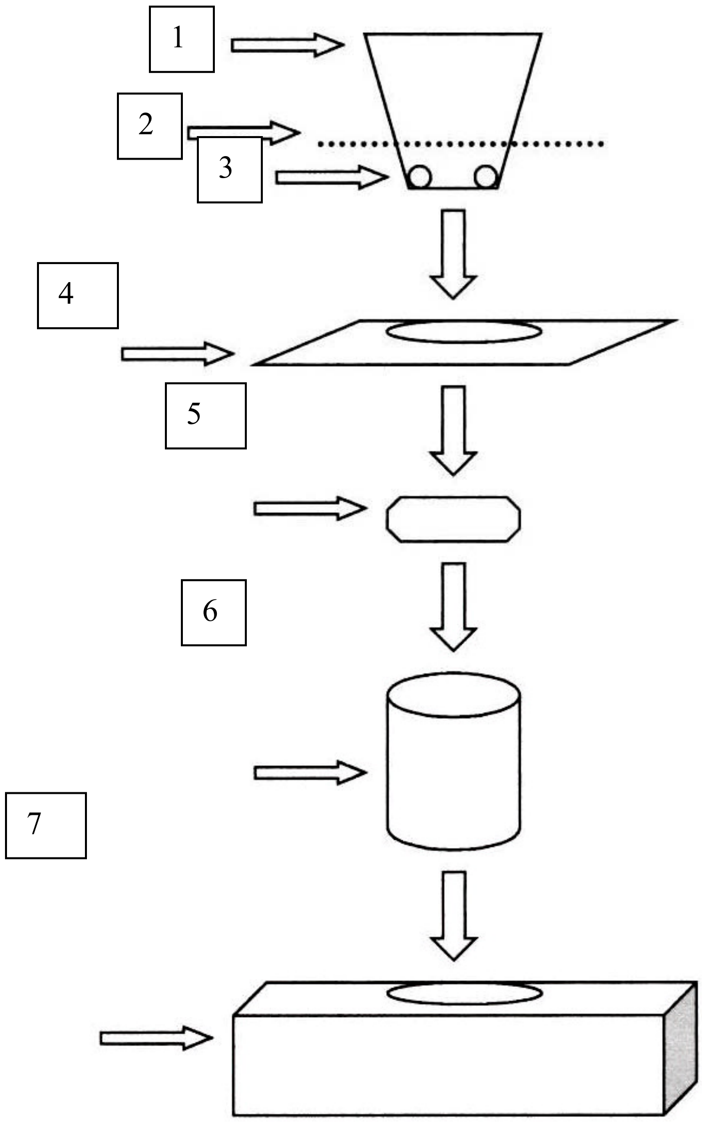
HW= Hardwood bark. WHC= water-holding capacity. TP= total porosity. AP= aeration porosity.
n=2.

Appendix 8. Physical properties of the six media treatments.

Treatment	Bulk Density	WHC	TP	AP
	.......g/cm^3......	..........................%..........................		
1	0.23	61.50	69.50	8.00
2	0.22	59.00	68.50	8.50
3	0.21	49.00	55.50	9.50
4	0.19	47.00	71.00	22.00
5	0.21	53.00	62.50	9.50
6		Missing Data		

WHC= water-holding capacity. TP= total porosity. AP= aeration porosity.
n=2.

Appendix 9. Diagram of closed-capture irrigation system used for effluent collection.



1. Pot; 2. location where gasket is fitted to pot; 3. drain holes; 4. rubber gasket; 5. oil drain screen; 6. effluent collection bag; 7. oil drain pan.

Appendix 10. Irrigation water analysis data for Burden Center (2004).

Results	ppm	Data Interpretation
Alkalinity	171	Medium
Calcium	1.1	Very low
Chloride	16.9	Low
Conductivity	327.0	Medium
Copper	2.7	Low
Iron	0.011	Low
Magnesium	0.014	Very low
Manganese	0.010	Low
Nitrate	4.5	Low
pH	8.4	High
Potassium	0.76	Low
Salts	209.3	Medium
SAR	20.4	Medium
Sodium	77.0	Low
Sulfur	3.7	Low

Analysis Performed by: Department of Agronomy, Louisiana State University

Appendix 11. Weekly average of rainfall, maximum temperature, and minimum temperature at the Burden Center from October-December 2004.

Date (weeks)	Rainfall ···(in.)···	Max. Temp ·········°F·········	Min. Temp
October			
1	0.57	86.1	67.3
2	0.22	77.0	58.6
3	0.008	87.6	70.3
4	0.0	87.0	64.4
November			
1	0.15	76.9	52.9
2	0.009	69.3	54.8
3	0.16	74.7	63.0
4	0.32	70.1	44.3
December			
1	0.11	66.5	48.9
2	0.01	62.6	40.0
3	0.15	58.5	34.5
4	0.0	62.6	36.6

Data collected from: LSU Ag Center, Louisiana Agriclimatic Information.

Appendix 12. Weekly average of rainfall, maximum temperature, and minimum temperature at the Burden Center from January-July 2005.

Date (weeks)	Rainfall ···(in.)···	Max. Temp	Min. Temp
		························°F·························	
January			
1	0.03	73.6	59.3
2	0.004	67.0	48.6
3	0.001	59.4	35.9
4	0.37	60.7	46.1
February			
1	0.07	59.4	46.7
2	0.24	66.4	46.9
3	0.0	72.1	52.9
4	0.23	66.4	50.6
March			
1	0.04	64.8	44.1
2	0.20	67.1	46.0
3	0.05	72.4	50.1
4	0.05	75.6	54.4
April			
1	0.02	75.5	60.3
2	0.17	79.0	53.0
3	0.0	80.7	56.0
4	0.19	77.4	52.7
May			
1	0.0	78.9	52.5
2	0.005	86.3	63.1
3	0.0	90.8	67.8
4	0.28	85.9	68.3
June			
1	0.21	88.6	70.0
2	0.08	91.5	72.0
3	0.42	90.3	68.4
4	0.13	93.0	71.7
July			
1	0.013	91.6	72.8
2	0.26	89.8	74.1
3	0.13	92.8	74.9
4	0.07	93.6	75.0

Data collected from: LSU Ag Center, Louisiana Agriclimatic Information.

Appendix 13. Influence of iron treatment on quality ratings of container grown ligustrum.

Treatment	I	II
High Granular	3.6a	3.3a
Low Granular	3.3a	3.3a
High Liquid	3.4a	3.3a
Low Liquid	3.4a	3.4a
Fertilizer	3.3a	3.2a
Control	2.6b	2.8a
Significance	*	NS
SE ±	0.08	0.08

Quality rating: 1=dead, 3=commercially acceptable, 5=superior.
Means with * are significant at the 0.05 level.
Means with NS are not significant.
Means with the same letters are not significantly different at the 0.05 level.
High Granular= 5 lbs/100 ft^2+ N; Low Granular= 2.5 lbs/100 ft^2+ N; High Liquid= 3 oz/gal.+ N; Low Liquid= 1.5 oz/gal.+ N; Fertilizer= N; Control= no application.
Iron Source= $FeSO_4$.
N= Nitrogen [Nursery Special (12-6-6)]; top-dressed.

Appendix 14. Influence of iron treatment on quality ratings of container grown Indian hawthorn.

Treatment	I	II
High Granular	3.3a	2.8ab
Low Granular	3.0a	2.3cd
High Liquid	3.4a	3.1a
Low Liquid	2.9a	2.6abc
Fertilizer	2.4b	2.3bcd
Control	2.2b	2.0d
Significance	**	*
SE ±	0.10	0.09

Quality rating: 1=dead, 3=commercially acceptable, 5=superior.
Means with * are significant at the 0.05 level.
Means with ** are highly significant at the 0.01 level.
Means with the same letters are not significantly different at the 0.05 level.
High Granular= 5 lbs/100 ft^2+ N; Low Granular= 2.5 lbs/100 ft^2+ N; High Liquid= 3 oz/gal.+ N; Low Liquid= 1.5 oz/gal.+ N; Fertilizer= N; Control= no application.
Iron Source= $FeSO_4$.
N= Nitrogen [Nursery Special (12-6-6)]; top-dressed.

Appendix 15 Influence of iron application on ligustrum foliar nutrient concentrations.

	N	P	K	Ca	Mg	S
Treatment	·····dwt %·····					
High Granular	1.2a	0.17a	1.0a	2.1a	0.25a	0.11a
Low Granular	1.1a	0.15a	1.0a	1.7a	0.23a	0.10a
High Liquid	1.3a	0.19a	1.0a	2.0a	0.26a	0.11a
Low Liquid	1.3a	0.21a	1.1a	1.8a	0.24a	0.11a
Fertilizer	1.3a	0.16a	1.0a	2.1a	0.22a	0.10a
Control	1.2a	0.20a	0.9a	1.9a	0.19a	0.10a
Significance	NS	NS	NS	NS	NS	NS
SE ±	0.24	0.15	0.33	0.54	0.15	0.08

Means with NS are not significant.
Means with the same letters are not significantly different at the 0.05 level.
High Granular= 5 lbs/100 ft^2+ N; Low Granular= 2.5 lbs/100 ft^2+ N; High Liquid= 3 oz/gal.+ N; Low Liquid= 1.5 oz/gal.+ N; Fertilizer= N; Control= no application.
Iron Source= $FeSO_4$.
N= Nitrogen [Nursery Special (12-6-6)]; top-dressed.

Appendix 16. Influence of iron application on ligustrum foliar nutrient concentrations.

	Fe	Mn	B	Cu	Zn	Na
Bark source	·····dwt (ppm)·····					
High Granular	94.3c	57.6a	42.7a	11.6ab	41.1a	3700a
Low Granular	81.2c	72.8a	43.6a	11.2abc	36.4a	3800a
High Liquid	500 a	53.4a	47.8a	13.2a	33.2a	3900a
Low Liquid	328 b	55.2a	57.9a	9.1c	34.0a	4300a
Fertilizer	58.7c	48.1a	48.8a	9.4bc	36.8a	3900a
Control	48.7c	49.8a	32.0a	11.0bc	38.1a	4300a
Significance	***	NS	NS	**	NS	NS
SE ±	6.6	3.0	3.0	1.0	2.5	0.22

Means with ** are highly significant at the 0.01 level.
Means with *** are very highly significant at the 0.001 level.
Means with NS are not significant.
Means with the same letters are not significant at the 0.05 level.
High Granular= 5 lbs/100 ft^2+ N; Low Granular= 2.5 lbs/100 ft^2+ N; High Liquid= 3 oz/gal.+ N; Low Liquid= 1.5 oz/gal.+ N; Fertilizer= N; Control= no application.
Iron Source= $FeSO_4$.
N= Nitrogen [Nursery Special (12-6-6)]; top-dressed.

Appendix 17 Influence of iron application on Indian hawthorn foliar nutrient concentrations.

	N	P	K	Ca	Mg	S
Treatment	····························	···········	········dwt %	···········	···········	····················
High Granular	1.4a	0.13a	1.0a	0.9a	0.08a	0.15a
Low Granular	1.3a	0.15a	0.9a	0.9a	0.09a	0.12a
High Liquid	1.3a	0.15a	1.1a	0.9a	0.08a	0.12a
Low Liquid	1.5a	0.16a	1.1a	0.9a	0.09a	0.11a
Fertilizer	1.5a	0.17a	1.2a	1.2a	0.09a	0.12a
Control	1.7a	0.21a	1.5a	1.3a	0.10a	0.12a
Significance	NS	NS	NS	NS	NS	NS
SE ±	0.49	0.18	0.41	0.50	0.09	0.09

Means with NS are not significant.
Means with the same letters are not significantly different at the 0.05 level.
High Granular= 5 lbs/100 ft^2+ N; Low Granular= 2.5 lbs/100 ft^2+ N; High Liquid= 3 oz/gal.+ N; Low Liquid= 1.5 oz/gal.+ N; Fertilizer= N; Control= no application.
Iron Source= $FeSO_4$.
N= Nitrogen [Nursery Special (12-6-6)]; top-dressed.

Appendix 18. Influence of iron application on Indian hawthorn foliar nutrient concentrations.

	Fe	Mn	B	Cu	Zn	Na
Bark source	····························	···········	········dwt (ppm)	···········	···········	·············
High Granular	99.1a	90.9a	44.9a	7.9a	28.6a	6100a
Low Granular	77.1a	59.3a	40.4a	9.7a	30.7a	6100a
High Liquid	410 a	62.7a	41.4a	8.2a	23.6a	6500a
Low Liquid	363 a	56.2a	42.7a	7.6a	36.6a	6300a
Fertilizer	63.5a	93.4a	38.8a	13.2a	32.9a	6600a
Control	45.9a	85.2a	44.7a	8.8a	36.0a	7200a
Significance	NS	NS	NS	NS	NS	NS
SE ±	12.3	4.0	1.8	1.8	2.5	0.32

Means with NS are not significant.
Means with the same letters are not significant at the 0.05 level.
High Granular= 5 lbs/100 ft^2+ N; Low Granular= 2.5 lbs/100 ft^2+ N; High Liquid= 3 oz/gal.+ N; Low Liquid= 1.5 oz/gal.+ N; Fertilizer= N; Control= no application.
Iron Source= $FeSO_4$.
N= Nitrogen [Nursery Special (12-6-6)]; top-dressed.

VITA

Michael Paul Richard, son of Leon M. Richard, Jr. and Merlie H. Richard, was born in Mathews, Louisiana, on 8 July 1981. He graduated from Central Lafourche High School, Mathews, Louisiana, in 1999. In 1999, he enrolled at Louisiana State University and graduated in 2004 with a Bachelor of Science in plant and soils systems, with a concentration in turfgrass management. After graduation he volunteered on the grounds crew for the 2004 Senior PGA Championship in Louisville, Kentucky. In July 2004, he entered graduate school in the Department of Horticulture at Louisiana State University to pursue a master's degree in ornamentals. He will receive that degree in May 2006.