EFFECTS OF DATE, NUTRITION AND MEDIA ON THE VEGETATIVE PROPAGATION AND GROWTH OF FIVE SELECTIONS OF LACEBARK ELM, ULMUS PARVIFOLIA

By

GARY GEORGE HICKMAN

Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

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LACEBARK ELM, _ULMUS_

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Thesis Approved:

Carl Whitcomb
Thesis Adviser

Ronald W. McNew

J. Steve Ownby

Norman N. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Ulmus parvifolia Jacq. (syn. U. sempervirens, U. chinensis Pers., U. parvifolia var. 'Sempervirens') , the lacebark elm (syn. Leatherleaf Elm, Chinese Elm), a member of the Ulmaceae family, is a native of Northern and Central China, Korea, Japan, and Formosa, and is planted across the United States (through hardiness Zone 5) especially in the Gulf and Pacific regions (2,17,22,28). Lacebark Elm is among the most adaptable of the landscape trees cultivated in the United States. Unlike some other members of the genus Ulmus, lacebark elm is highly resistant to Dutch elm disease caused by the fungus Ceratocystis ulmi, phloem necrosis caused by the virus Morus ulmi, and the elm leaf beetle Pyrrhalta luteola which have devastated several elm species (4).

Whitcomb (28) states that it is a fast grower in the southern United States, a slower grower in the northern U.S., and will attain a height of 40 to 60 feet. The species is characterized by a broad rounded crown of spreading branches and will develope a 30 to 40 foot spread. The distinctive bark has an outer layer which is mottled brown and sheds in flakes exposing a reddish-brown or salmon colored inner bark. The species is highly drought tolerant and withstands the severe conditions often associated with many urban sites such as soil compaction, restricted root systems, poor soils, and exposed locations (28).

Ulmus parvifolia Jacq. is sometimes confused with Ulmus pumila L. (28), the Siberian elm or Chinese elm. However, U. parvifolia is not suseptable to the insects and diseases which reduce the landscape value of Siberian elm.

Lacebark elm is commonly propagated by seed collected in the fall (Sept. to Oct.), cold stratified (35-40 degrees C) for 90 to 120 days, and planted in early spring (22). The average germination capacity is 55 percent (22). Schopmeyer (22) indicates that only 5 to 12 percent of the viable seed sown can be expected to produce plantable stock.

To eliminate seedling variation and increase production efficiency three cultivars of note have been named and vegetatively propagated (28). 'Sempervirens' exhibits superior foliage retention making it nearly evergreen in California and the deep south. 'Drake' has an upright growth habit with sweeping branches and dark green leaf color. 'True Green' is also more evergreen with leaves that are very glossy and dark green in color. Whitcomb (28) indicates that 'True Green' and 'Sempervirens' are less cold hardy than the species. All Three cultivars are propagated by softwood (greenwood) cuttings taken in the spring and rooted under mist.

In order to develop plants of superior landscape quality and improve nursery performance work has been done at the Oklahoma State University Nursery Research Center (unpublished work) with the selection and vegetative propagation of plants from seedling populations which exhibit superior growth rate, growth habit and foliage color. Work in this area began in 1973 when several thousand seed collected from a single tree on the O.S.U. campus were sown. At the time seed was collected, the tree was an isolated specimen on the campus. The closest pollinator was located several miles away. This proved desirable, in that the specimen from which seed was originaly collected has thrived under very adverse conditions of severe soil compaction and very restrictive conditions for root growth due to construction debris and paved surfaces. It may be that by self polination the high tollerance of this particular genotype might be transfered to its offspring.

Individuals were selected for growth form and growth rate from the seedling population that resulted in 1974. Softwood cuttings were later taken from several of the seedlings during 1977, 1978 and 1979 and some were successfully rooted. The rooted cuttings were transplanted into the field and evaluated for growth and landscape quality. Several of the vegetatively propagated plants have out performed seed propagated plants transplanted into adjacent plots, while other selections developed poorly after rooting and transplanting.

Of the selections, several plants have exibited rapid growth rate, superior foliage quality, excellent branch structure and a strong central leader. Attempts at propagating the selected trees by softwood cuttings have resulted in moderate to high rooting percentages. Hardwood cuttings have been less successful with low rooting percentages.

The purpose of this study was to evaluate five selections of *U. parvifolia* with regards to vegetative propagation by softwood cuttings and their subsequent growth. The treatments were designed to determine the effects of nutrition during propagation, propagation media, and time of taking cuttings on rooting and subsequent growth of the five selections.

CHAPTER II

LITERATURE REVIEW

Vegetative Propagation Within The Genus *Ulmus*

Early work with vegetative propagation of elms was prompted by the incidence of Dutch elm disease, phloem necrosis, and elm leaf bettles (4). Doran and McKenzie (8) evaluated the vegetative propagation of several elm species by softwood cuttings including seedlings of *Ulmus pumila*, Siberian elm, *U. parvifolia*, lacebark elm, *U. americana*, American elm, *U. japonica*, Japanese elm, and *U. carpinifolia* 'Buisman', the Christine Buisman elm. All cuttings were taken in June and treated with IBA at 0 or 50mg/l (50 ppm IBA) for 24 hrs. Siberian and lacebark elm rooted well in sand (no rooting percentages given). American elm rooted 95 percent in 5 weeks after treatment with IBA and 23 percent in 12 weeks without auxin treatment. Softwood cuttings of *U. japonica* achieved 89.3 percent rooting. Cuttings of Christine Buisman elm were taken on May 27, June 17 and July 13, however cuttings failed to root.

Bretz and Swingle (5) successfully propagated Christine Buisman elm from root cuttings. Shreiber (23) also successfully propagated America elm using root cuttings.

Cuttings taken from 10 different American elm seedlings were stuck on Nov. 30, Mar. 26 and June 14. Trees from which cuttings were taken ranged in age from 3 to 8 years. Average rooting ranged from 0 to 86.6 percent. Rooting percentages varied greatly with regard to plant age and individual trees.

Use of this method of propagation was not considered commercially feasible due to the difficulty of obtaining propagating material and the comparatively few propagules available from small trees. Pridham (19) reported that American elm softwood cuttings taken in May and June rooted 50 percent or better but rooting percentage fell off to occasional rooting from July and August cuttings in which the outer bark was light brown instead of green.

Additional benefits from propagating superior clones of trees from cuttings is the elimination of the inherent genetic variability of seed propagated elms. Whitcomb (personal communication) has indicated that field plantings of seedling lacebark elms have resulted in 25 percent or more culls at harvesting despite removal of culls when seedlings were transplanted from seedling containers to 3 gallon containers and again when transplanted from containers into the field.

Whitcomb (29) evaluated the propagation of five selections of lacebark elm which exibited superior landscape qualities. Softwood cuttings were taken on July 12, 1977, treated with talc-IBA preparation at 0, 16,000 and 30,000 ppm, and stuck in a 1:1 by volume mix of peat and perlite amended with 7.14 kg./cu.m. (12 lbs./cu.yd.) Osmocote 18-6-12. Whitcomb indicates that, " . . . cuttings rooted well, however, there appeared to be a relationship between softness of the cutting and ability to root. As the cuttings became more woody, rooting declined"(p. 53).

Storjohann et al. (25) evaluated the propagation of two seedling trees by softwood cuttings taken on July 16, and treated with 0, 8,000, 16,000, 25,000, and 35,000 ppm IBA as a talc preparation (Table I).

TABLE I

PERCENT ROOTING OF CUTTINGS FROM LACEBARK ELMS USING VARIOUS AUXIN LEVELS AFTER 5 WEEKS UNDER INTERMITTENT MIST

	Level Of IBA, ppm as a talc preperation				
	0	8,000	16,000	30.000	45,000
U. parvifolia selection #1	35	79	92	60	56
U. parvifolia selection #2	0.0	0.0	0.0	83	0.0

Cuttings from selection #1 increased rooting when treated with IBA to 92 percent at the 16,000 ppm level then declined, whereas selection #2 rooted 83 percent at the 30,000 ppm IBA level. This data also indicates substantial variation in rooting among seedling trees.

Wide variation among seedlings or clones is not limited to the lacebark elm. Sual and Zsuffa (21) evaluated the vegetative propagation of 10 clones of U. americana, 2 clones of U. pumila and 3 clones of U. japonica. Of the three American elms propagated as cuttings from the current season's growth of semi-mature wood, rooting percentages varied from 50 to 70 percent. Nine American elm clones propagated as hardwood cuttings rooted from 40 to 83 percent. Cuttings from U. pumila clones varied from 43 to 59 percent rooted. U. japonica clones rooted at 21 and 51 percent.

Fankhauser (9) studied the effect of several synthetic auxin formulations on the rooting of cuttings of Ulmus procera 'Van Houttei', the golden elm, native to southern England. Golden elm, has been propagated by grafting onto lacebark elm seedlings. However, Fankhauser states, " . . . with grafting, one person can do 300 to 400 per working day, compared to 1200 and 800 per day for softwoods and hardwoods respectively" (p. 168). Fankhauser collected cutting wood in late spring to early summer. Softwoods treated with a 50:50 0.37 percent NAA and 0.8 percent IBA solution resulted in 75 percent rooting as compared with 5 percent with no hormone treatment.

Croxton (7) reported on propagation of seedling lacebark elm and 'Catlin' elm (Ulmus parvifolia). Cuttings were made in spring and summer and rooted in 50 percent peat and 50 percent vermiculite (no rooting percentages given).

Clonal Variation Among Other Genera

Clonal variation in rooting of cuttings is not limited to the genus Ulmus. Good et al. (11) found that 6 of 15 deciduous trees studied exhibited considerable clonal variation with respect to rooting. Childers and Snyuder (6) studied the effect of time of taking cuttings on the rooting of three cultivars of American Holly (Ilex opaca). Cuttings from 'Arden', 'Old Hale and Hearty' and 'Cumberland' were collected at biweekly intervals from August 1 to November 15. The carbohydrate content at the time cuttings were taken was evaluated, because of the possibility that rooting could be predicted on this basis. Percent rooting among the three cultivars varied greatly. Within the October 15 date, 'Arden' rooted 94 percent, 'Old Hale and Hardy' 40 percent and 'Cumberland' 28 percent. All three cultivars rooted best on September 1, but following this date there was a sharp reduction in rooting percentages of 'Old Hale and Hearty' and 'Cumberland'. 'Arden' was rooted easily throughout the entire experiment. A study of the relationships between carbohydrate content (starch, acid hydrolyzable polysaccharides, total glucose, and reducing sugar) indicated that there was no progressive increase or decrease of carbohydrates with the advancement of the cutting season.

It was concluded that carbohydrate content of cutting wood was not the determining factor in rooting ability of the American holly cuttings evaluated, and that the influence of the time of making the cuttings is an expression of some other factor or factors.

Physiological And Anatomical Studies Relative To Timing And Other Factors Of Vegetative Propagation

The anatomical and physiological characteristics that determine the readiness of woody species for vegetative propagation have only been studied to a limited degree. Komosorov (15) summarizes reports of investigators which have evaluated the degree of starch accumulation, carbohydrate to nitrogen ratio, metabolic level, total carbohydrate level, and protease activity, in an attempt to correlate readiness of propagation which such factors. He concludes that these factors do not always indicate a greater capasity of shoots for propagation. He states, based on his findings, and those of other investigators:

> . . . it is difficult to judge the readiness of shoots for propagation by individual physiological or biochemical indexes, and the determination of these indexes is quite complicated and labor consuming. In production propagation of plants bycuttings, the readiness of shoots is best determined by the sum-total of the morphological characteristics which are typical of some definite phases of shoot developement (p. 56).

Komosorov (15) further explains that in different plant species the morphological characteristics showing readiness of the shoots for propagation vary, and include degree of lignification, as exibited by the rigidity of the shoot, development of axilliary buds and leaves, color and flexibility of the shoot, apical bud development, the presence or absence of herbaceous growth or expanding leaves, lenticel development, and development phase.

Kester (14) has studied the relationship of the juvenility or development phase to plant propagation. In many species the capacity to root is reduced with plant age, or as Kester prefers, with maturation of tissues or meristems. In some species of the genera Quercus (oak), Pinus (pine), Picea (spruce) and Pseudotsuga (Douglas fir), seedlings or young plants have the capasity to root whereas mature plants do not or their capasity to root is greatly reduced (15). Komosorov (15) suggests that this is due to a radical change in the plants characteristics of metabolism and may also relate to a peculiar specialization of cells and tissues which is unfavorable to the formation of root primordia.

Wardel (27) successfully induced the adult or flowering phase in tabacco by injecting extracts containing DNA from the flowering adult phase of a tobacco plant into a juvenile plant. This implies that the control of the phases of maturation is located in the chromosomes. Future experiments may develop means of regeneration of juvenile growth and rooting capacity by DNA transfer.

Adams and Roberts (1) developed a morphological time scale for predicting rooting potential in *Rhododendron* cuttings related to flower bud developement. A morphological indicator was chosen because the season influences growth rate and development, and thus plant parts can differ physiologically on the same date in different years (1).

Roberts (20) related timing of cutting propagation with changes in bud development, dormancy and auxin levels in Douglas fir. He concludes that auxin produced in developing buds is a factor controlling the capacity of shoots of douglas fir to develop adventitious roots.

It is apparent that variability among species, genera, clones, seasons and genetic potential, makes determining optimum timing of propagation very specific for each clone. For each plant there are also the additional effects of crown and branch order (15). These factors are complicated by seasonal differences. Komosorov (15) reported that cuttings taken from *Ginko biloba* (Ginko) at an early date (May 28) from the lower portion of the tree rooted 100 percent, middle 74 percent, and upper 33 percent. At the second date (June 21), semi-lignified shoots from the lower, middle, and upper parts of the crown rooted equally well. Cuttings taken on the third date (July 5), which exibited a greater degree of lignification, rooted better when taken in the upper less lignified portion than the lower storey.

Cultural Factors - Media And Nutrition In Propagation

The readiness of shoots for propagation cannot be determined without examining the influence of rooting conditions on the cuttings. Cuttings capable of forming adventitious roots may not root at all if the environmental conditions are inapropriate (15). Innovations in environmental control are expanding the application of vegetative propagation to many species which previously were either very difficult to root or had to be propagated by grafting or budding (12,30).

Two factors which greatly influence propagation success and subsequent growth are media and nutrition in propagation. Pokorny and Perkins (18) indicate that a rooting media should provide the proper moisture and air relationship, be light in weight, free of diseases and weeds, and provide physical support for the cutting. The cost and availability of the medium components should also be considered. Numerous soiless media have been evaluated for propagation based on their physical properties and plant response (18).

Sphagnum peat moss and perlite (expanded vulcanic material) are frequently used in propagation media combined with other media components such as vermiculite (expanded mica) or sand. Recently, milled pine bark has been studied as a substitute for peatmoss or sand in propagation medium, due to its lower cost compared to peat moss, and its superior physical properties compared to sand. Pokorny and Perkins (18) evaluated six propagation media, including 1:1 by volume peat moss and sand, 1:1 peat and perlite, 100 percent sand, 100 percent pine bark, 1:1 pine bark and sand, and 1:1 pine bark and perlite. Pine bark was aged two years and then ground with a hammermill shreader.

Porkorny and Perkins (18) found no significant difference in rooting response in 13 of 19 plant species or cultivars in the 6 different media tested. Cuttings of six plant species rooted significantely better in media containing milled pine bark or peat moss than the 100 percent sand. Cuttings of Rhododendron spp., southern indian hybrid 'Formosa' and Ilex crenata 'Repandens' rooted significantely better in 100 percent milled pine bark or one of the media containing pine bark than in the other media tested. It was observed that with 5 of the plant species evaluated, the highest rooting index was obtained in 100 percent milled pine bark or one of the media containing milled pine bark. The authors concluded that milled pine bark of the quality used in this study could be substituted for peat as a rooting media component.

Laiche (16) evaluated peat and pine bark as propagation media components in combination with sand, perlite and vermiculite. Freshly milled pine bark and european peat were used. Results indicated that media containing peat were better than media containing fresh bark for rooting Rhododendron spp. 'Formosa', Camellia sasanqua, 'Shishi

Gashira' and *Ligustrum lucidum*. *Ilex vomitoria* 'Nana". Cuttings rooted better in media containing peat than pine bark. The author indicates that the media containing bark were difficult to wet and keep moist. It was suggested that the larger particle size of the pine bark increased drainage and thus reduced available water. The different results of the two studies may relate to age, particle size or milling, and/or source of the pine bark used, the source of peat, or other environmental or stock plant differences.

The use of slow-release fertilizers in the rooting medium is a relatively new supplement to vegetative propagation. Prior to the mid 1960's it was rare for growers to apply fertilizers to cuttings under mist. In the mid 1960's, nutrient mist was used, in an attempt to replace the nutrients lost due to leaching (24). Complications of increased desease and algae growth lead to the evaluation of slow-release fertilizers in the rooting media. Schulte and Whitcomb (24) evaluated Osmocote 18-6-12, a resin coated N-P-K fertilizer, incorporated at 0, 896.8, 1,345.2 and 1,936 kg. N/hectare/year (0, 800, 1,200, and 1,600 lbs. N/acre/year). *Ilex cornuta* 'Burfordi' cuttings increased in rooting percentage and average visual root grade with increased rate of Osmocote up to 1,345.2 kg. N/hectare/year. The highest rate of Osmocote gave no significant additional rooting percentage or root grade. The authors believe that the Osmocote may have stimulated root initiation and/or stimulated root development following actual root initiation.

Gibson et al. (10) compared three Osmocote formulations and two rooting and growing media on liner quality. Three rates of Osmocote 19-6-12, (3-4 months), 18-6-12 (6-9 months) and 18-5-11 (12-14 months) at 4.76, 7.14, and 9.52 kg./cu.m. (8, 12, and 16 lbs./cu.yd., were evaluated, in 2 rooting media. Media formulations were 1:1 by volume peat and perlite and 2:1:1 bark, peat and sand.

Osmocote 18-6-12 produced superior liners compared to the other formulations, with 19-6-12 resulting in the lowest top and root weights and fewest bud breaks on all species evaluated. The best rate of Osmocote 18-6-12 was 7.14 kg./cu.m. (12 lbs./cu.yd.) for *Ligustrim vicaryi*, and *Euonymus fortunei* 'Coloratus', with regard to top and root fresh weights, however, 9.52 kg./cu.m. (16 lbs./cu. yd.) was best for *Lagerstroemia indica*. Peat and perlite media was superior to bark, peat and sand for all species with regard to top and root fresh weight and number of branches.

CHAPTER III

METHODS AND MATERIALS

Based on results from preliminary studies of the propagation of the lacebark elm selections and previous work done with propagation date and other cultural factors, a factorial study was begun in 1982 to evaluate the effects of 3 propagation media, 4 fertilizer levels, and 3 propagation dates on 5 promising selections of Lacebark Elm. A split-split plot experimental design was employed in the propagation phase of the experiment with 6 replications and 5 subsamples per treatment. The design provided for date of taking cuttings as a main plot, media-fertilizer as a subplot, and selection as a sub-subplot. The study included 30 cuttings per treatment combination for a total of 5400 cuttings. All cuttings received constant amounts of rooting hormone, 8000ppm IBA applied as a talc preperation to the base of the cutting, micronutrient fertilizer in propagation, 0.595 kg/cu.m. (1 lb. per cu.yd. Micromax), and post propagation media, fertilizer, irrigation, and all other post propagation cultural treatments.

Terminal softwood cuttings were taken from the five most promising Lacebark Elm selections (designated as selections A thru E), which were made from an original seedling population begun in 1974. The five selecions possess improved growth rate and visual characteristics over the general seedling population of the parent species.

Selection A has an upright multiple leader, a moderately dense foliage canopy and dark green leaf color (Figure 1).

Figure 1. Selection A

Selection B also has an upright multiple leader growth habit. It also possesses a dense foliage canopy and dark green foliage color with a waxy leaf surface. Selection C is broad and rounded in its overall form and possesses a spreading, almost weeping, growth character with attractive flaking bark which is more prominent than other selections. Selection D has a broad and rounded growth habit with a very dense foliage canopy of small leaves and dark green foliage color. Selection E has a rather open canopy with a multiple leader growth habit, a moderately dense foliage character and dark green color.

Cuttings from the selections were taken at three dates, May 3, June 3, and July 3, 1982 to evaluate the effect of date or relative age of the wood on adventitious root development and subsequent plant growth and quality. Typical cuttings taken from the five selections at each date were of the current seasons wood, 12.5 cm. (5 inches) in length and with axilliary buds developing as exhibited by a prominent swelling (Figure 2). Apical bud development varied among selections and propagation dates.

On each propagation date cuttings were taken from three trees per selection growing in adjacent plots. All selections were located in the same field. Cuttings were collected from the lower two-thirds of the tree canopy of each plant at all three propagation dates. Cuttings from the three trees of each selection were randomly distributed across fertilizer and media treatment combinations to compensate for any inherent nutritional differences among particular trees. The cuttings were taken from second order shoots for each selection at all three dates. First order shoots provided for insufficient quantities of cuttings and were excessively succulent or green with axillary buds which had broken.

Figure 2. Typical cutting

The stage of shoot development varied among selections at each propagation date. A description of the cutting wood for each selection at the three dates follows:

May 3, 1982 - This date proved to be the earliest date for taking cuttings of the desired length (12 cm.) this season. The trees had broken bud 6-8 weeks earlier, with date of bud break varying among selections. Cuttings were of a uniform current season's first growth flush for all selections. Cuttings were selected for uniform internode length, number of leaves, shoot diameter, and color of wood (green to pale brown). Shoots with axillary buds which had broken were avoided.

June 3, 1982 - Selections varied with regard to the presence of an active apical growth flush. Cuttings of selections A, C and E were all of the current season's first growth flush with apical bud fully developed. Selections B and D possesed a second growth flush exibited by apical bud break and expanding leaves at the shoot apex. The base of all cuttings across selections was of the current seasons growth flush. Lignification of the shoots was begining at this propagation date as evidenced by the increased rigidity and brownish color of the shoots compared to the May 3 date. Cutting length was the same as taken on May 3, and all were selected and graded as per the May 3 propagation date.

July 3, 1982 - Selections A through E all possessed a second growth flush. The shoots were further lignified with the base of the cutting having a darker brownish-green cast than the second cutting date. Cuttings were selected and graded as described previously.

To study the effect of media on rooting and subsequent growth, the 3 media formulations were by volume a) 100 % pine bark, with average partical size of 1 cm., b) 50 % pine bark, 25 % canadian sphagnum peat moss and 25 % coarce grade perlite, and c) 50 % sphagnum peat moss and 50 % coarse perlite.

Fertilizer treatments were 0, 2.38, 4.76, and 7.14 kg./cu. m. (0, 4, 8 and 12 lb./cu. yd.) Osmocote 18-6-12, a slow release N-P-K fertilizer with a 6 to 9 month release time, incorporated into the media. Molded plastic propagation trays, 35.5 cm. by 35.5 cm. (14 in. by 14 in.) with 25 separate cavities per tray, 228.9 cu. cm. (14 cu. in.) per cavity, were filled with the fertilizer-media combinations and randomly assigned block positions within each replication.

Wounding of the cuttings was limited to that which occured as the lower three to four leaves were stripped from the base of the cutting. An 8,000 ppm talc was then applied to the base of the cutting after which selections were randomly assigned a row of 5 cavities per tray.

Propagation trays with cuttings were placed on raised expanded metal greenhouse benches in a fiberglass-covered, unshaded, quonset-type greenhouse. Cuttings were rooted with intermittent mist with 4 to 8 seconds on every 8 minutes. Duration of misting varied with weather conditions and greenhouse temperatures. The greenhouse was heated when night temperature dropped below 21 degrees C. (70 degrees F.). Evaporative cooling was used as daytime temperatures exceeded 30 degrees C. (86 degrees F.) in July and August.

After rooting, plants were hardened off, evaluated for root development and transplanted. Four of the five subsamples from each treatment combination were evaluated for root development. Roots were graded visually for root quality and quantity on a 1 - 10 scale using standards of 1, 4, 7 and 10 for comparison with a 1 indicating no root developement and 10 superior rooting (Figure 3).

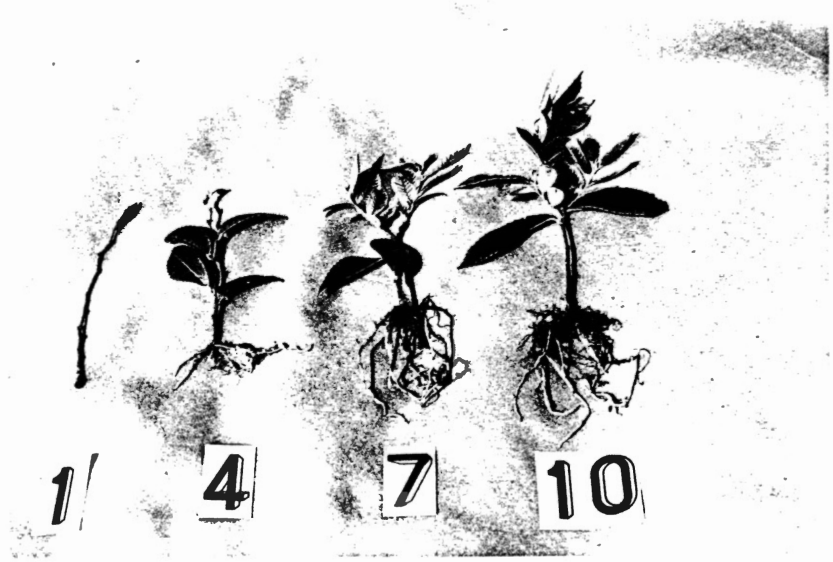


Figure 3. Visual Root Grade on a 1 to 10 Scale

One subsample from each replication of each treatment was bare rooted and transplanted into an 11.4 liter (3 gallon) white and black laminated poly bag. Growing media was a 3:1:1 volumetric ratio of ground pine bark, sphagnum peat and cource sand amended with 17-7-12 and 18-6-12

Osmocote, Micromax, and dolomite at 6, 2.4, .89 , and 3.57 kg./cu.m. respectively (10, 4, 1.5, and 8 lbs./cu.yd.).

Growth response of transplanted liners was determined by the height and number of branches in late November 1982, after 18, 14, and 12 weeks for the May 5, June 5, and August 5 propagation dates respectivly. Plants were closely packed and mulched with straw for winter protection.

CHAPTER IV

RESULTS AND DISCUSION

Rooting Percentages

The May 3 date provided the highest percent rooted, 80.9, when averaged over selections, media and fertilizer levels (Table II) . Average rooting percentages for all selections were 53 percent on June 3 and 42.8 on July 3.

For the May 3 propagation date selections A, B, and C rooted 96.2, 72.9 and 86.1 percent respectively. Selections D and E rooted 81.6 and 67.7 percent. At the June 3 propagation date, selection B rooted 77.8 percent followed by selection A, 61.8 percent and selection C, and E, and D with rooting percentages of 50.3, 46.9 and 28.1 respectively. Rooting percentages were significantly greater at the May 3 date for all selections with the exception of B which exhibited no significant difference in rooting percentage between the May and June 3 propagation dates (Table II).

TABLE II

EFFECTS OF DATE AND SELECTION ON PERCENT ROOTED OF LACEBARK ELM CUTTINGS

Selection	Date: May 3	Date: July 3	Date: July 3	Average
A	96.2 (d,[x]2[y])	61.8 (c,1)	60.1 (d,1)	72.7 c
B	72.9 (ab,2)	77.8 (d,2)	51.4 (cd,1)	67.4 c
C	86.1 (cd,3)	50.3 (b,2)	34.7 (b,1)	57.1 b
D	81.6 (bc,2)	28.1 (a,1)	20.1 (a,1)	43.3 a
E	67.7 (a,2)	46.9 (b,1)	47.7 (c,1)	54.1 b
Average	80.9 (3)	53 (2)	42.8 (1)	

x all means in columns followed by the same letter are not significantly different at the .05 level

y all means in rows followed by the same letter are not significantly different at the .05 level

Variation among seedlings or clones is not uncommon; Black (3) reports that,

> . . . genotype was observed to be the most important factor affecting cutting rootability. Trees growing side by side under apparently identical environmental conditions, and of the same chronological age showed extreme variability in rooting potential (p. 143).

The date effect may relate to a greater capacity of selections A, C, D, and E to form adventitious roots at the May 3 date due to some physiological, anatomical, or metabolic factors. Roberts (20) suggests that a change in assimilation of the stock plant.

The date effect may also be a reflection of poorer rooting conditions, such as higher greenhouse temperatures at later propagation dates. Tustin (26) indicates that excessively high basal temperatures may result in basal decay prior to root initiation. Prolonged high temperatures may also create an imbalance in the photosynthesis - respiration ratio.

Visual Root Grade

Highest mean visual root grade was obtained at the May 3 date for selections A, C, and D, with root grades of 5.8, 4.4, and 3.9 respectively (Table III). Mean root grades of selection B were best on June 3 (5.4 root grade vs. 4.2 for May 3). Similarities between the rooting percentage and root grade data for propagation dates and selections suggests a direct relationship between the capacity to form roots and the quality of the root system which develops. Selections with low rooting percentages averaged over media and fertility developed root systems of lesser quality than those which rooted at high percentages. For selection E propagation date had no significant effect on root grade (Table III), whereas there was a marked difference as to rooting percentages when comparing dates (67.7 percent for May 3 vs. 46.9 for June 3 - Table II).

Visual root grade was greatest for cuttings of all selections rooted in 1:1 peat and perlite compared to either selections rooted in 1:1 peat and perlite compared to either of the media containing pine bark (table 4). In general, root grades decreased as the bark fraction in the rooting medium increased. These media effects parallel those reported by Laiche (16). Low root grades in the media containing bark may relate to the lower water holding capacity of the bark due to its larger particle size.

TABLE III

EFFECTS OF DATE AND SELECTION ON VISUAL ROOT GRADES OF LACEBARK ELM CUTTINGS

Selection	Date		
	May 3	June 3	July 3
A	5.8 (c,[x]3[y])	4.7 (c,2)	3.9 (c,1)
B	4.2 (ab,2)	5.4 (d,3)	3.9 (c,1)
C	4.4 (b,3)	3.8 (b,2)	3.1 (b,1)
D	3.9 (a,3)	3.0 (a,2)	2.4 (a,1)
E	3.7 (a,1)	3.8 (b,1)	3.5 (bc,1)

x all means within columns followed by the same letter are not significantly different at the .05 level.

y all means within rows followed by the same number are not significantly different at the .05 level.

Selections A and B had the highest mean root grades for all three media. Selection A in the 1:1 peat and perlite medium had greater mean root grades (5.9) than all other selections (Table IV).

TABLE IV

EFFECTS OF MEDIA AND SELECTION ON VISUAL ROOT GRADE OF LACEBARK ELM CUTTINGS

	Media		
Selections	Bark	2:1:1 Bark - Peat - Perlite	1:1 Peat - Perlite
A	3.7 (b^x,2^y)	4.8 (c,2)	5.9 (d,3)
B	3.7 (b,1)	4.7 (c,2)	5.0 (c,2)
C	3.1 (a,1)	3.9 (a,1)	4.2 (a,2)
D	3.0 (a,1)	2.8 (a,1)	3.4 (a,2)
E	3.5 (ab,1)	3.4 (b,1)	4.2 (b,2)

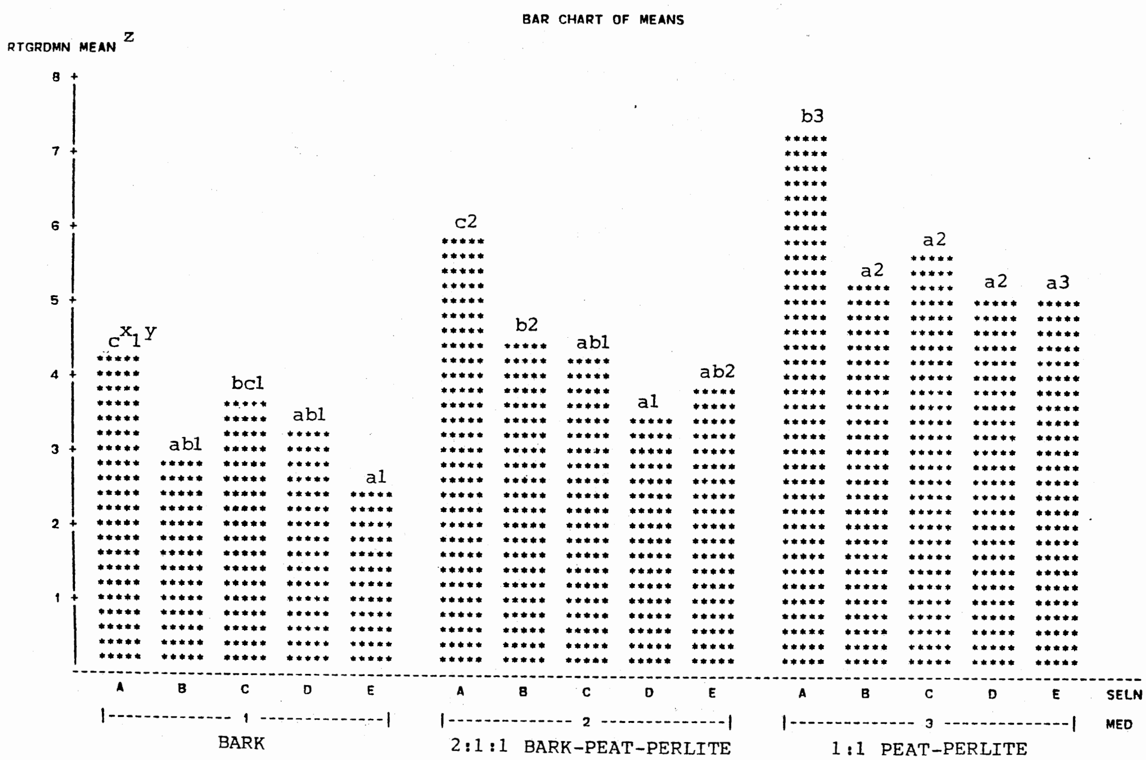
x all means in columns followed by the same letter are not significantly different at the .05 level.

y all means in rows followed by the same number are not significantly different at the .05 level.

Selection B ranked second among selections in all media with 3.7, 4.74, and 5.02 root grades for the bark, 2:1:1

bark, peat and perlite and 1:1 peat and perlite media respectively. Selection C and E were intermediate and D rooted poorest in all three media.

Selection A had significantly greater root grades than all other selections in the peat and perlite and 2:1:1 bark, peat and perlite media at the May 3 propagation date (Figure 4).



x all means within a medium followed by the same letter are not significantly different at the .05 level

y all means for a selection across media followed by the same number are not significantly different at the .05 level

z RTGRD MEAN = mean visual root grade on a 1-10 scale

Figure 4. Effects of Date and Selections on Visual Root Grade of Lacebark Elm Cutting

Selections A and C ranked first and second (4.4 and 3.4 respectively) in the 100 percent bark medium (Figure 4). With the July 3 propagation date, media had no significant effect on root grades averaged over selections, whereas at the May 3 propagation date, mean root grades increased from 3.2 for the 100 bark media to 4.3 and 5.6 for the 2:1:1 bark, peat and perlite and 1:1 peat and perlite media respectively (Table V). At the June 3 propagation date differences between the 2:1:1 bark, peat and perlite and 1:1 peat and perlite media were less pronounced, whowever, both significantly increased root grades compared to the 100 percent bark media

Table V

EFFECTS OF DATE AND MEDIA ON VISUAL ROOT GRADES OF LACEBARK ELM ROOTED CUTTINGS

	Media		
Date	Bark	2:1:1 Bark - Peat - Perlite	1:1 Peat-Perlite
May 3	3.2 (a,[x]1[y])	4.3 (b,2)	5.6 (c,3)
June 3	3.7 (b,1)	4.2 (b,2)	4.5 (b,2)
July 3	3.2 (a,1)	3.3 (a,1)	3.5 (a,1)

x all means in columns followed by the same letter are not significantly different at the .05 level.

y all means in rows followed by the same number are not significantly different at the .05 level.

Root grades increased from 3.5 to 3.9 and 4.3 for the 0, 2.38, and 4.76 kg./cu.m. (0, 4, and 8 lbs./cu.yd.) rates of Osmocote 18-6-12 respectively (Table VI). Root grades decreased at the 7.14 kg./cu.m. (12 lbs./cu.yd.) to 4.2. A comparison of all fertilizer levels indicates a linear trend at the .0001 level and a quadratic trend at the .0004 operational significance level. This suggests that 4.76 kg./cu.m (8 lbs./cu.yd.) is an adequate rate of Osmocote 18-6-12 in propagation and that a higher or lower rate would result in lower root grades.

TABLE VI

EFFECT OF FERTILIZER LEVEL ON ROOT GRADES
OF LACEBARK ELM ROOTED CUTTINGS

	kg./cu.m. Osmocote 18-6-12			
	0	2.38	4.76	7.14
Main Effects	3.5 (a^x)	3.9 (b)	4.3 (c)	4.2 (bc)

x all means followed by the same letter are not significantly different at the .05 level

Height And Branch Count

For all selections, branch counts were 3 times greater for plants propagated on May 3 than those propagated on June

3 and 4 times greater than the July 3 date (selection A, 31.0, 16.3, and 15.0 respectively - Table VII).

TABLE VII

EFFECTS OF DATE AND SELECTION ON BRANCH COUNT

Selection	Date		
	May 3	June 3	July 3
A	31.0 (d,[x]1[y])	16.3 (c,2)	15.0 (ab,1)
B	29.0 (c,3)	19.2 (d,2)	15.7 (b,1)
C	23.9 (b,2)	14.4 (a,1)	14.9 (ab,1)
D	21.7 (a,2)	13.6 (a,1)	13.3 (a,1)
E	27.2 (c,3)	15.6 (ab,2)	14.0 (ab,1)

x all means in columns followed by the same letter are not significantly different at the .05 level.

y all means in fows followed by the same letter are not significantly different at the .05 level

With the May 3 propagation date, selection A had a brand count of 42 followed by selections B and C which had counts of 32.4 and 31.9 respectively, however selections B and C were not significantly different. Selections E and C had the poorest branch counts (28.0 and 22.4 respectively).

Despite having ranked relatively low with respect to rooting percentage and intermediate with respect to root grade, selection B ranked second in plant height at the May 3 propagation date and first at the June 3 propagation date at the end of the growing season (Table VIII). Selection C and E were of intermediate height (23.9 and 27.24 cm. respectively) at the May 3 date. Selection D consistently ranked last for all propagation dates with respect to plant height, however it was not significantly different from selections C and E on the May 3 and July 3 propagation dates.

TABLE VIII

EFFECTS OF DATE AND SELECTION ON PLANT HEIGHT

Selection	Date May 3	June 3	July 3
A	42.0 (d,[x]3[y])	12.5 (c,2)	8.6 (b,1)
B	32.3 (c,3)	14.1 (c,2)	6.5 (ab,1)
C	22.4 (a,2)	6.2 (a,1)	6.3 (ab,1)
D	31.9 (c,2)	8.7 (ab,1)	6.5 (ab,1)
E	28.0 (b,3)	9.0 (b,2)	5.3 (a,1)

x all means in columns followed by the same letter are not significantly different at the .05 level.

y all means in rows followed by the same number are not significantly different at the .05 level.

Branch count (Table VII) and plant height of selection C ranked among the poorest selections despite having a relatively good rooting percentage and root grade. It was observed that selection C did not develop a dominant leader after transplanting, as did other selections. Selection C remained short with a rather sparce appearance.

The poor performance of selections C and D after transplanting may relate to variation among selections as influenced by the origin of the cutting wood or the order of branching. Komossorov (15) reported that maple cuttings taken from the first order of branching develop a dominant vigorous leader, whereas cuttings from shoots of higher order of branching developed into less vigorous plants which were brushy in appearance. First order cuttings of selection C may develop a dominant leader and vigorous growth habit. In addition, an earlier propagation date in which shoots with an active terminal bud are selected, may result in transplants which develop a dominant leader regardless of the order of branching selected.

Cuttings stuck in 1:1 peat and perlite had a greater branch count than those in media containing bark on May 3, likewise, peat and perlite had an average branch count of 13.8, whereas the 2:1:1 bark, peat and perlite and 100 percent bark media had average branch counts of 9.3 and 7.2 respectively on June 3. (Table IX).

The interaction of date and media on plant height reflects a less pronounced difference among media at the

July 3 propagation date compared with the two earlier dates (Table X). In general, as with branch count and root grade, as the proportion of bark in the propagation media decreased, plant growth improved.

TABLE IX

EFFECTS OF DATE AND MEDIA ON BRANCH COUNT

	Media		
Date	Bark	2:1:1 Bark Peat - Perlite	1:1 Peat-Perlite
May 3	23.5 (b,[x]1[y])	29.1 (c,2)	41.4 (c,3)
June 3	7.2 (a,1)	9.3 (b,1)	13.8 (b,2)
July 3	5.7 (a,1)	6.4 (a,1,2)	7.9 (a,2)

x all means in columns followed by the same letter are not significantly different at the .05 level.

y all means in rows followed by the same letter are not significantly different at the .05 level.

Propagation media had no significant effect on height of selection D, whereas for other selections as the proportion of bark content in the propagation media decreased, plant height increased (Table XI).

Within the bark medium the 4.76 and 7.14 kg./cu.m. (8 and 12 lbs./cu.yd.) levels of Osmocote gave the best mean plant height, 18.6 cm. (Table XII). The best fertilizer treatments for the 2:1:1 bark, peat and perlite medium were the 4.76 and 7.14 kg./cu.yd. (8 and 12 lbs./cu.yd.) rates of Osmocote which were not significantly different at the .05 level. The best fertilizer treatment for the peat and perlite medium was the 2.38 kg./cu.m. (4 lbs./cu. yd.) rate of Osmocote. A comparison of fertilizer main effects indicated a linear trend at the .0001 level and a quadratic trend at the .0004 level.

TABLE X

EFFECTS OF DATE AND MEDIA ON PLANT HEIGHT

Date	Media		
	Bark	2:1:1 Bark - Peat - Perlite	1:1 Peat-Perlite
May 3	23.8 (b,[x]1[y]	25.6 (b,1)	30.3 (c,2)
June 3	13.5 (a,1)	15.8 (a,2)	18.1 (b,3)
July 3	13.5 (a,1)	14.7 (a,1,2)	15.6 (a,2)

x all means in columns followed by the same letter are not significantly different at the .05 level.

y all means in rows followed by the same number are not significantly different at the .05 level.

A summary of branch count means for the 4 fertilizer levels at the three dates indicates an increase in mean number of branches as fertilizer level increases (Table XII). At the June and July 3 propagation dates mean branch counts were not significantly different at the 4.76 and 7.14 kg./cu.yd. (8 and 12 lbs./cu.yd.) rate of Osmocote 18-6-12 . For the July 3 propagation date there was no significant difference among fertilizer treatments when averaged over selections and media. A comparison of the main effects of fertilizer rate on branch count indicated a linear response at the .0001 level.

TABLE XI

EFFECTS OF MEDIA AND SELECTIONS ON PLANT HEIGHT

	Media		
Selections	Bark	2:1:1 Bark - Peat - perlite	1:1 Peat - Perlite
A	18.2 (b,[x]1[y])	20.84 (b,2)	23.3 (cd,3)
B	19.1 (b,1)	19.7 (b,1)	25.1 (d,2)
C	16.2 (a,1)	17.6 (a,1,2)	19.3 (b,2)
D	15.4 (a,1)	16.0 (a,1)	17.2 (a,1)
E	15.8 (a,1)	19.3 (ab,2)	21.8 (c,3)

x all means within columns followed by the same letter are not significantly different at the .05 level.

y all means within rows followed by the same letter are not significantly different at the .05 level.

TABLE XII

EFFECTS OF FERTILIZER LEVEL AND MEDIA ON PLANT HEIGHT

g./cu.m. Osmocote 18-6-12	Media: Bark	Media: 2:1:1 Bark - Peat - Perlite	Media: 1:1 Peat Perlite
0	14.9 (a,[x]1[y])	16.4 (a,2)	19.0 (a,3)
2.38	15.7 (a,1)	18.8 (b,2)	23.1 (c,3)
4.76	18.6 (b,1)	19.7 (bc,1,2)	21.8 (bc,3)
7.14	18.4 (b,1)	20.0 (c,2)	21.2 (b,2)

TABLE XIII

EFFECTS OF DATE AND FERTILIZER LEVEL ON BRANCH COUNTS

g./cu.m. Osmocote 18-6-12	Date: May 3	Date: June 3	Date: July 3
0	25.6 (a,[x]3[y])	6.4 (a,1)	5.5 (a,1)
2.38	29.1 (b,3)	9.7 (b,2)	6.3 (a,1)
4.76	33.8 (c,3)	11.3 (bc,2)	7.6 (a,1)
7.14	36.7 (d,3)	13.0 (c,2)	7.2 (a,1)

x all means in columns followed by the same letter are not significantly different at the .05 level.

y all means in rows followed by the same letter are not significantly different at the .05 level.

CHAPTER V

SUMMARY AND CONCLUSIONS

Of the three propagation dates evaluated, the May 3 date resulted in the highest rooting percentages, visual root grades, and plant height and number of branches after one growing season, for selections A, C, D, and E. Selection B was the only plant for which June 3 resulted in a higher visual root grade. This effect was in spite of the less desirable conditions after transplanting of higher heat and drying winds. However, plant height and number of branches were greater for selection B at the May 3 propagation date.

Selections A and B outperformed all other plants with respect to all parameters measured with the exception of visual root grade for the May 3 propagation date. At this date selection C ranked second to selection A, however, subsequent growth of C after transplanting was relatively poor in comparison with other selections. Selection D rooted well but grew poorely after transplanting. Growth of selection E was relatively good but cuttings rooted poorly.

The 1:1 peat and perlite medium gave the best results for all growth parameters measured, for all treatment combinations. In general, root grades, plant height and branch count increased with fertilizer rate to the 4.76

lb./cu.yd. level. The 4.76 and kg./cu.m. (8 lbs./cu. yd.) rate of Osmocote 18-6-12 incorporated into the propagation medium gave consistently better root grades, plant heights and number of branches than either lower or higher fertilizer rates.

Based on the results of this study, selections A and B should be propagated at the earliest date when cuttings can be obtained that are of the current seasons wood, approximately 12.5 cm. (5 inches) in length and with axilliary buds developing. This would give the best results of the five selections and three propagation dates evaluated.

A propagation medium of 1:1 peat and perlite or a medium with equivalent physical properties would give acceptable rooting percentages and good liner quality. Osmocote 18-6-12 incorporated at 4.76 kg./cu.m. (8 lbs./cu.yd.) would provide adequate nutrition in propagation.

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VITA 4

Gary George Hickman

Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF DATE, NUTRITION AND MEDIA ON THE VEGETATIVE PROPAGATION AND GROWTH OF FIVE SELECTIONS OF LACEBARK ELM, ULMUS PARVIFOLIA

Major Field: Horticulture

Biographical:

Personal Data: Born in Newark, New Jersey, September 28, 1959, the son of Mr. and Mrs. George Hickman.

Education: Graduated from East Central High School, Tulsa, Oklahoma, in May 1977; recieved Bachelor of Science in Agriculture degree in Horticulture from Oklahoma State University in 1981; completed requirements for the Master of Science degree at Oklahoma State University in July 1983.

Professional Experience: Assistant Horticulturist, Las Colinas Landscape Services, summer 1980; Production Supervisor, Las Colinas Landscape Services, summer 1981; Graduate Research Assistant, Oklahoma State University Department of Horticulture, 1981-1983; Graduate Teaching Assistant, Oklahoma State Univiversity Department of Horticulture, 1982; Owner, Sunbelt Landscape Development Co., started 1982.