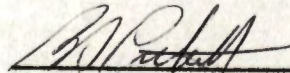


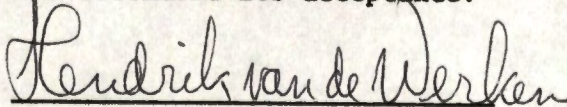
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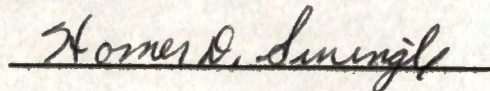
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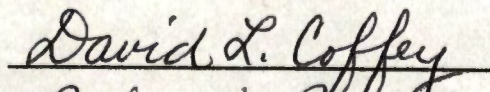
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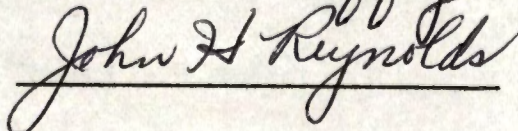

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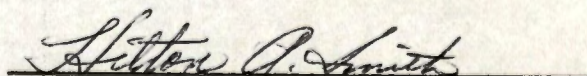

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EVALUATION OF HARDWOOD BARK AS A GROWING MEDIUM

FOR CONTAINER-GROWN ILEX CRENATA 'HETZI'

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

Robert John Black

December 1972



TO MY WIFE, BETTY

whose hard work and inspiration helped to make this possible.

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ABSTRACT

The purpose of this study was to evaluate hardwood bark as an organic component of media for container-grown Japanese holly (Ilex crenata 'Hetzi'). The evaluation included the effect of species of bark, particle size of bark, and ratio of bark to media on the growth of Japanese holly. The bark was treated with polyvinyl alcohol to determine its effect on the rate of decomposition and possible toxic effects of the different species of bark.

The evaluation included plant responses and laboratory analyses of the plant material and media. The growth responses measured were: fresh weight, dry weight, percent dry weight, stem diameter, and relative growth rate. The dried leaf tissue of the plants was analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, and iron content. The media were analyzed to determine their chemical composition, pH, cation exchange capacity, total soluble salts, bulk density, and percent shrinkage.

The media composed of 100 percent peat produced plants which were superior to plants grown in any other media. Plants grown in media containing 50 percent hardwood bark and 50 percent sand, with the exception of media containing ash bark and poplar bark, produced plants which were as good, and in some cases better than, plants grown in a 1:1 mixture of peat and sand. The plants grown in media containing poplar bark and ash bark were smaller and generally inferior to plants grown in peat and sand.

The finer of the two particle sizes of bark incorporated into the media produced better plants as an average of all media. Plants grown in media composed of 50 percent bark and 50 percent sand were generally superior to plants grown in a 100 percent bark media.

The treatment of bark with polyvinyl alcohol had no significant effect on plant growth or rate of decomposition of the bark.

There was no evidence that toxic substances were released from any of the bark species. The chlorosis which developed in plants grown in some of the bark media was believed to have been a symptom of iron deficiency caused either by high pH or improper nutrient balance in the media.



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CHAPTER I

INTRODUCTION

The wood industry uses large quantities of hardwood logs for lumber and paper. The bark from these logs is a by-product and accumulates in large quantities at sawmills. Because of recent concern for cleaner air, the sawmill industries have been receiving pressure to discontinue burning their by-products. The cost of transporting the bark makes dumping economically unfeasible. Therefore, the wood industry is now looking for ways of turning bark into a useful by-product.

At the same time, producers of container-grown ornamental plants are looking for an inexpensive organic amendment to add to their growing media. In the past, sphagnum peat has been used quite extensively and satisfactorily. However, peat is becoming less available and more expensive.

The use of hardwood bark as a growing medium for container-grown ornamentals has been the subject of many studies. These studies indicate that special attention should be given to the particle size of the bark, age of the bark, pH of the bark, watering of the bark media, and the nitrogen supply in the bark media (38,39,40,41,42). Another important factor to consider when working with hardwood bark is its rapid decomposition rate. Methods which have been used to retard the microbial breakdown of hardwood bark are composting and ammoniation (16).

There has been very little work done to determine the effect of individual species of bark on plant growth. Therefore, this study was undertaken to determine the effect of different species of hardwood bark on the growth of Japanese holly (Ilex crenata 'Hetzi'). Also the possibility of retarding the rapid rate of decomposition of hardwood bark by plasticizing the bark particles with polyvinyl alcohol was investigated. The effect of the size of the bark particles and the ratio of bark to medium on plant growth was also studied.

CHAPTER II

REVIEW OF LITERATURE

I. GENERAL PROPERTIES OF HARDWOOD BARK

Structure and Composition of Bark

Bark is the outer part of woody stems and branches (22,23,32,56). It is a highly complex, heterogeneous material composed mainly of a thin, physiologically active inner layer and a complex, relatively inert outer layer (48).

Bark is formed by cell division at the cambium, which produces xylem on the inside and phloem on the exterior bark side. The physiologically active tissue adjacent to the cambium is known as the inner bark and is relatively thin and light colored. As layers of phloem are laid down year after year, the outer layers become crushed and compressed. This tissue no longer takes part in physiological processes and is transformed into the relatively inert, dark outer bark that comprises the bulk of most tree barks (48).

There is a second cambial layer within the bark called the phellogen or cork cambium. This cambium layer produces the cork or periderm which makes up the structure of the outer bark. The innermost layer of periderm is usually considered the boundary between the inner and outer bark. Some barks are thin and contain a high proportion of inner bark, while other barks are thick and contain a very high percentage of outer bark (48). The bark of the redwood and the giant

sequoia may reach a thickness of one foot or more, while the bark of beech, paper birch, and soft maple may be less than 1/2 inch thick (4).

Bark is a complex physical and chemical mixture of many organic compounds. The structural components of bark are carbohydrates, lignin, and cork. The carbohydrates include such compounds as holocelluloses, hemicelluloses, galactans, mannans, glucosans, arabans, and uronic acids. The chemical compounds that comprise cork are suberic acid, suberin, cutose, quercitin, and dihydroquercitin (15).

The nonstructural components of bark are: (1) coloring matter; (2) tannins; (3) polysaccharides, glucosides, sugars, and gums; (4) volatile acids and oils; (5) nonvolatile fatty oils and steroids; (6) miscellaneous organic materials; and (7) minerals.

Mineral Content and Nutrient Value of Hardwood Bark

The mineral content of bark differs not only with species but also with the age of the tree, environmental factors, and with the location in which the tree was grown (30,31). The mineral content of bark is determined by the availability of the elements in the soil rather than the amount necessary to satisfy nutritional needs of the tree (15).

Gartner et al. (41) conducted a chemical analysis on bark obtained from a midwestern paper mill. The bark was a mixture obtained from many species of trees, of which the three largest categories were oak species (35 percent), eastern cottonwood (21 percent), and silver maple (15 percent). The bark contained a trace of nitrate and ammonium nitrogen; 2 ppm available phosphorus; 520 ppm available potassium; 68 ppm

available calcium; 380 ppm available magnesium; and 0.237 percent total iron.

There are some differences of opinion on the nutrient value of hardwood bark. Bollen (15) stated that bark has almost no plant nutrient value. He found that the nitrogen content was very low and the phosphorus content was much less than that of nitrogen. However, he found that the calcium content was relatively high compared with other minerals.

Baker (10) stated that bark has frequently been found to be well supplied with phosphorus and potassium in an available form.

Rigby (65), working with Douglas-fir and hemlock bark, found a trace of nitrogen in the nitrate form and usually about one pound in the form of ammonium per 1000 square feet of bark six inches deep. He found that 1000 square feet of bark six inches deep contains 1/2 pound of available phosphorus and three pounds of potassium. In addition, more phosphorus and potassium becomes available as the bark breaks down. He also found that bark contains appreciable amounts of iron and magnesium.

Lunt and Clark (55) stated that in certain cases, potassium and phosphorus derived from bark appear to make a contribution to a planting for a period of one month. However, they emphasize that the principal effect of barks on the macro element nutrition of plantings in soil mixes is to dilute the soil with relatively inert materials and, therefore, more frequent fertilization is generally required.

Cation Exchange Capacity of Hardwood Bark

There is very little information on the cation exchange capacity (CEC) of hardwood bark in the literature. This is because most of the research with bark has been done with softwood bark.

Scott (66), working with hardwood bark, found bark fines had a CEC of 44 meq per 100 g. This was more than double the CEC of hardwood sawdust which had a CEC of 18 meq per 100 g.

Bollen (15) reported that the CEC of the Douglas-fir bark varied with the particle size from 44.8 meq per 100 g to 60.5 meq per 100 g. He compared the CEC of the bark with that of a silt loam soil. He found the CEC of ground bark may be two to three times greater than that of silt loam soil. He attributes the high CEC of bark to the uronic acid substances in bark which may have a CEC as high as 100 meq per 100 g.

Fahey et al. (33) found that the phenolic acid polymers in bark (absent in wood) have neutralization equivalents in the range of about 100-200 meq per 100 g.

pH of Hardwood Bark

Hardwood barks are generally acidic (7). Gartner et al. (41) reported a pH of 5.0 for a hardwood bark mixture, of which the three largest categories were oak species (35 percent), eastern cottonwood (21 percent), and silver maple (15 percent). McCool (57) stated that most barks and wood fragments have pH values that range from about 3.5 to about 7.0. Allison (4) found that soft maple, beech, and walnut leachate pH values range from 4.3 to 4.9.

II. HORTICULTURAL USES OF BARK

The primary uses of bark in horticulture have been as a soil conditioner (4,5,6,17,55), mulch (4,5,6,11,16,17,18,44,46,55), and as a carrier for fertilizer (5,12) and herbicides (14,28,36,46,47). Certain softwood barks have been recommended for use as a potting medium for orchids. Bark has been used in combination with other media such as coarse sand as a rooting medium for propagating plants (29,62). There has been some work conducted on the use of hardwood bark for packaging of bare root nursery stock (29,30). Bark has been used as a decorative ground cover around plantings and on walkways (4).

III. HARDWOOD BARK AS AN ORGANIC COMPONENT FOR CONTAINER-GROWN ORNAMENTALS

Age of Hardwood Bark

Hardwood bark should be stockpiled for a period of 3 weeks prior to utilization to allow it to go through the heating period (7).

Bollen (15) found that composting increased the value of bark as a soil amendment. In the composting process the carbon to nitrogen ratio was lowered, which was very beneficial in reducing the nitrogen draft associated with bark. Also, composted bark was found to be more resistant to microbial breakdown. Dunn (29) reported that hardwood bark which was stockpiled for several years gave higher crop yields than bark fresh from the mill.

Particle Size of Hardwood Bark

Gartner, Saupe, Klett, and Yocom (41) stated that the particle size of hardwood bark played an important role in drainage, aeration, and moisture of the growing medium. If the particle size was too fine (less than 1/16 of an inch) poor aeration resulted. If the particle size was too large (over 1 inch) drying of the roots occurred.

Gartner, Meyer, and Saupe (40) found that geranium plants did not grow well in a soil:bark (1:2 by volume) medium when the bark was ground too fine (under 1/50 of an inch). The plants seemed to suffer from insufficient aeration.

Gartner, Saupe, Klett, and Yocom (41) reported that good results were obtained when particle sizes from 1/16 to 1/4 of an inch were used. However, they obtained the best results from a mixture of particle sizes as the bark came from a hammer mill.

Rigby (65) suggested that bark should be passed through a 3/8 inch mesh screen.

Neal et al. (59) stated that regardless of mesh size, the screened bark contains an assortment of particle sizes ranging down to fine dust.

Ratio of Hardwood Bark in Media

Joiner and Conover (50) stated that "the best level of peat and bark when mixed with sand was 50 percent." Organic materials in more than 1:1 ratio by volume mixture with sand were unnecessary and resulted in lower cation exchange capacity by volume.

Dunn (29) found with varying portions of hardwood bark to soil, that low concentrations of bark gave better yields than higher ones.

In early experiments, Gartner, Saupe, Klett, and Yocom (41) used hardwood bark as a substitute for peat in the standard soil mix of 1/3 soil, 1/3 peat, and 1/3 perlite. The results were so good that they eliminated perlite and increased the bark and soil to 50 percent of each. Again the results were good, and they increased the bark to 2/3 and the soil was reduced to 1/3. They reported that they obtained the best results with the mix containing 2/3 hardwood bark and 1/3 soil or fine sand. Gartner, Saupe, Yocom, and Kundrot (38) stated that they are now using a mix of 2/3 hardwood bark and 1/3 fine sand, with soil eliminated entirely.

Fertilization of a Hardwood Bark Media

Nitrogen. The principal disadvantage of the use of bark has been the draft on the nitrogen supply in the media (16,17,21,24,40,41,42,50,55,65,71). When bark fragments are incorporated into a media, they furnish various organic materials that are readily used as energy sources by microorganisms (55). As the microorganism population increases, their consumption of nitrogen increases and, as a consequence, higher plants that are competing with microorganisms for available nitrogen may suffer from nitrogen deficiency (55). Lunt and Clark (55) reported that the duration of induced nitrogen deficiency varies with the rate of application of bark. Lunt (34) found that the magnitude of nitrogen deficiency was proportional to the rate of decomposition.

The ordinary liquid fertilization methods that are used for soils amended with peat or softwood bark do not work for hardwood bark amended

soils (24,40,41). Allison and Murphy (3) reported that hardwoods were attacked much more readily than most softwoods, and consequently more nitrogen was required by the microorganisms that decomposed them. Conover and Joiner (24) stated that initial decomposition of bark required compensatory nitrogen as compared with peat for rapidly growing crops maintained in containers four months or less, however, after this time added nitrogen was apparently released for plant growth and bark was as good as peat in the mixture. However, they (50) later found that where more than 50 percent of the media was composed of bark, additional nitrogen was needed for periods exceeding four months.

Bollen and Glennie (16) suggested several methods of dealing with this problem of the draft on the nitrogen supply in hardwood bark media. The methods were: (1) including nitrogen fertilizers with raw wood wastes, (2) chemical processing to incorporate nitrogen, and (3) composting.

Many workers (7,24,40,41,42,55,65) have incorporated preplant nitrogen fertilizer into media of which bark is a component. Lunt and Clark (55) suggested as a general rule, that an extra one pound of actual nitrogen be added to every hundred pounds of dry bark fragments to maintain a good carbon to nitrogen balance. Gartner, Saupe, Klett, and Yocom (41) found that the nitrogen deficiency in a mix composed of 2/3 hardwood bark and 1/3 fine sand could be prevented by the addition of slow-release nitrogen to the basic mix. They obtained the best results when Osmocote (18-6-12) or MagAmp (7-40-6) was used at the rate of eight pounds per cubic yard of mix. They also fertilized with water

soluble fertilizer (20-20-20) at the rate of 200 ppm of nitrogen at each watering. Gartner, Meyer, and Saupe (40) reported that Osmocote (14-14-14) applied at 15 pounds per cubic yard to soil-bark media resulted in more plant growth of chrysanthemums than Ureaform (38-0-0) applied at 6 pounds per cubic yard. They also found that the application of Osmocote (14-14-14) applied at a rate of 7.5 pounds per cubic yard to soil-bark media produced more growth in Forsythia intermedia and Taxus media than Osmocote applied at 15 pounds per cubic yard and Ureaform at 3 pounds per cubic yard. Gartner et al. (40) suggested that the reason for Osmocote's superiority to MagAmp and Ureaform may be due to the slower release of nitrogen from the latter, and also, part of the nitrogen in Osmocote is in the nitrate form.

The incorporation of nitrogen into bark has been investigated as a method of supplying the additional nitrogen needed in the decomposition of bark (8,15,17,40).

Ammoniation is a process which has been used to fortify bark with nitrogen (15). In this process, ground bark is sprayed with aqua ammonia. Due to the presence of polyphenols, bark is highly acid and readily absorbs ammonia when wet (15). Spraying ground bark with aqua ammonia can add about 2 percent nitrogen (17). Aspitrate (9) and Bollen and Gennie (17), working with Douglas-fir bark, reported that they could add 5 percent nitrogen into bark by applying anhydrous ammonia to the bark in a closed screw conveyor system. Bollen and Glennis (16) found that besides increasing the nitrogen content of bark, ammoniation gives

bark a dark, pleasing color and increases its resistance to microbial breakdown.

Bollen and Glennie (17) reported that ammoniated bark releases available nitrogen slowly in soil, but it will prevent nitrogen starvation and increases plant growth. Gartner et al., working with chrysanthemums (40), found that ammoniated hardwood bark (treated with anhydrous ammonia) gave growth as good as soil:peat:perlite mix when mixed 1:1 with soil. However, plants grown in 2/3 ammoniated bark and 1/3 soil grew significantly less than the plants grown in soil:peat:perlite mix. They suggest that ammoniation appeared to supply some of the nitrogen required, but not all of it.

Bollen and Glennie (17) added nitrogen to Douglas-fir bark by treating it with nitric acid, urea, urea plus phosphoric acid and ammonium hydroxide. They found that all four treatments added enough nitrogen to prevent nitrogen starvation with most crops. The urea and phosphoric acid treatment increased nitrogen in bark from 0.14 percent in untreated bark to 1.78 percent. The other treatments added nitrogen in slightly lower percentages.

Composting is a process which stabilizes bark while overcoming its nitrogen deficiency. Bollen (15) describes the process as follows:

In the composting process, organic residues undergo sufficient decomposition to narrow the C:N ratio, much of the carbon passing off as carbon dioxide. The action should be allowed to proceed to near humification where some nitrogen becomes available as ammonium or nitrate.

The composting action can be hastened by the addition of some nitrogen source such as manure, sewage, or a nitrogen fertilizer (15). Bollerslev

(19) described a successful commercial operation wherein the best product is produced by composting ammoniated bark at 135° to 159° F for approximately 90 days.

Farber and Hind (34) devised another approach to the nitrogen depletion problem. They developed a chemical treatment to render bark resistant to decay. When wood residues were treated with acid at a high temperature, a substance called humin was produced. This substance rendered wood residues resistant to decay.

Burton (21) developed a process of using bark fibers in trickling filters for secondary treatment of sewage effluent. Dunn (29) found that addition of sewage to composted hardwood bark at the rate of 1 part sewage to 8 parts bark produced a medium which grew cabbage plants of significantly higher dry weight than those grown in soil.

Phosphorus. Allison and Anderson (2) found the addition of phosphorus was necessary in most wood waste soil mixes for bacterial requirements. Conover and Joiner (24) confirmed the need for phosphorus in media containing high levels of bark or sawdust, but not with peat.

Calcium and magnesium. The addition of dolomitic limestone to media containing hardwood bark resulted in a rapid rise in pH of the media (7,40,41,42). Therefore other sources of calcium and magnesium were needed. Gartner et al. suggested the elimination of dolomitic limestone and the addition of gypsum (calcium sulfate) at the rate of 5 pounds per cubic yard and magnesium sulfate at the rate of 1 pound per cubic yard of mix.

pH of Hardwood Bark Mixture

Hardwood barks are acid with a pH around 5.3 (7). Some of the early workers adjusted the pH of media containing hardwood bark by adding lime or dolomitic lime (40,41,42). The addition of lime to media containing softwood bark such as pine and Douglas-fir bark was advocated by many researchers working with softwood barks (13,55,61,62). However, the pH of a media containing hardwood bark to which lime had been added was found to rise rapidly after plants had been growing in it for a while (7,40,41,42).

Gartner et al. (40) questioned the value of adding lime to hardwood bark mixtures. They found that lime stimulated growth in media composed of 1 soil, 1 bark, 1 perlite, but not in the 1 soil, 1 bark mixtures. The pH of bark media tended to go over 7.0 after about 6 weeks whereas peat-amended media tended to stay under 7.0. They suggested that the requirement for lime needed for peat does not appear needed for hardwood bark to raise the pH and the needed calcium and magnesium could be supplied by calcium and magnesium sulfate rather than dolomitic lime.

Gartner et al. (40) found that the pH increase in hardwood bark mixtures depended on the amount of bark in the mixture, the pH of the sand or soil that was mixed with the bark, and the pH of the irrigation water. They suggested that where the irrigation water or the sand or the soil in the mix is alkaline, 1 pound of flowers of sulphur should be added to each cubic yard of mix.

Wettability and Water-Holding Capacity

Bark is initially hard to wet (41,42,65). For the first few weeks after planting, plants must be watched very closely to prevent drying out. However, after the bark is thoroughly saturated, it has very good water-holding capacity (41,42,46,65).

Dunn (17) devised a study to compare the moisture-holding capacity of shredded bark and peat. At the end of 13 days, a 1000 g moist sample of peat retained more water than 1000 g samples of hardwood and softwood bark. He also found that old bark retained more water than new bark.

Decomposition of Hardwood Bark

In a growing mixture that contains bark or any other decomposable material, the decomposition rate of that material can be important (26). This is particularly true in container production since a slow rate of decomposition is desirable to prevent rapid loss of volume in the container (26).

Size of bark particles influences the rate of decomposition (15). The smaller the particles, the more surface area exposed for decomposition (15).

Allison (1) and Bollen and Glennie (16) found that under favorable conditions, bark decomposes more rapidly during the first few days of exposure to microbial activity.

Bollen (15) reported that old-growth Douglas-fir bark decomposes more slowly than young-growth bark. He also found that ammoniated bark and composted bark were quite resistant to decomposition.

Bollen and Glennie (17) stated that the rate of decomposition and nature of the end products vary with available nitrogen. Optimum decomposition in soil resulted when the ratio of carbon to nitrogen was about 20:1. Allison and Murphy (3) measured the rate of decomposition of woods and barks of 9 species of hardwoods at two nitrogen levels. They found that nitrogen fertilizer increased the rate of decomposition for all 9 wood samples, but for only 5 of the barks (black oak, red oak, post oak, yellow poplar, and chestnut). They suggested that the decomposition rates of the remaining barks (white oak, hickory, red gum, and black walnut) were so low that the soil supplied as much available nitrogen as needed by the microorganisms. They found with these barks that the addition of more nitrogen than needed had only a slight depressing effect. Of the 9 barks, they found that hickory and black walnut were the most resistant to microbial decomposition, whereas yellow poplar was the least resistant and decomposed at about the same rate as the wood.

Allison and Murphy (3) found that hardwood bark decomposed at 3 times the rate of softwood bark. They presumed that the water insoluble resins in the softwoods were largely responsible for their slow decomposition.

Plant Growth in Media Containing Hardwood Bark

Gartner, Carbonneau, and Saupe (38) have grown salable geraniums in media containing 1/3 to 1/2 hardwood bark.

Dunn (29) obtained a higher yield for snapdragons grown in a mixture of composted hardwood bark and soil than in peat-soil or soil

only. He also obtained higher yields for cabbage and barley grown in a mixture of composted hardwood bark and soil than in soil only. He grew tomatoes in 100 percent peat and 100 percent composted hardwood bark. The crop in the peat was a total failure. However, total yields of fruit, as well as size of fruit, were greater in the bark than in soil.

Gartner, Saupe, Yocom, and Kundrot (42) reported that they had successfully grown several crops of geraniums, chrysanthemums, lilies, poinsettias, forsythia, taxus, junipers, barberry, cotoneaster, ribes, and pyracantha in hardwood bark mixes.

Harkin and Rowe (48) found that pines, firs, junipers, holly, forsythia, rhododendrons, gardenias, azaleas, pieris, camellias, heather, and orchids grow well in a bark potting medium.

Gartner, Mayer, and Saupe (40) showed that the forsythia and taxus will grow in hardwood bark mixtures if proper amendments are added. The plants in some of the bark media grew as well or better than plants in peat-amended media.

With the addition of adequate nutrients, especially nitrogen, plant growth in soil to which bark has been added is generally better than in unamended soil (16,18,29).

Toxic Effects of Wood and Bark

It is mentioned in the literature that many woods and barks contain agents that are toxic to plants (1,15,20,47,52,55,58). Some workers (15,48,55) believe that the so called "toxic effects" are due to nitrogen deficiency induced by wood and bark.

Lunt and Clark (55) observed a marked retardation in growth of tomatoes in mixes containing cedar or walnut shavings. Bollen (15) reported that red cedar bark may be toxic to plants, although it is used extensively for mulching with no bad results. Allison (1) found both bark and wood of incense-cedar to be toxic to garden peas. Krueger (52) reported that the compound thujaplicins, found in wood of cedar, can be toxic to young roots on direct contact. Harkin et al. (48) found that fresh walnut bark occasionally may inhibit germination of many types of seed owing to the phytotoxic glycoside juglone it contains.

Haramaki et al. (47) watered the potted plants of zinnia, marigold, Japanese holly, and dwarf Japanese yew with concentrated water soluble extractives made from barks of basswood, beech, birch, cherry, hemlock, red maple, sugar maple, yellow poplar, walnut, and white pine. The extracts from only two barks, beech and red maple, caused browning at the leaf edges and eventual death of the marigolds and zinnias. The Japanese holly and Japanese yew were not affected.

Morris and Milbocker (58) reported that Japanese holly developed chlorosis very similar to the chlorosis described for iron deficient Japanese hollies when grown in a medium containing red oak bark. They believed that manganese was preferentially leached from the bark raising the ratio of manganese to iron higher than the plants could tolerate. They found that the addition of fritted iron at the rate of 3 teaspoons per bushel of bark was successful in overcoming the manganese toxicity.

Harkin and Rowe (48) stated that "the toxic effects are seldom observed beyond a short time after initial application of the wood wastes."

IV. EFFECT OF BARK ON SOIL-BORNE PLANT DISEASES AND SOIL ORGANISMS

Beneficial effects of bark in depressing soil-borne plant diseases have been observed (16). Bollen (16) found that treated Douglas-fir bark was quite effective in controlling red stele disease when used as a mulch around strawberries. He also stated that because bark improves drainage in certain soils, it has been found to reduce root knot, damping off, and olive wilt.

Bollen (15) reported that wood residues composted with poultry manure and rice bran have been found to depress many soil-borne plant diseases. He suggested that the compost contained an abundance of antibiotics-producing microbes such as Trichoderma and Streptomyces.

Cook (25) found that certain plant pathogenic fungi are inhibited and finally killed by tannin added to culture media. Williams (73) believed that tannin probably tanned the pectolytic enzymes of the fungi.

Dunn (29) found that growing apples in hardwood bark does not confer immunity to the fungous disease known as apple scab.

Allison and Murphy (3) observed no toxic effects to the micro-organisms in media containing 9 species of hardwood bark and wood.

V. ADVANTAGES AND DISADVANTAGES OF HARDWOOD BARK AS A COMPONENT OF MEDIA FOR CONTAINER-GROWN PLANTS

The addition of hardwood bark to media was found to have the following advantages:

1. Increases water-holding capacity (7,15,16,41,42).
2. Increases water penetration and drainage (15,41,42,48).
3. Increases aeration and improves tilth by lending body to sandy or silty soils and loosening up clay soils (7,15,16,41,42,48).
4. Light in weight, which facilitates handling and shipping (7,41,42,65).
5. Relatively inexpensive (7,41,65).
6. Readily available (41).
7. Permits standardization of physical, chemical and biological properties of the media (15).
8. Facilitates addition of formulated nutrients on schedule (15).
9. Readily sterilized (15).
10. Contains minor elements for plant growth (7,65).
11. Depresses some soil-borne plant diseases (15,16).

The addition of hardwood bark to media was found to have the following disadvantages:

1. Competition between microorganisms and plants for available nitrogen, and to a lesser extent other elements (16,17,21,24,40,41,42,50,65,71).
2. Bark is initially hard to wet (41,42,65).
3. Retardation of temperature increase following cold periods (16).
4. Decrease of pH if material was strongly fermented (16).
5. Rapid rise in pH, if lime is added (7,40,41,42).
6. Packing of fine materials (16).

7. Thorough mixing required to obtain an even and thorough distribution of fertilizer (41).
8. Small, sharp slivers make the wearing of gloves necessary while the plants are being potted (16,65).
9. Objectionable dust in handling of dry bark (16).

VI. POLYVINYL ALCOHOL AS A SYNTHETIC SOIL CONDITIONER

Polyvinyl alcohol is a chemical manufactured by polymerization of vinyl acetate and partial or complete hydrolysis of the intermediate polyvinyl acetate to polyvinyl alcohol.

There are 11 grades of polyvinyl alcohol under the trade name Elvanol (Dupont). These grades vary in molecular weight and degree of hydrolysis. The degree of polymerization and the degree of hydrolysis have definite effect on the properties of these chemicals.

Polyvinyl alcohol comes in a granular or powder form which varies in color from white to cream. It is heat stable and burns at about the rate of paper. All grades of Elvanol are soluble in water, however, the temperature at which the compound can be completely dissolved varies with the grade, depending chiefly on percent hydrolysis. All grades of Elvanol polyvinyl alcohol are hygroscopic. Moisture absorption varies to some extent with both percent hydrolysis and degree of polymerization of the Elvanol.

Polyvinyl alcohol (PVA) has many uses. Greenland (45) found that the addition of PVA to soils strengthened soil aggregates and increased

their resistance to dispersion. Van de Werken and Black (unpublished) found that fine sand treated with 1 percent (by weight) Elvanol 71-30 (hot water soluble PVA) produced higher quality pot mums than the standard Cornell peat-lite mix. They also found that PVA was effective in controlling soil erosion.



CHAPTER III

MATERIALS AND METHODS

I. PREPARATION OF MEDIA COMPONENTS

Hardwood Bark

Hardwood bark from the following 9 species of trees was obtained from the Burroughs-Ross-Colville Company in McMinnville, Tennessee:

1. American beech (Fagus americana)
2. American elm (Ulmus americana)
3. American basswood (Tilia americana)
4. Southern red oak (Quercus falcata)
5. Yellow poplar (Liriodendron tulipifera)
6. Black walnut (Juglans nigra)
7. White ash (Fraxinus americana)
8. Sugar maple (Acer saccharum)
9. Mockernut hickory (Carya tomentosa)

A blend containing an unknown mixture of bark from the above species was also obtained.

The bark was taken from the debarker and ground into two grades with a small hammer mill. The coarse grade passed through a screen with round holes 1/2-inch in diameter and 3/16-inch apart. The fine grade was acquired by passing the coarse grade through a screen with holes 1/4-inch in diameter and 1/8-inch apart.

Half of both grades of each of the 9 species of bark and the bark mixture was treated with 3 percent (by weight) Elvanol 71-30. Elvanol 71-30 is a grade of hot water soluble polyvinyl alcohol (PVA) manufactured by E. I. Dupont De Nemours and Co. (Inc.), Wilmington, Delaware. The addition of PVA to the bark was incorporated into the study to determine if plastic coating of the bark particles with PVA would prevent rapid decomposition and possible toxic effects of the bark.

Elvanol 71-30 (PVA), which is granular in form, was mixed into the bark by hand. The bark was then moistened and heated to a temperature of 94 C with steam. The treated bark was allowed to dry before placing it in plastic bags.

The treated and untreated bark was stored in a covered cold frame for 5 months (July 1971 - November 1971) before it was used in potting.

Sphagnum Peat

Canadian sphagnum peat was divided into two grades by sifting it through 18 x 16 mesh insect wire screening. The fraction that passed through the screening was considered the fine grade and the fraction which did not pass through the screening was considered the coarse grade.

Half of both grades of peat was treated with 3 percent (by weight) PVA in the same manner as was the bark. The treated and untreated peat was stored with the bark for 5 months before it was used in potting.

II. PLANT MATERIAL

Bare-rooted Japanese holly (Ilex crenata "Hetzi") liners were obtained from the Tennessee Valley Nursery of Winchester, Tennessee, on

April 29, 1971. The liners were placed into a cold frame and heeled in with sphagnum moss (Figure 1).

The liners were removed from the sphagnum moss on June 24, 1971, and tops and roots of the plants were cut to 6 inches from the crown. The liners were then planted in a loam soil inside a cold frame (Figure 2). The plants were fertilized every month with water soluble 20-20-20 fertilizer at the rate of 200 ppm nitrogen. The plants remained in the soil until the day they were potted.

III. PREPARATION OF MEDIA AND POTTING OF PLANTS

Fine untreated river sand was mixed with each of the two grades of the treated and untreated bark and peat at a ratio of 1:1 by volume. In addition, both grades of treated and untreated mixed bark and peat were also used as media without sand.

The following amounts of nutrients were incorporated into each cubic yard of mix:

1. 4 pounds Osmocote (18-9-9),
2. 4 pounds superphosphate (20 percent),
3. 5 pounds gypsum (calcium sulfate) were incorporated into bark mixes only,
4. 5 pounds calcium carbonate (reagent grade) were incorporated into peat mixes only,
5. 1 pound magnesium sulfate,
6. 1/4 pound fritted trace elements.



Figure 1. Japanese holly liners heeled in with sphagnum moss in a cold frame.



Figure 2. Japanese holly liners growing in a loam soil in a cold frame.

Gypsum was incorporated in all the mixes containing bark, while calcium carbonate was added to the mixes containing peat. This was done to prevent an anticipated rapid rise in pH in the bark mixes (7,40 41,42).

In the mixes containing 100 percent peat or bark, the amount of calcium carbonate and gypsum was increased from 5 to 7-1/2 pounds.

The plants were potted in semirigid, 4 quart, plastic pots. Fiber glass plugs were inserted into the drainage holes of the pots to prevent the loss of media.

While the plants were being potted, a gypsum block was placed midway down into the media of one pot in each treatment. The gypsum blocks were used to measure the moisture content of the media. From the moisture readings obtained from the gypsum blocks, an effort was made to maintain similar moisture levels in all media. Later in the experiment, the gypsum blocks were moved so that the top of the blocks was 3/4-inch from the top of the medium. Still later, the gypsum block readings were disregarded and pots were watered individually when they looked and felt dry.

After all the Japanese holly plants were potted (December 1, 1971 - December 21, 1971), the temperature in the greenhouse was raised from the ambient temperature to 21 C. The greenhouse temperature was kept at 21 C while the plants were in the greenhouse.

IV. PLOT ARRANGEMENT AND STATISTICAL DESIGN

In this experiment, a split-split-plot arrangement of treatments in a randomized complete block design was adopted. The two levels of

PVA were the main-plots and the two grades of bark were the split-plots. The fourteen media made up the split-split-plots. The main-plots, split-plots, and split-split-plots were randomized within each of three replications. Each treatment had four samples in each replication.

V. PLANT LOCATION AND SUPPLEMENTAL FERTILIZATION

The Japanese holly plants were grown in the greenhouse from December 21, 1971, through May 1, 1972 (Figure 3). On February 15, 1972, 600 ml of water soluble 20-20-20 fertilizer at the rate of 200 ppm nitrogen was applied to all treatments.

Iron chelate (Sequestrene 330 Fe) was applied as a foliar spray to all treatments at the rate of 1 teaspoon per gallon of water on February 23, 1972. On March 21, 1972, iron chelate was applied as a drench. Each treatment received 600 ml of iron chelate at the rate of 1 tablespoon per gallon of water.

On May 2, 1972, the plants were moved from the greenhouse into two small Quonset shade houses (Figure 4).

VI. ANALYSES OF PLANT MATERIAL

From June 15 to June 18, 1972, plants from all treatments were cut and weighed. The plants were cut just above the crown and weighed immediately. The diameter of the stems was taken with a caliper 2 cm above the point at which the stem was severed from the crown.

The plants were then dried in a large forced-air drying oven at a temperature of 70 C for 24 hours. The dried plants were taken from



Figure 3. Potted Japanese holly plants in the greenhouse.

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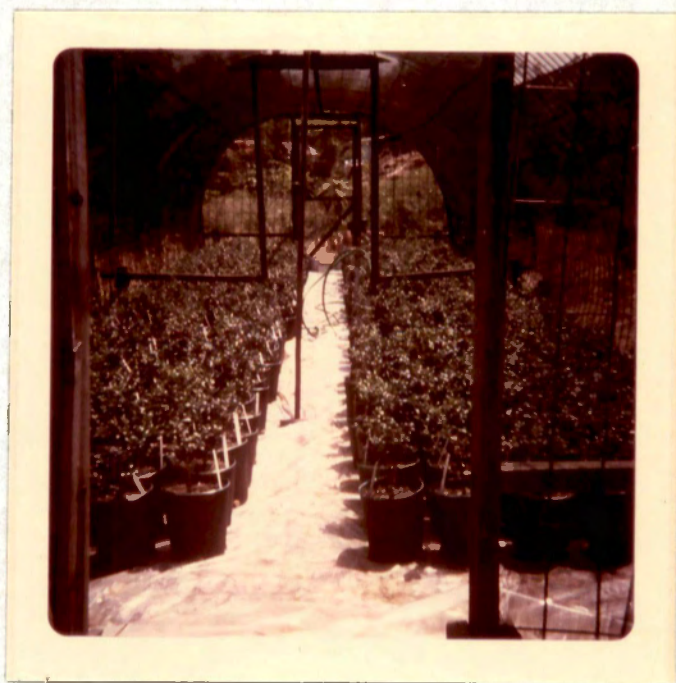


Figure 4. Japanese holly plants in Quonset shade house.

the oven and weighed. After each plant was weighed, all the leaves were stripped from the plant. The leaves from the four sample plants in each replication were pooled. The dried leaves were ground to a coarse powder in a Wiley mill and stored in air tight plastic vials.

A quantitative measure of plant growth was determined by the relative growth rate. The relative growth rate (RGR) as defined by Radford (68) is "the increase of plant material per unit of time." The mean RGR was determined by the following formula (35):

$$\overline{\text{RGR}} = \frac{\log e \text{ final dry weight} - \log e \text{ initial dry weight}}{6 \text{ (growth period in months)}}$$

The initial weight of the plants was obtained by determining the average dry weight of 60 plants chosen at random from the total population of plants before potting.

The ground leaf tissue for the analysis of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and iron (Fe) was prepared by wet ashing with sulfuric acid as described by Linder and Harley (53). Two hundred mg samples of ground leaf tissue were placed into 50-ml graduated Folin-Wu tubes. Four ml of concentrated sulfuric acid and 1 glass bead were added to the tubes. The tubes were then covered with 25 mm funnels and placed into a digestion block. The samples were allowed to stand overnight (predigestion). The digestion block was then placed on a hot plate in a fume hood and the samples were digested at 200-230 C for 2 hours. The tubes were removed from the digestion block and allowed to cool. After the tubes were cooled, 2 ml of 30 percent hydrogen peroxide were added to each tube. The tubes

were placed back into the digestion block and reheated for 30 minutes. The funnels were then removed, and the hydrogen peroxide was allowed to evaporate. The tubes were cooled and then brought to a volume of 50 ml with distilled water.

The percent of K, Ca, Mg, and Fe in the dried tissue samples was determined by analyzing the digested tissue solution with a Perkin-Elmer Atomic Absorption Spectrophotometer Model 290B.

The method used to determine the percent nitrogen in the digest was a modification of the method used by Linder and Harley (53).

Five ml aliquots of digest were transferred to 50-ml volumetric flasks. Three ml of 2.5N sodium hydroxide were added to each 5 ml of digest to partially neutralize the excess acid. After the addition of 5 ml of 10 percent sodium tartrate, 7 ml of 0.5 percent gum arabic, and 5 ml of Nessler's reagent, the volumetric flasks were brought to volume with distilled water and shaken well. The solutions were allowed to stand for 20 minutes before their absorbances were read at 480 nm on a Bausch and Lomb Spectronic 20 Colorimeter.

The absorbance of standard solutions containing from 0 to 12 ppm nitrogen was determined. The amounts of nitrogen in the standard solutions were divided by their corresponding absorbances and the resulting factors averaged to give the conversion factor. The absorbances of the unknown samples were multiplied by this factor to give the milligrams of nitrogen in the 5 ml aliquots of digest.

The percent nitrogen in the dried leaf tissue was then calculated by the following formula:

$$\text{percent nitrogen} = \frac{\text{mg nitrogen in 5 ml digest} \times 10}{200 \text{ mg}} \times 100$$

The phosphorus content of the digest was determined colorimetrically by the phosphomolybdate method (74).

The two reagents used in this method were ammonium molybdate reagent and a reducing solution. The ammonium molybdate reagent was made by dissolving 25 g of ammonium molybdate in 250 ml of distilled water, adding 125 ml of concentrated sulfuric acid, and bringing to a volume of 500 ml with distilled water.

The reducing solution was made in three steps. First, 150 g of sodium bisulfite were dissolved in 850 ml of distilled water, aged three days, filtered, and stored in a brown bottle. Next, 140 g of sodium sulfite were dissolved in 560 ml of distilled water, filtered, and stored in a brown bottle. Finally, 0.125 g of 1,2,4-amino naphthol sulfonic acid was added to 44 ml of sodium bisulfite solution. Five ml of sodium sulfite solution were added and the resulting solution was heated to a temperature just below boiling.

In this method, 10 ml aliquots of digest were pipetted into 50-ml volumetric flasks. Next, the 10 ml aliquots were diluted with 35 ml of distilled water. Five ml of ammonium molybdate solution were added and the flasks were shaken well. After the addition of 2 ml of reducing solution, the flasks were brought to volume with distilled water and shaken. The absorbances of the solutions were read on a Bausch and Lomb Spectronic 20 Colorimeter at 750 nm using the red filter and red sensitive photo-tube.

Standard solutions containing from 0 to 6 ppm phosphorus were prepared and their absorbances determined. A conversion factor was calculated in the same manner as in the nitrogen analysis. The milligrams of phosphorus in each 10 ml aliquot were determined by multiplying its absorbance by the conversion factor.

The percent phosphorus in the dried leaf tissue was then calculated by the following formula:

$$\text{percent phosphorus} = \frac{\text{mg P in 10 ml digest} \times 5}{200 \text{ mg}} \times 100$$

VII. MEDIA SHRINKAGE

The reduction in volume of media over the 6 month growing period was termed "media shrinkage." The percent media shrinkage was determined by the following formula:

$$\text{percent media shrinkage} = 1 - \frac{\text{volume of media after 6 months}}{\text{initial volume of media}} \times 100$$

VIII. ANALYSES OF MEDIA

On July 13, 1972, samples from three replications of each media were sent to the soil testing and plant analysis laboratory at the University of Georgia in Athens, Georgia.

This laboratory used the soil testing systems currently in use at Michigan State University for analyzing the media. The media samples were air dried and screened before analysis. A brief description of their analysis was as follows:

pH_W - Water pH: Deionized water was added to an aliquot of sample to have free water on the surface. After 30 minutes, the pH was determined with a glass electrode pH meter.

pH_B - Buffer pH: a 20 ml aliquot of the Adams-Evans buffer solution was added to the same sample used to determine the water pH. After stirring and standing 30 minutes, the pH was read as given above.

P - Spurway Active: A 2.5 g sample of media was extracted with 20 ml 0.015N HOAc. Media composed of 100 percent peat and 100 percent bark were extracted with 40 ml 0.015N HOAc. Results were given in ppm.

K, Ca, Mg - Exchangeable: A 2.5 g sample of media was extracted with 20 ml 1N NH_4OAc , pH 7.0. Media composed of 100 percent peat and 100 percent bark were extracted with 40 ml 1N NH_4OAc . Results were given in ppm.

Mn and Fe - Extractable: A 2.5 g sample of media was extracted with 20 ml 0.1N HCl. Media composed of 100 percent peat and 100 percent bark were extracted with 40 ml 0.1N HCl. Results were given in ppm.

$\text{NO}_3\text{-N}$ - A 2.5 g sample of media was extracted with 50 ml saturated calcium sulfate solution. Media composed of 100 percent peat and 100 percent bark were extracted with 100 ml of saturated calcium sulfate solution. Results were given in ppm.

Soluble Salts - a 50 ml aliquot of mix was leached with 100 ml of water and the conductivity determined on the extract. The results were given in $\text{mhos} \times 10^{-5}$.

Density - The weight of 25 ml of mix was determined and the results expressed as grams per cc.

IX. ANALYSES OF DATA

All results were subjected to the standard analysis of variance according to Snedecor (67) and the means were analyzed for significance using Duncan's multiple range test (27). All analyses of data were carried out on an IBM 360/65 computer system at The University of Tennessee Computing Center.

CHAPTER IV

RESULTS AND DISCUSSION

I. PROBLEMS ENCOUNTERED DURING GROWTH OF THE PLANTS

Fertilizer Burn

The attempt to regulate the moisture levels in the pots with gypsum blocks was a failure. The gypsum blocks were not sensitive enough to read small changes in moisture level. Only after the media became very dry did the blocks read any change in moisture level. The failure of the gypsum blocks could have been due to the coarse texture of the soilless media. There probably was not enough contact between medium and gypsum block to draw the moisture from the block. Therefore, the medium around the gypsum block could become very dry before the gypsum block would read any change in moisture level. As a result of allowing the media to become dry, some of the plants developed symptoms of fertilizer burn (high soluble salts). Browning of the leaf margins and partial defoliation were the symptoms that were manifested in the least severely affected plants (Figure 5). In cases of heavy fertilizer burn, complete defoliation occurred. Fertilizer burn occurred almost exclusively in media containing 50 or 100 percent peat. There were only two bark media which showed symptoms of fertilizer burn. Plants grown in a 1:1 mix of untreated (without PVA) coarse walnut bark and sand and in a 1:1 mix of treated coarse elm bark and sand developed slight symptoms of fertilizer burn.



Figure 5. Japanese holly plants with fertilizer burn.

CRANES & DRESS

The burned plants recovered completely after heavy watering.

At this point, the gypsum block readings were no longer taken, and the pots were watered when they looked and felt dry. While the plants were in the greenhouse, the bark media required watering approximately once every two weeks. The media containing peat remained moist from 2-1/2 to 3 weeks. There was some difficulty in judging the moisture level of media containing 100 percent bark. The surface of bark dried very quickly, so the media looked dry 24 hours after watering. In order to make an accurate determination, it was necessary to note the moisture level 1 inch below the surface of the media.

Chlorosis

The leaves of plants in about half the treatments began to show symptoms of iron chlorosis about 5 weeks after potting (Table 1). The leaves developed the typical yellowing between veins which is characteristic of iron deficiency in holly (Figure 6).

All plants grown in media containing ash bark, untreated (without PVA) coarse poplar bark, untreated coarse beech bark, and treated fine elm bark developed heavy chlorosis (Table 1).

With the exception of the untreated coarse basswood medium, light chlorosis occurred in plants grown in all media containing walnut bark and basswood bark. Light chlorosis also developed in plants grown in some of the media containing hickory bark, maple bark, oak bark, elm bark, and peat. The plants grown in the check medium (untreated peat and sand) also became slightly chlorotic (Table 1).

TABLE 1

EFFECT OF MEDIA AND pH ON CHLOROSIS OF JAPANESE HOLLY

Treatment	Grade	Media	pH ^a	Chlorosis ^b	
				Before Iron	After ^c Iron
Without PVA	Coarse	Peat + Sand ^d (Ck)	5.2	L	-
		Ash + Sand	8.3	H	L
		Poplar + Sand	8.5	H	-
		Walnut + Sand	5.0	L	-
		Basswood + Sand	6.6	-	-
		Hickory + Sand	7.1	-	-
		Elm + Sand	5.3	-	-
		Beech + Sand	6.5	H	-
		Maple + Sand	6.3	-	-
		Oak + Sand	6.6	-	-
		Mixed Bark + Sand	6.9	-	-
		100% Mixed Bark	6.8	-	-
		100% Peat	5.4	-	-
		Peat + Sand	5.0	-	-
	Fine	Peat + Sand (Ck)	5.2	L	-
		Ash + Sand	8.0	H	L
		Poplar + Sand	8.0	L	-
		Walnut + Sand	5.2	L	-
		Basswood + Sand	7.3	L	-
		Hickory + Sand	6.9	L	-
		Elm + Sand	6.5	-	-
		Beech + Sand	6.9	-	-
		Maple + Sand	6.1	L	-
		Oak + Sand	6.3	-	-
		Mixed Bark + Sand	6.5	-	-
		100% Mixed Bark	6.7	-	-
With PVA	Coarse	Peat + Sand ^d (Ck)	5.1	L	-
		Ash + Sand	7.8	H	L
		Poplar + Sand	7.1	L	-
		Walnut + Sand	6.6	L	-
		Basswood + Sand	6.6	L	-
		Hickory + Sand	6.8	-	-
		Elm + Sand	7.1	L	-
		Beech + Sand	6.7	-	-

TABLE 1 (continued)

Treatment	Grade	Media	pH ^a	Chlorosis ^b	
				Before Iron	After ^c Iron
With PVA	Coarse	Maple + Sand	6.7	-	-
		Oak + Sand	6.4	L	-
		Mixed Bark + Sand	7.0	-	-
		100% Mixed Bark	6.4	-	-
		100% Peat	5.1	-	-
		Peat + Sand	5.5	L	-
	Fine	Peat + Sand (Ck)	5.2	L	-
		Ash + Sand	7.7	H	L
		Poplar + Sand	6.7	L	-
		Walnut + Sand	6.7	L	-
		Basswood + Sand	7.1	L	-
		Hickory + Sand	6.7	L	-
		Elm + Sand	7.2	H	L
		Beech + Sand	7.2	-	-
		Maple + Sand	6.2	-	-
		Oak + Sand	6.1	-	-
		Mixed Bark + Sand	6.9	-	-
		100% Mixed Bark	6.7	-	-
		100% Peat	5.5	-	-
		Peat + Sand	5.6	-	-

^apH determined from a leachate with a glass electrode pH meter.

^bH denotes heavy chlorosis, L denotes light chlorosis, and (-) denotes no chlorosis.

^cIron chelate (Sequestrene 330 Fe) applied as a foliar spray (1 teaspoon per gallon) and again as a drench (1 tablespoon per gallon).

^dIn media where sand was a component it composed 50 percent of the media.



Figure 6. Chlorosis in Japanese holly plants.

After the application of iron chelate, chlorosis was still evident in the plants grown in all media containing ash bark and in the media containing treated fine elm bark, but the application of iron chelate completely eliminated plant chlorosis in the other media.

With the exception of the 50 percent mixed bark media and the check medium, there was no significant difference between the iron content of plants grown in media containing ash bark and elm bark and the plants grown in the other medium. These two media produced plants with significantly higher iron content than did any other media.

The cause of chlorosis in the plants grown in mixtures containing 1:1 bark and sand, 1:1 peat and sand, and 100 percent peat was not obvious. Antognini (8) states that iron chlorosis may be caused by actual deficiency of iron in the media or lack of available iron. The unavailability of iron could have been due to a high pH (above approximately 7.0), a high manganese content, a high copper content, or a high CaCO_3 content of the media.

Iron was applied in equal amounts to each media in the form of a fritted trace element. However, chlorosis developed in plants in at least one medium containing one each of the 9 bark species. It occurred most frequently in media containing ash, poplar, and walnut barks and was most severe in media containing ash bark. Chlorosis of plants did not occur in any media containing mixed bark.

The pH of the media may have had some effect on the development of chlorosis in the plants. In most cases of heavy chlorosis, the media had a pH above 7.0 (Table 1). The only exception was the medium

containing untreated coarse beech bark which produced heavily chlorotic plants when the pH of the medium was 6.5. However, light chlorosis of the plants occurred in media ranging in pH from 6.5 to 4.9 (Table 1, page 41). At this pH range, the iron should have been readily available. There were also cases where the pH of the medium was above 7.0 (untreated coarse hickory) and no chlorosis developed in the plants. This suggests that there could have been some interaction between the amount of iron present and the availability of the iron.

Morris and Milbocker (58) found that Japanese holly plants developed a chlorosis very similar to that described for iron deficient Japanese holly plants when they grew in a medium containing red oak bark. They suggested that the manganese was preferentially leached from the bark, raising the ratio of manganese to iron higher than the plants could tolerate. Sommers and Shive (68) suggested that manganese inactivates iron in leaves by oxidizing it to the ferric state with consequent precipitation as ferric organic complexes. Bennett (13) found that manganese is not very toxic, that it does not interfere with utilization of iron in the leaf, and that the ratio of manganese to iron in the tissue has no relation to the chlorosis produced. He states that manganese evidently produced chlorosis by depressing absorption of iron.

The media which produced chlorotic plants in spite of the addition of iron chelate (1:1 mix of ash and sand) had, in some cases, a significantly lower manganese content than media in which iron chlorosis of the plants was alleviated with the addition of iron chelate. The media composed of 100 percent mixed bark produced plants which never showed

symptoms of iron chlorosis but had a significantly higher manganese content than any other media.

Teuscher and Adler (70) stated that surplus calcium, magnesium, and potassium can depress the absorption of other nutrient elements such as iron and manganese. They also stated that a high phosphate level lowers the solubility and thus the availability of iron. The phosphorus content of the media which produced heavy chlorosis in plants was very high, i.e., ash bark media phosphorus content was 183.7 ppm. Teuscher and Adler (70) also reported that a high calcium content in plants can induce physiological iron deficiency. They stated that after the iron was absorbed by the roots the movement of the elements within the plant was impeded by being precipitated within the cells. They found that the addition of iron to the soil was quite useless. The calcium content of plants grown in media containing ash bark was significantly higher than that of plants grown in the other media. The calcium-induced physiological iron deficiency could explain why the plants grown in the media containing ash bark still remained chlorotic after the addition of iron chelate.

Fungi

Three weeks after potting, saprophytic fungi began to appear on media containing bark. Fungi grew on media containing mixed bark and media containing each species of bark, except basswood bark. The fungal growth was particularly heavy in media containing poplar bark (Figure 7).



Figure 7. Saprophytic fungi in media containing poplar bark.

The polyvinyl alcohol treatment and grade of bark had no effect on the occurrence of the fungi. Most of the fungal growths were gone two to three weeks from their appearance.

II. CHARACTERISTICS OF THE PLANTS

A brief description of the plants grown in each medium is presented in Table 2. Plants grown in media containing ash bark were poor (Figure 8B). The plants were small with small, yellowish-green leaves. The leaves showed symptoms of iron deficiency. Leaves of plants grown in media containing treated fine elm bark also showed symptoms of iron deficiency.

The untreated coarse mixed bark and sand medium and the treated coarse peat and sand medium produced small, poorly branched plants with small leaves (Figure 8C and 8D). Plants grown in media containing untreated fine oak and treated coarse oak (Figure 8E) were poorly branched and had yellowish-green leaves. The leaves of plants grown in media composed of 100 percent mixed bark, with the exception of untreated coarse mixed bark, were yellowish-green in color (Figure 8F). The yellowing of the leaves was general and not characteristic of chlorosis due to iron deficiency. This same general yellowing of the leaves occurred in plants grown in media containing treated coarse maple bark (Figure 8G).

Most of the media containing bark, with the exception of the above mentioned, produced plants which were as good as those grown in the check medium (Figure 9).

TABLE 2

EFFECT OF MEDIA ON LEAF COLOR AND DEVELOPMENT OF JAPANESE HOLLY

Grade	Treatments		Leaf Color	Leaf Size	Branching	Plant Size	Comments
	Without	PVA					
Coarse	Peat + Sand* (Ck)		Green	Medium	Medium	Medium	
	Basswood + Sand		Green	Medium	Medium	Medium	
	Maple + Sand		Green	Medium	Medium	Large	
	Walnut + Sand		Green	Medium	Medium	Medium	
	Ash + Sand		Yellow	Small	Light	Small	Poor plant, Chlorosis
	Elm + Sand		Green	Medium	Medium	Medium	
	Beech + Sand		Green	Small	Medium	Small	
	Oak + Sand		Green	Medium	Medium	Large	
	Hickory + Sand		Green	Medium	Light	Medium	
	Poplar + Sand		Green	Small	Medium	Small	
	Mixed Bark + Sand		Green	Small	Light	Small	Poor plant
	100% Mixed Bark		Green	Medium	Medium	Medium	
	Peat + Sand		Green	Medium	Medium	Medium	
	100% Peat		Green	Medium	Medium	Medium	
	Peat + Sand (Ck)		Dark Green	Medium	Heavy	Medium	Good plant
Fine	Basswood + Sand		Green	Medium	Medium	Medium	
	Maple + Sand		Green	Medium	Medium	Medium	
	Walnut + Sand		Green	Medium	Medium	Medium	
	Ash + Sand		Green	Small	Light	Small	Poor plant, Chlorosis
	Elm + Sand		Green	Medium	Medium	Medium	
	Beech + Sand		Green	Medium	Medium	Large	
	Oak + Sand		Yellow	Medium	Light	Medium	Poor plant
	Hickory + Sand		Green	Medium	Medium	Large	
	Poplar + Sand		Green	Small	Medium	Medium	
	Mixed Bark + Sand		Green	Medium	Medium	Medium	
	100% Mixed Bark		Yellow	Medium	Light	Medium	Poor plant
	Peat + Sand		Dark Green	Medium	Heavy	Large	
	100% Peat		Dark Green	Large	Heavy	Large	
	Peat + Sand (Ck)		Dark Green	Medium	Medium	Medium	Poor plant
							Good plant
							Very good plant

TABLE 2 (continued)

Grade	Treatments		Leaf Color	Leaf Size	Branching	Plant Size	Comments
	With PVA						
Coarse	Peat + Sand ^a (Ck)		Green	Medium	Heavy	Medium	Dense plant
	Basswood + Sand		Green	Medium	Medium	Medium	
	Maple + Sand		Yellow Green	Medium	Medium	Small	Poor plant
	Walnut + Sand		Green	Medium	Medium	Medium	
	Ash + Sand		Yellow Green	Small	Light	Small	Poor plant, Chlorosis
	Elm + Sand		Yellow Green	Medium	Medium	Medium	
	Beech + Sand		Green	Medium	Medium	Medium	
	Oak + Sand		Yellow Green	Medium	Light	Medium	Poor plant
	Hickory + Sand		Green	Medium	Medium	Medium	
	Poplar + Sand		Green	Medium	Light	Medium	
	Mixed Bark + Sand		Green	Medium	Medium	Large	
	100% Mixed Bark		Yellow Green	Medium	Light	Small	Poor plant
	Peat + Sand		Green	Small	Light	Small	
	100% Peat		Green	Medium	Heavy	Medium	Dense plant
	Peat + Sand (Ck)		Green	Medium	Heavy	Large	Good plant
Fine	Basswood + Sand		Green	Medium	Light	Large	
	Maple + Sand		Green	Medium	Light	Large	
	Walnut + Sand		Green	Small	Medium	Medium	Tall plant
	Ash + Sand		Yellow Green	Small	Medium	Small	Poor plant, Chlorosis
	Elm + Sand		Yellow Green	Medium	Light	Medium	Chlorosis
	Beech + Sand		Yellow Green	Medium	Light	Medium	
	Oak + Sand		Green	Medium	Medium	Large	
	Hickory + Sand		Green	Medium	Light	Large	
	Poplar + Sand		Green	Medium	Medium	Medium	
	Mixed Bark + Sand		Green	Medium	Medium	Large	
	100% Mixed Bark		Yellow Green	Medium	Medium	Medium	
	Peat + Sand		Dark Green	Large	Medium	Large	Good plant
	100% Peat		Dark Green	Large	Heavy	Large	Good plant

^aIn media where sand was a component it composed 50 percent of the media.



A. Check medium.



B. Treated coarse ash and sand.



C. Untreated coarse mixed bark and sand.



D. Treated coarse peat and sand.

Figure 8. Characteristics of Japanese holly grown in different media.



E. Treated coarse oak and sand.



F. Treated coarse mixed bark.



G. Treated coarse maple and sand.

Figure 8. (continued)



Untreated coarse maple and sand.



Check medium.

Figure 9. Japanese holly plants grown in media containing maple bark.

The most attractive plants were grown in media containing both treated and untreated fine peat. While the 1:1 mixture of fine peat and sand produced good plants, the 100 percent fine peat produced plants which were superior to all other plants (Figure 10).

III. GROWTH RESPONSES OF THE PLANTS

Fresh Weight

The fresh weight of the plants grown in the 14 media are presented in Table 3. Plants grown in 100 percent peat had significantly higher fresh weight than plants grown in any other media. The media composed of maple bark and sand produced plants with an average fresh weight of 37.91 g. This was significantly lower than plants grown in 100 percent peat, but significantly higher than plants grown in any other media. The plants grown in media composed of basswood bark and sand, mixed bark and sand, and peat and sand produced plants with an average fresh weight significantly higher than plants grown in the check medium. The average fresh weight of plants grown in media containing walnut, elm, beech, oak, and hickory barks was not significantly different from that of the plants grown in the check medium. The two media composed of poplar bark and 100 percent mixed bark yielded plants of significantly lower fresh weights than all other media with the exception of the media containing ash bark. The ash bark and sand media produced plants of significantly lower fresh weight than plants grown in any other media.

The addition of PVA to bark and peat had no significant effect on the fresh weight of the plants grown in media containing these treated components (Table 4).



Untreated fine peat.



Untreated fine peat and sand.

Figure 10. Japanese holly plants grown in media containing fine peat,

TABLE 3

EFFECT OF MEDIA ON THE GROWTH OF JAPANESE HOLLY

Media ^a	Fresh Wt. (g)	Dry Wt. (g)	Percent Dry Wt.	Stem Dia. (mm)	Mean Relative ^b Growth Rate Per Month
Peat + Sand (Ck)	28.53 ef ^c	9.52 f	33.60 e	7.210 de	.1460 d
Basswood + Sand	31.91 cd	11.76 c	37.45 b	7.991 a	.1778 bc
Maple + Sand	37.19 b	12.84 b	34.50 de	7.731 ab	.1938 ab
Walnut + Sand	30.61 de	11.09 c-e	36.83 bc	7.350 b-d	.1695 c
Ash + Sand	17.35 h	6.83 h	39.46 a	6.933 e	.0906 f
Elm + Sand	26.68 f	10.24 ef	38.76 a	7.743 ab	.1601 cd
Beech + Sand	29.57 d-f	10.78 c-e	36.85 bc	7.876 a	.1674 c
Oak + Sand	29.65 d-f	10.38 d-f	35.10 d	7.743 ab	.1594 cd
Hickory + Sand	31.62 c-e	11.33 cd	36.02 c	7.611 a-d	.1758 c
Poplar + Sand	20.35 g	7.62 gh	39.44 a	7.210 de	.0998 f
Mixed Bark + Sand	32.17 cd	11.43 cd	36.24 c	7.921 a	.1707 c
100% Mixed Bark	23.00 g	8.44 g	36.70 bc	7.441 b-d	.1275 e
Peat + Sand	33.99 c	11.31 cd	34.07 e	7.313 c-e	.1672 c
100% Peat	44.25 a	13.82 a	32.09 f	7.644 a-c	.1985 a

^a In media where sand was a component it composed 50 percent of the dry media.

^b Determined by the following formula: $\overline{\text{RGR}} = \frac{\text{Log e final dry wt.} - \text{Log e initial dry wt.}}{6 \text{ months}}$

^c Means followed by a common letter are not significantly different at $P > 0.05$.

TABLE 4
EFFECT OF POLYVINYL ALCOHOL AS A MEDIUM ADDITIVE
ON THE GROWTH OF JAPANESE HOLLY

Treatment	Fresh Wt. (g)	Dry Wt. (g)	Percent Dry Wt.	Stem Dia. (mm)	Mean Relative ^a Growth Rate Per Month
Without PVA	30.18 a ^b	10.63 a	36.08 a	7.585 a	.1597 a
With PVA ^c	29.37 a	10.42 a	36.36 a	7.512 a	.1551 a

^a Determined by the following formula: $\overline{\text{RGR}} = \frac{\text{Log } e \text{ final dry wt.} - \text{log } e \text{ initial dry wt.}}{6 \text{ months}}$

^b Means followed by a common letter are not significantly different at $P > 0.05$.

^c Bark and peat treated with 3 percent (by weight) polyvinyl alcohol.

The fine grade of organic components added to the media produced plants of significantly higher fresh weight than plants grown in media containing the coarse grade (Table 5).

The effect of grade and media on the fresh weight of the plants is shown in Table 6. Media containing the fine grade of basswood bark, maple bark, beech bark, hickory bark, 50 percent mixed bark, and both 50 percent peat and 100 percent peat yielded plants of significantly higher fresh weight than plants grown in media containing the coarse grade of these barks and peat. The grade of ash bark, walnut bark, oak bark, poplar bark, and 100 percent mixed bark had no significant effect on the fresh weight of plants grown in media containing these species of bark. The plants grown in media containing coarse elm bark had a significantly higher average fresh weight than plants grown in media containing fine elm bark.

Dry Weight

The dry weights of the plants grown in the 14 media are presented in Table 3. The media consisting of 100 percent peat yielded plants of significantly higher dry weight than plants grown in any other media. The dry weight of plants grown in the media containing maple bark was significantly lower than that of plants grown in 100 percent peat, but significantly higher than that of plants grown in any other media. The plants grown in media containing basswood bark, walnut bark, beech bark, hickory bark, mixed bark, and peat produced plants of significantly higher dry weight than plants grown in the check medium. The dry weight of plants grown in media containing elm and oak bark was not

TABLE 5
EFFECT OF GRADE OF THE ORGANIC COMPONENTS OF THE MEDIA
ON THE GROWTH OF JAPANESE HOLLY

Grade	Fresh Wt. (g)	Dry Wt. (g)	Percent Dry Wt.	Stem Dia. (mm)	Mean Relative ^a Growth Rate Per month
Coarse	26.52 b ^b	9.60 b	36.89 a	7.342 b	.1441 b
Fine	33.04 a	11.46 a	35.56 a	7.760 a	.1708 a

^a Determined by the following formula: $\overline{\text{RGR}} = \frac{\text{Log e final wt.} - \text{Log e initial dry wt.}}{6 \text{ months}}$

^b Means followed by a common letter are not significantly different at $P > 0.05$.

TABLE 6
EFFECT OF GRADE OF THE ORGANIC COMPONENTS AND MEDIA
ON THE GROWTH OF JAPANESE HOLLY

Grade	Media ^a	Fresh Wt. (g)	Dry Wt. (g)	Stem Dia. (mm)	Mean Relative ^b Growth Rate Per Month
Coarse	Peat + Sand (Ck)	24.48 k-n ^c	8.42 l-o	7.012 j-m	.1275 i-l
	Basswood + Sand	23.38 h-k	10.65 f-j	7.780 b-i	.1610 e-h
	Maple + Sand	34.21 d-g	11.72 d-g	7.284 g-m	.1784 c-e
	Walnut + Sand	30.43 f-j	11.02 e-h	7.342 f-m	.1704 c-g
	Ash + Sand	17.84 pq	7.04 op	7.069 j-m	.0987 m-o
	Elm + Sand	30.02 g-j	11.04 e-h	7.574 e-j	.1740 c-f
	Beech + Sand	27.17 j-m	10.21 g-k	7.590 d-j	.1600 e-h
	Oak + Sand	27.60 i-l	9.90 h-l	7.681 c-i	.1528 e-i
	Hickory + Sand	28.42 h-k	10.18 g-k	7.367 f-l	.1574 e-h
	Poplar + Sand	19.18 o-q	7.24 op	7.177 i-m	.0906 no
	Mixed Bark + Sand	29.13 h-j	10.68 f-j	7.557 f-j	.1497 e-i
	100% Mixed Bark	24.48 k-n	9.13 j-n	7.706 b-i	.1421 g-j
	Peat + Sand	22.89 m-o	8.09 m-p	6.755 m	.1194 j-m
	100% Peat	27.02 j-m	9.05 k-n	6.896 k-m	.1360 h-k
	Peat + Sand (Ck)	32.59 d-h	10.61 f-j	7.408 f-k	.1645 d-g
Fine	Basswood + Sand	35.44 d	12.87 cd	8.202 a-c	.1947 bc
	Maple + Sand	40.16 c	13.97 bc	8.177 a-d	.2093 b
	Walnut + Sand	30.80 e-j	11.16 e-h	7.359 f-l	.1686 c-g
	Ash + Sand	16.87 q	6.62 p	6.796 lm	.0825 o
	Elm + Sand	23.33 l-o	9.43 i-m	7.913 a-f	.1462 f-i
	Beech + Sand	31.98 d-i	11.35 e-h	8.161 a-e	.1748 c-f
	Oak + Sand	31.70 d-j	10.85 f-i	7.805 a-h	.1660 d-g
	Hickory + Sand	34.83 d-f	12.47 d-e	7.855 a-h	.1942 bc
	Poplar + Sand	21.51 n-p	8.01 m-p	7.243 h-m	.1091 l-n
	Mixed Bark + Sand	35.22 de	12.18 d-f	8.285 ab	.1917 b-d

TABLE 6 (continued)

Grade	Media ^a	Fresh Wt. (g)	Dry Wt. (g)	Stem Dia. (mm)	Mean Relative Growth Rate Per Month ^b
Fine	100% Mixed Bark	21.53 n-p	7.74 n-p	7.177 i-m	.1128 k-n
	Peat + Sand	45.09 b	14.54 b	7.871 a-g	.2151 b
	100% Peat	61.49 a	18.58 a	8.392 a	.2610 A

^aIn media where sand was a component it composed 50 percent of the media.

^bDetermined by the following formula: $\overline{RGR} = \frac{\log e \text{ final dry wt.} - \log e \text{ initial dry wt.}}{6 \text{ months}}$

^cMeans followed by a common letter are not significantly different at $P > 0.05$.

significantly different from that of plants grown in the check medium. Media containing ash bark and poplar bark produced plants with significantly lower dry weights than plants grown in any other media. The dry weight of plants grown in media containing ash bark was significantly lower than that of plants grown in media containing poplar bark.

The PVA treatment of bark and peat had no significant effect on the dry weight of plants grown in media containing these treated components (Table 4, page 57).

The effect of grade of the organic components added to the media on the dry weight of plants was found to be significant (Table 5). The effect of grade and media on the dry weights of plants is presented in Table 6. Media containing the fine grade of basswood bark, maple bark, hickory bark, and both 50 percent peat and 100 percent peat grew plants of significantly higher dry weight than media containing the coarse grade of these barks and peat. The grade of walnut bark, ash bark, beech bark, oak bark, poplar bark, and both the 50 percent mixed bark and 100 percent mixed bark had no significant effect on the dry weight of plants grown in media containing these barks. Media containing coarse elm bark produced plants of significantly higher dry weight than plants grown in media containing fine elm bark.

Percent Dry Weight

The percent dry weight of the Japanese holly plants grown in the 14 media is presented in Table 3, page 56. Media containing ash bark, elm bark, and poplar bark yielded plants with significantly higher percent dry weight than plants grown in any other media. This would be

expected, since the plants grown in media containing these barks, in particular ash and poplar bark, produced plants which had very low fresh weight.

The media containing basswood bark, walnut bark, beech bark, oak bark, hickory bark, and both 50 percent mixed bark and 100 percent mixed bark yielded plants of significantly higher percent dry weight than the check medium. Media containing maple bark and peat produced plants with a percent dry weight which was not significantly different from that of plants grown in the check medium. The percent dry weight of plants grown in the media composed of 100 percent peat was significantly lower than that of plants grown in any other media.

Polyvinyl alcohol treatment and grade had no significant effect on the percent dry weight of plants (Tables 4, page 57, and 5, page 59).

Stem Diameter

The effect of media on the stem diameter is presented in Table 3, page 56. Media to which basswood bark, 50 percent mixed bark, beech bark, 100 percent peat, oak bark, maple bark, or elm bark was added grew plants with significantly larger stem diameter than plants grown in the check medium.

The stem diameter of plants grown in media containing basswood bark, mixed bark, and beech bark was significantly larger than plants grown in media containing walnut bark, poplar bark, ash bark, and the check medium.

The effect of polyvinyl alcohol on stem diameter of the plants was not significant (Table 4).

The effect of grade of the organic components added to the media on the stem diameter of the plants was significant (Table 5, page 59). The interaction of grade and media with respect to stem diameter was also significant (Table 6, page 60). Plants grown in media containing fine maple bark and 50 percent fine mixed bark had significantly larger stem diameters than plants grown in media containing the coarse grade of these barks. The stem diameter was also significantly larger for plants grown in media containing 50 percent fine peat and 100 percent fine peat than for plants grown in media containing the coarse grade of peat. The effect of grade was not significant for the stem diameter of plants grown in media containing each of the remaining 8 species of bark or 100 percent mixed bark.

Mean Relative Growth Rate

The mean relative growth rate ($\overline{\text{RGR}}$) per month of plants grown in the 14 media is presented in Table 3, page 56. The $\overline{\text{RGR}}$ of plants grown in 100 percent peat was significantly higher than the $\overline{\text{RGR}}$ of plants grown in all the other media with the exception of those grown in media containing maple bark. Media containing maple bark produced plants which had a $\overline{\text{RGR}}$ not significantly higher than plants grown in 100 percent peat or media containing basswood bark, but significantly higher than plants grown in the other media.

The plants grown in media containing basswood bark, hickory bark, 50 percent mixed bark, walnut bark, beech bark, and 50 percent peat had a significantly higher $\overline{\text{RGR}}$ than plants grown in the check medium. The $\overline{\text{RGR}}$ of plants grown in media containing elm bark and oak bark was not

significantly different from the $\overline{\text{RGR}}$ of plants grown in the check medium. Plants grown in media containing 100 percent mixed bark, poplar bark, and ash bark had an $\overline{\text{RGR}}$ significantly lower than plants grown in any other media. The $\overline{\text{RGR}}$ of plants grown in ash and poplar bark was significantly lower than that of plants grown in 100 percent mixed bark.

The addition of polyvinyl alcohol to bark and peat had no significant effect on the $\overline{\text{RGR}}$ of plants grown in media containing these treated components (Table 4, page 57).

The effect of grade on the $\overline{\text{RGR}}$ of the holly plants was found to be significant (Table 5, page 59). Also, the effect of grade and media on the $\overline{\text{RGR}}$ of the plants was significant (Table 6, page 60).

The 100 percent fine peat media yielded plants with an $\overline{\text{RGR}}$ which was significantly higher than that of plants grown in any other media. Plants grown in media containing the fine grade of basswood bark, maple bark, hickory bark, 50 percent mixed bark, 50 percent peat, and 100 percent peat had a significantly higher $\overline{\text{RGR}}$ than plants grown in media containing the coarse grade of these barks and peat.

In plants grown in media containing walnut bark, ash bark, beech bark, oak bark, and poplar bark, the grade of bark had no significant effect on the $\overline{\text{RGR}}$. However, plants grown in 100 percent coarse mixed bark had a significantly higher $\overline{\text{RGR}}$ than plants grown in 100 percent fine mixed bark.

Radford (63) stated that the only assumption necessary in determining the $\overline{\text{RGR}}$ was that the dry weight varies without discontinuity throughout the period that the $\overline{\text{RGR}}$ is measured. The $\overline{\text{RGR}}$ can be applied

without becoming involved in any assumption about the form of the growth curves and, therefore, is particularly useful for comparing data from different experiments as well as for comparing treatment differences within a single experiment. Radford (63) also noted that meaningful values can be obtained when it is possible to take only two harvests.

IV. CHEMICAL ANALYSES OF MEDIA

The chemical analyses of the media were determined approximately 3 weeks after the plants were removed from the pots.

The nitrate nitrogen content of the media is presented in Table 7. The 100 percent peat media and the 100 percent mixed bark media contained significantly more nitrate nitrogen than any other media. The nitrate nitrogen content of the 100 percent peat media was significantly higher than the 100 percent mixed bark media. There was no significant difference in nitrate nitrogen content among the other 12 media.

The high nitrate nitrogen content of the 100 percent peat media and the 100 percent mixed bark media was probably due to their high water-holding capacity which allowed only a small loss of nitrate nitrogen by leaching. The difference in the nitrate nitrogen content of the peat and mixed bark can be explained by the greater water-holding capacity of peat. Dunn (29) found that peat had a greater water-holding capacity than hardwood or softwood bark.

Polyvinyl alcohol treatment or grade had no significant effect on the nitrate nitrogen content of the media (Tables 8 and 9).

TABLE 7

CHEMICAL COMPOSITION OF THE MEDIA THREE WEEKS
AFTER PLANTS WERE REMOVED FROM THE POTS

Media ^a	ppm						
	NO ₃	P	K	Ca	Mg	Fe	Mn
Peat + Sand (Ck)	25.00 c ^b	40.0 f	64.9 e	1083 d	147.0 c	58.67 cd	39.3 gh
Basswood + Sand	25.00 c	144.3 bc	89.0 d	1465 cd	97.7 e	53.25 d-f	57.8 de
Maple + Sand	27.08 c	92.7 de	107.7 b-d	1396 cd	108.7 de	51.67 ef	41.9 f-h
Walnut + Sand	25.00 c	133.3 bc	90.9 d	1375 cd	109.7 de	51.08 f	47.7 fg
Ash + Sand	25.00 c	183.7 a	105.0 b-d	1740 c	98.0 e	57.25 de	59.5 d
Elm + Sand	25.00 c	152.3 b	108.0 b-d	1773 c	102.0 de	53.92 d-f	69.6 c
Beech + Sand	25.00 c	125.7 c	116.7 bc	1468 cd	116.3 c-e	54.67 d-f	91.1 b
Oak + Sand	25.00 c	82.0 e	117.0 bc	1405 cd	110.0 de	72.08 b	49.4 ef
Hickory + Sand	25.00 c	106.7 d	100.7 b-d	1272 cd	115.0 c-e	63.58 c	78.0 c
Poplar + Sand	25.00 c	143.3 bc	98.0 cd	1089 d	91.7 e	69.33 b	49.5 ef
Mixed Bark + Sand	25.00 c	89.3 de	121.3 b	1578 cd	123.0 c-e	58.67 cd	74.2 c
100% Mixed Bark	47.92 b	143.0 bc	156.3 a	3740 b	251.3 b	42.83 g	130.7 a
Peat + Sand	25.00 c	40.0 f	64.2 e	1173 d	135.2 cd	56.58 d-f	33.5 h
100% Peat	91.67 a	142.0 bc	169.7 a	4517 a	545.3 a	79.67 a	37.2 h

^aIn media where sand was a component it composed 50 percent of the media.

^bMeans followed by a common letter are not significantly different at $p > 0.05$.

TABLE 8
EFFECT OF POLYVINYL ALCOHOL AS A MEDIUM ADDITIVE ON THE
CHEMICAL COMPOSITION OF THE MEDIA

Treatment	NO ₃	P	K	ppm		
				Ca	Mg	Mn
Without PVA	33.04 a ^a	111.3 a	116.6 a	1909 a	155.8 a	57.62 a
With PVA ^b	30.06 a	119.9 a	98.9 b	1673 a	151.4 a	59.99 a
						63.25 a

^aMeans followed by a common letter are not significantly different at P>0.05.

^bBark and peat treated with 3 percent (by weight) polyvinyl alcohol.

TABLE 9
EFFECT OF GRADE OF THE ORGANIC COMPONENTS ON THE
CHEMICAL COMPOSITION OF THE MEDIA

Grade	ppm					
	NO ₃	P	K	Ca	Mg	Mn
Coarse	31.25 ^a	119.4 a	108.3 a	1749 a	145.0 a	58.49 a
Fine	31.84 a	111.8 a	107.3 a	1832 a	162.2 a	59.12 a
						61.06 a
						61.70 a

^a Means followed by a common letter are not significantly different at $P > 0.05$.

The phosphorus content of media containing ash bark was significantly higher than any other media (Table 7). Elm bark media had a significantly lower phosphorus content than media containing ash bark, but significantly higher phosphorus content than any of the other 12 media. The check medium and the media composed of 50 percent peat had the significantly lowest phosphorus content of the 14 media.

Polyvinyl alcohol treatment or grade had no significant effect on the phosphorus content of the media.

The media composed of 100 percent peat and 100 percent mixed bark had potassium contents which were not significantly different from each other, but both were significantly higher than any other media. As with the phosphorus content, the check medium and the 50 percent peat media had the significantly lowest potassium content of the 14 media. The effect of grade on the amount of potassium in a medium was not significant (Table 9). However, PVA had significant effect on the potassium content of the media (Table 8). Polyvinyl alcohol significantly reduced the amount of potassium in the media. The interaction of PVA and media with respect to the potassium content of the media was found to be nonsignificant.

The calcium and magnesium contents were significantly higher in the media composed of 100 percent peat than in the other media (Table 7). With the exception of the 100 percent mixed bark media, the calcium and magnesium content of the 100 percent peat media was 3 to 5 times greater than the other media. The media composed of 100 percent mixed bark had a calcium and magnesium content significantly lower than the 100 percent peat media, but significantly higher than the other media.

The effect of PVA or grade on the calcium and magnesium content of the media was found to be nonsignificant (Tables 8, page 68, and 9, page 69).

The high potassium, calcium, and magnesium content of the media composed of 100 percent peat and 100 percent mixed bark can be explained by the high cation exchange capacity of these media.

The media composed of 100 percent peat had significantly more iron than the other media (Table 7, page 67). The iron content of media containing oak bark and poplar bark was significantly higher than the other media, with the exception of 100 percent peat. Surprisingly enough, the 100 percent mixed bark media, which was high in nitrate nitrogen, phosphorus, potassium, calcium, and magnesium had the significantly lowest iron content of all the media.

The iron content of the media was not significantly affected by PVA treatment or grade (Tables 8 and 9).

The manganese content of the media is presented in Table 7. The media composed of 100 percent mixed bark had a manganese content 2 to 3 times as high as the other media. The media containing oak bark contained significantly more manganese than the other media, with the exception of 100 percent mixed bark media. All media composed of peat or to which peat was added contained significantly less manganese than the media containing bark with the exception of maple bark and walnut bark media. This would indicate that the barks supplied the media with substantial amounts of manganese.

Polyvinyl alcohol treatment and grade had no significant effect on the manganese content of the media.

V. CHEMICAL ANALYSES OF LEAF TISSUE

The nitrogen content of the dried leaf tissue of plants grown in the 14 media is presented in Table 10. The plants grown in the media containing 50 percent peat, 100 percent peat, and the check medium had significantly higher nitrogen content than plants grown in any other media. The high nitrogen content of plants grown in 100 percent peat would be expected since this media had the highest nitrate nitrogen content of all the media. However, the high nitrogen content of plants grown in 50 percent peat media and in the check medium was not a result of high nitrate nitrogen content of these media (Table 7, page 67). Media containing ash bark produced plants with the significantly lowest nitrogen content of plants grown in any media. However, the nitrate nitrogen content of this media was not unusually low (Table 7). Klett et al. (51), working with media containing various amounts of hardwood bark, soil, peat, sand, and perlite, found that leaf tissue analyses of Forsythia intermedia showed no great difference in nitrogen, phosphorus, or potassium values. However, they found the greatest nitrogen percentage from leaf samples to be from plants grown in a 1:1:1 mix of bark, soil, and peat.

Polyvinyl alcohol and grade had no significant effect on the nitrogen content of the leaf tissue of the plants (Tables 11 and 12).

TABLE 10
EFFECT OF MEDIA ON THE CHEMICAL COMPOSITION OF JAPANESE HOLLY LEAVES

Media ^a	Percent Dry Weight in Tissue					
	N	P	K	Ca	Mg	Fe
Peat + Sand (Ck)	3.191 a ^b	.5151 a	1.781 d	1.535 d-f	.3056 gh	.1272 ab
Basswood + Sand	2.477 b-d	.1478 ef	1.776 d	1.675 c-e	.3971 b-e	.0728 c
Maple + Sand	2.515 b-d	.4058 bc	1.880 d	1.335 f	.3769 c-f	.0591 c
Walnut + Sand	2.550 bc	.1646 ef	1.974 cd	1.790 bc	.4188 a-d	.0788 bc
Ash + Sand	1.916 f	.0884 f	3.521 a	2.464 a	.3908 b-e	.0600 c
Elm + Sand	2.192 e	.1173 ef	2.427 b	1.733 b-d	.3723 d-f	.0612 c
Beech + Sand	2.375 b-e	.1797 e	1.864 d	1.881 bc	.4377 ab	.0694 c
Oak + Sand	2.382 b-e	.4592 ab	2.260 bc	1.556 d-f	.3942 b-e	.0616 c
Hickory + Sand	2.591 b	.1992 e	1.688 d	1.514 d-f	.4481 a	.0684 c
Poplar + Sand	2.486 b-d	.1345 ef	1.953 cd	1.842 bc	.4279 ab	.0750 c
Mixed Bark + Sand	2.288 c-e	.2840 d	1.860 d	1.733 b-d	.4217 a-c	.1338 a
100% Mixed Bark	2.260 de	.3608 cd	2.213 bc	1.942 b	.3698 ef	.0572 c
Peat + Sand	3.354 a	.4762 ab	1.786 d	1.648 c-e	.2904 h	.1066 a-c
100% Peat	3.357 a	.4943 a	2.016 cd	1.458 ef	.3371 fg	.0600 c

^aIn media where sand was a component it composed 50 percent of the media.

^bMeans followed by a common letter are not significantly different at $P > 0.05$.

TABLE 11
EFFECT OF POLYVINYL ALCOHOL AS A MEDIUM ADDITIVE ON THE
CHEMICAL COMPOSITION OF JAPANESE HOLLY LEAVES

Treatment	Percent Dry Weight in Tissue				
	N	P	K	Ca	Mg
Without PVA	2.638 ^a	.2846 a	2.193 a	1.738 a	3.749 a
With PVA ^b	2.496 a	.2907 a	1.950 b	1.706 a	3.949 a
					.0801 a
					.0757 a

^a Means followed by a common letter are not significantly different at $P > 0.05$.

^b Bark and peat treated with 3 percent (by weight) polyvinyl alcohol.

TABLE 12
EFFECT OF GRADE OF THE ORGANIC COMPONENTS OF THE MEDIA ON THE
CHEMICAL COMPOSITION OF JAPANESE HOLLY LEAVES

Grade	Percent Dry Weight in Tissue				
	N	P	K	Ca	Mg
Coarse	2.546 ^a	0.284 a	2.051 a	1.723 a	.3842 a
Fine	2.587 a	0.291 a	2.092 a	1.721 a	.3856 a

^a Means followed by a common letter are not significantly different at $P > 0.05$.

The phosphorus content of the leaf tissue of plants grown in the 14 media is presented in Table 10. The leaf tissue of plants grown in the check medium and the 100 percent peat media contained significantly more phosphorus than plants grown in other media with the exception of the 50 percent peat and oak bark media. However, the check medium was one of two media with the lowest phosphorus content (40 ppm) of all the media (Table 7, page 67). Also, the media containing ash bark had the significantly highest amount of phosphorus, but produced plants with the lowest phosphorus content. The reason for this contradiction is puzzling. The soil test for phosphorus determined the Spurway (69) active phosphorus. In the Spurway method (69), phosphorus is extracted from the media sample with a very dilute acetic acid solution. It is possible that at a high pH, as in the ash bark media, a large portion of the phosphorus could have been unavailable to the plants. The phosphorus could have been present in the form of tricalcium phosphate which is practically insoluble (70).

The phosphorus content of the plants was not significantly affected by PVA treatment or grade (Tables 11 and 12).

The potassium content of the plants grown in media containing ash bark was significantly higher than plants grown in the other media (Table 10). The plants grown in media containing elm bark contained significantly less potassium than plants grown in media containing ash bark, but significantly more potassium than plants grown in the other media. The potassium content of the media containing ash bark and elm bark was 105 ppm and 108 ppm, respectively. These concentrations

were not exceptionally high when compared with 169.7 ppm potassium found in the media composed of 100 percent peat.

The grade of bark or peat added to the media had no significant effect on the potassium content of the plants grown in the media (Table 12).

The polyvinyl alcohol treated bark and peat added to the media significantly affected the potassium content of plants grown in these media (Table 11, page 74). The effect of PVA and media on the potassium content of the plants was also found to be significant (Table 13). Plants grown in media containing untreated walnut, ash, elm, and poplar barks yielded plants with significantly higher potassium content than plants grown in media containing these treated barks. The media containing untreated ash bark produced plants significantly higher in potassium content than plants grown in any other media. Polyvinyl alcohol treatment of the other barks and peat did not significantly affect the potassium content of plants grown in media containing these treated barks and peat.

The low potassium content in media containing treated bark and peat, which resulted in significantly lower amounts of potassium in plants grown in these media, could be attributed to the effect of PVA on the cation exchange capacity. Polyvinyl alcohol significantly reduced the cation exchange capacity of media on the volume basis (Table 14).

The calcium content of the leaf tissue of plants grown in the 14 media is presented in Table 10, page 73. Plants grown in media

TABLE 13

EFFECT OF POLYVINYL ALCOHOL AND MEDIA ON THE POTASSIUM
CONTENT OF JAPANESE HOLLY LEAVES

Treatment	Media ^a	Percent dry Weight in Tissue K
Without PVA	Peat + Sand (Ck)	1.750 f-i ^b
	Basswood + Sand	1.917 e-i
	Maple + Sand	2.062 d-i
	Walnut + Sand	2.260 c-e
	Ash + Sand	3.750 a
	Elm + Sand	2.188 d-g
	Beech + Sand	2.083 d-i
	Oak + Sand	2.490 cd
	Hickory + Sand	1.708 g-i
	Poplar + Sand	2.271 c-e
	Mixed Bark + Sand	2.062 d-i
	100% Mixed Bark	2.167 d-h
	Peat + Sand	1.771 f-i
	100% Peat	2.219 c-f
With PVA ^c	Peat + Sand (Ck)	1.812 e-i
	Basswood + Sand	1.635 i
	Maple + Sand	1.698 hi
	Walnut + Sand	1.688 hi
	Ash + Sand	3.292 b
	Elm + Sand	2.667 c
	Beech + Sand	1.646 i
	Oak + Sand	2.031 d-i
	Hickory + Sand	1.667 i
	Poplar + Sand	1.635 i
	Mixed Bark + Sand	1.656 i
	100% Mixed Bark	2.260 c-e
	Peat + Sand	1.802 e-i
	100% Peat	1.812 e-i

^aIn media where sand was a component it composed 50 percent of the media.

^bMeans followed by a common letter are not significantly different at $P > 0.05$.

^cBark and peat treated with 3 percent (by weight) polyvinyl alcohol.

TABLE 14
CHARACTERISTICS OF THE MEDIA THREE WEEKS AFTER
THE PLANTS WERE REMOVED FROM THE POTS

Media ^a	pH	CEC meq/100g	CEC ^b meq/pot	Bulk Density g/cc	Sol. Salts mhos x 10 ⁻⁵	Percent Shrinkage
Peat + Sand (Ck)	5.3 h ^c	8.87 cd	168.6 de	.6525 c	22.6 e	3.50 de
Basswood + Sand	6.6 f	8.93 cd	198.2 a-d	.8592 a	30.8 a-d	12.03 a
Maple + Sand	6.7 f	8.99 cd	191.2 b-d	.7217 bc	28.6 b-e	4.54 cd
Walnut + Sand	7.0 de	8.59 cd	203.2 a-d	.8100 ab	35.1 ab	4.96 bc
Ash + Sand	7.4 ab	10.22 c	226.0 ab	.7892 ab	33.0 a-c	6.18 b
Elm + Sand	7.5 a	10.59 c	237.4 a	.7925 ab	31.7 a-c	5.60 bc
Beech + Sand	7.5 a	9.18 cd	217.2 a-c	.8325 a	24.2 de	5.01 bc
Oak + Sand	7.0 de	9.11 cd	215.4 a-c	.8175 a	26.8 c-e	3.44 de
Hickory + Sand	7.3 b	8.21 cd	206.1 a-d	.8633 a	29.1 a-e	4.47 cd
Poplar + Sand	7.1 cd	7.03 d	149.3 e	.8100 ab	34.7 ab	11.32 a
Mixed Bark + Sand	7.2 bc	9.86 c	194.8 b-d	.8267 a	30.4 a-d	2.66 e
100% Mixed Bark	6.9 e	22.60 b	206.2 a-d	.3117 d	35.5 a	3.46 de
Peat + Sand	5.8 g	9.12 cd	177.6 c-e	.6608 c	27.1 c-e	2.90 e
100% Peat	5.0 i	33.53 a	167.4 de	.1750 e	27.1 c-e	2.53 e

^aIn media where sand was a component it composed 50 percent of the media.

^bDetermined by the following formula: CEC in meq/pot = CEC in meq/100g x bulk density in g/cc x volume of media in cc.

^cMeans followed by a common letter are not significantly different at P>0.05.

containing ash bark had a significantly higher calcium content than plants grown in other media. The calcium content of the media containing ash bark was not significantly higher than most media containing bark. It contained significantly less calcium than did the 100 percent mixed bark or 100 percent peat. The calcium content of the plants grown in 100 percent mixed bark was significantly higher than plants grown in media containing basswood bark, hickory bark, 50 percent peat, oak bark, maple bark, 100 percent peat, and the check medium.

Polyvinyl alcohol and grade had no significant effect on the calcium content in the leaf tissue of the plants (Tables 11, page 74, and 12, page 75).

The leaf tissue analysis showed no great difference in magnesium content among plants grown in the 14 media (Table 10, page 73). However, the media containing peat produced plants with the lowest magnesium content. This occurred in spite of the fact that the magnesium content of the 100 percent peat media was 4 times as great as most of the media containing bark.

Polyvinyl alcohol and grade had no significant effect on the magnesium content in the dried leaves of the plants (Tables 11 and 12).

Klett et al. (51) found that the calcium and magnesium content of leaf tissue from two cultivars of forsythia was higher in bark-amended mixes than in a standard 1:1:1 mix of soil, peat, and perlite. They suggested that the reason for this was the high concentration of calcium and magnesium in the bark material or in the water used during the experiment.

The iron content of plants grown in media containing 50 percent mixed bark was significantly higher than plants grown in the other media, with the exceptions of the check medium and the 50 percent peat media (Table 10, page 73). The 50 percent mixed bark media did not contain a high amount of iron (Table 7, page 67).

The media consisting of 100 percent peat produced plants with a significantly lower iron content than the plants grown in the check medium, in spite of the fact that this media had a significantly higher iron content than all other media. Due to the low pH of this media (pH 5.0) the iron should have been readily available (Table 14, page 79). Klett et al. (51) found that forsythia plants grown in media containing peat had a higher iron content than plants grown in media containing bark. They stated that since the pH values of mixes containing peat and soil are more acidic than the bark and sand mixes, the iron cations are more soluble.

VI. CHARACTERISTICS OF THE MEDIA

The following media characteristics were determined approximately 3 weeks after the plants were removed from the pots.

pH

The media containing ash bark, elm bark, beech bark, and oak bark had a pH of 7.0 or above (Table 14). The pH of media containing elm and beech bark was significantly higher than any other media with the exceptions of media containing ash bark. The media containing basswood bark,

maple bark, and 100 percent mixed bark had pH values of 6.6, 6.7, and 6.9, respectively.

The media containing peat were acidic (Table 14, page 79). The media composed of 100 percent peat had the significantly lowest pH of all the media.

Klett et al. (51) reported that the pH values of mixes containing peat and soil were more acidic than the bark and sand mixes. It is well established in the literature that the addition of lime will result in a rapid rise in pH of media containing hardwood bark (42,41,3,7,48). Harkin (48) stated that the acidic nature of bark begins to subside 4 to 5 months after the initial potting due to an increase in cation exchange capacity of the media as a result of decomposition. Gartner et al. (40) found that the amount the pH would increase in hardwood bark mixtures depended on the amount of bark in the mixture, the pH of the sand or soil that was mixed with the bark, and the pH of the irrigation water. They suggested that where the irrigation water, the sand, or the soil in the mix was alkaline, 1 pound of flowers of sulphur should be added to each cubic yard of mix.

Cation Exchange Capacity

The cation exchange capacity (CEC) of the media is presented in Table 14. The CEC is presented in milliequivalents (meq) per 100 g of media and in meq per pot of medium. In a study to correlate physical and chemical properties of natural and artificial media combinations to cultural requirements and plant growth responses, Joiner and Conover

(49) found that the CEC is of value to container plant growers only if reported in terms of meq per volume rather than meq per 100 g.

The CEC per 100 g (CEC/100 g) of 100 percent peat media was significantly higher than the other media. The 100 percent mixed bark media had a CEC/100 g significantly lower than that of the media composed of 100 percent peat, but significantly higher than the other media. The high CEC/100 g of these two organic media was expected. However, after converting the CEC/100 g to CEC per pot (CEC/pot), the CEC of these two media were reduced in relation to the other media. The CEC/pot of the 100 percent peat media was significantly lower than the CEC/pot of media containing elm, ash, beech, or oak bark. Joiner and Conover (50) stated that organic materials which usually have low bulk densities should not be added to mixtures for container growing of plants above the level at which the CEC decreased in meq per volume while the meq per weight increased.

The CEC/pot of media containing elm bark, ash bark, beech bark, and oak bark was significantly greater than the CEC/pot of the check medium. The CEC/pot of media containing poplar bark was the lowest of all the media. However, it was not significantly lower than media containing 50 percent peat, 100 percent peat, or the check medium. The reasons for the low CEC/pot of media containing ash bark are that the CEC/100 g of media containing ash bark was very low and the volume of these media was smaller than most media due to a high percentage of media shrinkage (Table 14, page 79).

Polyvinyl alcohol treatment of bark and peat had no significant effect on the CEC/100 g of the media, but it had a significant effect on the CEC/pot of the media (Table 15). Media containing either treated bark or peat had a significantly lower CEC/pot than did media containing untreated bark or peat. The interaction of PVA and media on the CEC/pot of the media was not significant.

The effect of grade was nonsignificant for CEC/100 g of media, but significant for CEC/pot of the media (Table 16). The interaction of grade and media was also significant (Table 17). The CEC/pot of media containing 50 percent fine peat and 100 percent fine mixed bark was significantly higher than it was in the coarse grade of these media. The grade of the organic component added to the media had no significant effect on the CEC/pot of the media containing other barks and peat.

Bulk Density

The bulk densities of the media are presented in Table 14, page 79. The media containing hickory bark, basswood bark, beech bark, mixed bark, and oak bark had significantly higher bulk densities than media containing maple bark, peat, 100 percent peat, 100 percent mixed bark, and the check medium.

Although the density of the 100 percent peat media was significantly lower than that of the 100 percent mixed bark media, both media had bulk densities significantly lower than those of the other media.

Polyvinyl alcohol treatment and grade had no significant effect on the bulk density of the media (Tables 15 and 16).

TABLE 15
EFFECT OF POLYVINYL ALCOHOL AS A MEDIUM ADDITIVE ON THE
CHARACTERISTICS OF THE MEDIA

Treatment	pH	CEC meq/100g	CEC ^a meq/pot	Bulk Density g/cc	Sol. Salts mhos x 10 ⁻⁵	Percent Shrinkage
Without PVA	6.7 a ^b	12.42 a	216.2 a	.7133 a	29.4 a	5.486 a
With PVA ^c	6.7 a	11.13 a	177.9 b	.7042 a	30.1 a	4.884 a

^aDetermined by the following formula: CEC in meq/pot = CEC in meq/100g x bulk density in g/cc x volume of media in cc.

^bMeans followed by a common letter are not significantly different at P>0.05.

^cBark and peat treated with 3 percent (by weight) polyvinyl alcohol.

TABLE 16
EFFECT OF GRADE OF THE ORGANIC COMPONENTS ON THE
CHARACTERISTICS OF THE MEDIA

Grade	pH	meq/100g	CEC ^a meq/pot	Bulk Density g/cc	Sol. Salts mhos x 10 ⁻⁵	Percent Shrinkage
Coarse	6.7 a ^b	11.44 a	185.47 b	.7009 a	29.8 a	4.633 b
Fine	6.7 a	12.10 a	208.64 a	.7165 a	29.7 a	5.736 a

^aDetermined by the following formula: CEC in meq/pot = CEC in meq/100g x bulk density in g/cc x volume of media in cc.

^bMeans followed by a common letter are not significantly different at $P > 0.05$.

TABLE 17

EFFECT OF GRADE AND MEDIA ON THE CEC AND
PERCENT SHRINKAGE OF THE MEDIA

Grade	Media ^a	CEC ^b meq/pot	Percent Shrinkage
Coarse	Peat + Sand (Ck)	164.1 d-h ^c	3.52 h-j
	Basswood + Sand	200.9 a-g	10.40 b
	Maple + Sand	163.0 d-h	5.82 c-f
	Walnut + Sand	206.8 a-f	4.23 e-i
	Ash + Sand	230.6 a-c	6.00 c-e
	Elm + Sand	238.6 ab	4.92 c-h
	Beech + Sand	220.6 a-d	4.83 c-i
	Oak + Sand	202.2 a-g	2.28 jk
	Hickory + Sand	183.1 b-h	4.51 c-i
	Poplar + Sand	154.7 f-h	10.97 b
	Mixed Bark + Sand	189.4 b-h	0.98 k
	100% Mixed Bark	159.2 e-h	2.95 ij
	Peat + Sand	137.1 h	2.24 jk
	100% Peat	146.2 gh	1.20 k
Fine	Peat + Sand (Ck)	173.1 c-h	3.48 h-j
	Basswood + Sand	195.4 a-h	13.66 a
	Maple + Sand	219.4 a-e	3.26 h-j
	Walnut + Sand	199.7 a-g	5.69 c-g
	Ash + Sand	221.4 a-d	6.36 c
	Elm + Sand	236.2 ab	6.28 cd
	Beech + Sand	213.9 a-f	5.18 c-h
	Oak + Sand	228.5 a-c	4.60 c-i
	Hickory + Sand	229.2 a-c	4.42 d-i
	Poplar + Sand	143.8 g	11.67 b
	Mixed Bark + Sand	200.1 a-g	4.34 e-i
	100% Mixed Bark	253.2 a	3.96 f-j
	Peat + Sand	218.2 a-e	3.55 h-j
	100% Peat	188.7 b-h	3.87 g-j

^aIn media where sand was a component it composed 50 percent of the media.

^bDetermined by the following formula: $\text{CEC in meq/pot} = \text{CEC in meq/100g} \times \text{bulk density in g/cc} \times \text{volume of media in cc}$.

^cMeans followed by a common letter are not significantly different at $P > 0.05$.

Soluble Salts

The total soluble salt levels of the media are presented in Table 14, page 79. The salt levels of the 14 media varied from 22.5 mhos (measure of electrical conductivity) for the check medium to 35.5 mhos for the 100 percent mixed bark media. In one interpretation of soluble salt levels of a 1:2 mixture of soil to water by volume, readings below 15 mhos were considered low and readings from 50 to 180 mhos were considered a satisfactory range for established plants (43). Waters et al. (72) interpreted soluble salt readings of a 1:2 mixture of dry soil to water by volume for ornamental plants. Their interpretation included salt readings for the following three types of media: (1) sandy soils, (2) media composed of 1 part sand and 1 part peat, and (3) peat or light weight media. Low salt readings for the above mentioned media were below 25 mhos, below 33 mhos, and below 50 mhos, respectively.

The soluble salts level of media containing walnut bark, poplar bark, and 100 percent mixed bark was significantly higher than media containing 50 percent peat, 100 percent peat, oak bark, beech bark, and the check medium. The relatively low salt levels of the media containing peat were unexpected. Early in the experiment, plants grown in these media suffered from high soluble salts damage.

Although there were significant differences among the total salt levels of the media, the differences were not of practical importance.

Grade and PVA treatment of the organic components had no significant effect on the soluble salt levels of the media (Tables 15 and 16).

Media Shrinkage

The percent shrinkage of the media is presented in Table 14, page 79. Shrinkage of the media was measured as the loss in volume due to decomposition of the organic components of the media. The shrinkage of a medium in container-plant production can be very important, especially if the plant is grown in the container for periods greater than 1 year.

Media containing basswood bark and poplar bark had the highest percent shrinkage. The physical properties that these two barks had in common were their fibrous nature and their low bulk density. The bark fibers of these barks tended to cling and mat together.

The percent shrinkage of media containing ash bark was significantly higher than all other media except those containing elm bark, beech bark, and walnut bark.

Media shrinkage was the lowest in media containing 50 and 100 percent peat and 50 percent mixed bark. However, the percent shrinkage for these media was not significantly lower than media containing oak bark, 100 percent mixed bark, and the check medium.

Treatment of the bark and peat with polyvinyl alcohol had no significant effect on percent media shrinkage (Table 15, page 85).

Grade of the organic components added to the media had a significant effect on media shrinkage (Table 16, page 86). Media containing the fine grade of basswood bark, oak bark, 50 percent mixed bark, and 100 percent peat had significantly higher percent shrinkage than media containing the coarse grade of these barks and peat (Table 17, page 87).

The media containing coarse maple bark had a significantly higher percent shrinkage than media containing fine maple bark. The grade had no significant effect on the percent shrinkage of media containing walnut bark, ash bark, elm bark, beech bark, hickory bark, 50 percent peat, poplar bark, and 100 percent mixed bark.

CRANES & CREST

CHAPTER V

SUMMARY

This study was conducted to evaluate milled hardwood bark as an organic component for container culture of Japanese holly (Ilex crenata 'Hetzi'). Included in the evaluation was the effect of species of bark, particle size of bark, and ratio of bark to media on the growth of Japanese holly. Polyvinyl alcohol (PVA) was added to bark before incorporation into the media to determine its effect on the rate of decomposition and possible toxic effects of the different species of bark.

The media consisted of fine river sand mixed with each of two grades (coarse and fine) of treated (PVA) and untreated bark and peat at a ratio of 1:1 by volume. In addition, both grades of treated and untreated mixed bark and peat were also used as media without sand. The check medium was composed of 1/2 untreated peat and 1/2 fine river sand.

The evaluation included plant responses and laboratory analyses of the plant material and media. The plant responses measured were: fresh weight, dry weight, percent dry weight, stem diameter, and mean relative growth rate. The laboratory analyses of the plants consisted of tissue analyses to determine the percentage of nitrogen, phosphorus, potassium, calcium, magnesium, and iron in the dried leaves of the plants. After the plants were removed from the pots, samples of the media were sent to the soil testing and plant analysis laboratory at the University of Georgia to determine the nitrogen, phosphorus, potassium,

calcium, magnesium, iron, and manganese content of the media. The pH, cation exchange capacity, bulk density and soluble salts of the media were also determined at the soil testing laboratory. The percent shrinkage of the media was determined.

Five weeks after potting, chlorosis developed in plants grown in at least one medium containing one each of the 9 bark species. Slight chlorosis also developed in some of the media containing peat. The leaves of the plants developed the typical yellowing between veins which is characteristic of iron deficiency in holly. Chlorosis was particularly heavy in plants grown in media containing ash bark, untreated coarse poplar bark, untreated coarse beech bark, and treated fine elm bark. After the addition of iron chelate, chlorosis was eliminated in plants grown in all media except in those plants grown in media containing ash bark and treated fine elm bark. One possible explanation for the failure of iron chelate to eliminate the chlorosis of plants grown in these media is that the high concentration of calcium in the media depressed the absorption of iron. Another possible explanation is that the high calcium content in the tissue induced physiological iron deficiency by precipitating the iron within the cells.

The most attractive plants were grown in media composed of 100 percent peat. These plants were large and dense with large, glossy, dark green leaves. They had significantly higher fresh and dry weight than plants grown in any other media. The stem diameter of these plants was significantly larger than plants grown in the check medium. The RGR of plants grown in 100 percent peat was not significantly higher

than plants grown in media containing maple bark, but significantly higher than plants grown in any other media. The nitrogen, phosphorus, and potassium content of the media and the plants were high. The calcium, magnesium, and iron content of these media was high, but the plants contained amounts of these elements comparable to plants grown in the other media. The average pH of these media was 5.0. The 100 percent peat media had the highest CEC/100 g, but a low CEC/pot when compared with many of the bark media. These media had the lowest bulk density, low soluble salts, and a very low percent shrinkage.

The plants grown in media composed of a 1:1 mixture of maple bark and sand and a 1:1 mixture of basswood bark and sand produced plants which were generally superior to plants grown in the check medium. These two bark media produced plants which were superior to the check medium in terms of fresh weight, dry weight, stem diameter, and $\overline{\text{RGR}}$. The maple bark and basswood bark media had pH values of 6.7 and 6.6, respectively, which were significantly lower than the pH value of any other bark media. The relatively low pH of these two media could have been the major factor contributing to their superiority to the other bark media. The cation exchange capacity of these two media was comparable to other bark media. The bulk density and percent shrinkage of basswood bark media were significantly higher than those of the maple bark media.

Plants grown in media containing walnut bark, hickory bark, elm bark, beech bark, oak bark, and 50 percent and 100 percent mixed bark were as good as plants grown in the check medium. There were some

exceptions, however, to this statement. Media containing untreated fine oak and treated coarse oak were poorly branched and had yellowish-green leaves. The leaves of plants grown in media composed of treated coarse maple and 100 percent mixed bark, with the exception of untreated coarse mixed bark, were also yellowish-green in color. The yellowing of the leaves was general and not characteristic of chlorosis due to iron deficiency. The media containing 50 percent untreated coarse mixed bark produced small, poorly branched plants with small leaves.

The media containing ash and poplar bark produced plants which were inferior to plants grown in the check medium. The plants grown in media containing poplar bark were small. Media containing ash bark produced the poorest plants of all the media. These plants were small, poorly branched with small chlorotic leaves. Both the ash bark media and the poplar bark media produced plants with a significantly higher percent dry weight than plants grown in any other media. The leaf tissue of plants grown in media containing ash bark had low nitrogen and phosphorus content, but the potassium and calcium contents were significantly higher than plants grown in other media. The pH of media containing ash bark and poplar bark was above 7.0. The CEC/pot of media containing ash bark was significantly higher than all other media, while that of poplar bark was significantly lower than all other media. The percent shrinkage of media containing poplar bark was significantly higher than the other media, with the exception of media containing basswood bark. The percent shrinkage of the ash bark media was significantly higher than the check medium.

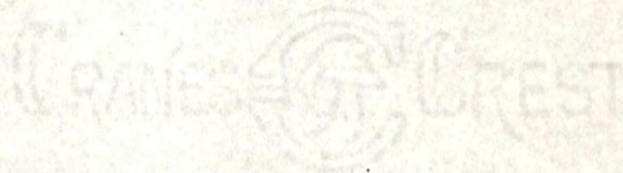
The grade of bark and peat added to the media had a definite effect on the growth of the holly plants. In general, the fine grade of bark and peat resulted in better growth than the coarse grade of bark and peat. Plants grown in media containing the fine grade of bark and peat had significantly higher fresh weights, dry weights and $\overline{\text{RGR}}$ than plants grown in media containing the coarse grade of bark and peat. The stem diameter of the plants grown in the media containing the fine grade of the organic components was significantly larger than the stem diameter of plants grown in media containing the coarse grade of these organic components. The media containing fine bark and peat had a significantly higher CEC/pot than media containing coarse bark and peat. Percent shrinkage was significantly higher in media containing the fine organic components than in media containing the coarse organic components.

The treatment of bark and peat with polyvinyl alcohol resulted in no significant effect on plant growth as an average of all media and grade. However, PVA treated bark and peat incorporated in the media resulted in a significantly lower potassium content of the media and of the plants grown in these media.

The amount of peat or bark added to the media had a definite effect on plant growth. Plants grown in 100 percent peat were superior to plants grown in media composed of 50 percent peat and 50 percent sand. However, the opposite was true for plants grown in mixed bark. The media composed of 50 percent mixed bark and 50 percent sand produced plants which were superior to plants grown in 100 percent mixed bark.

There was no evidence that toxic chemicals were released from any of the bark species. The general yellowing of leaves which occurred in the plants grown in some of the media could be attributed to nitrogen deficiency. This yellowing of leaves occurred 5 to 6 months after potting, at which time the nitrogen supplied by the Osmocote beads probably had been depleted. The chlorosis which developed in many of the treatments could be attributed to iron deficiency. The poor growth of plants grown in media containing ash bark and poplar bark is believed to have been a result of improper nutrient balance in these media.

It is evident from this study that 100 percent peat was superior to the other media for growing Japanese holly in containers. However, a 1:1 mixture of hardwood bark and sand produced plants which were as good as or better than plants grown in a 1:1 mixture of peat and sand. The media containing the fine grade of hardwood bark produced better plants than the media containing the coarse grade of bark. Hardwood bark mixture composed of 50 percent bark and 50 percent sand produced better plants than a 100 percent bark media. Special care must be taken with fertilization of bark-amended media.



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