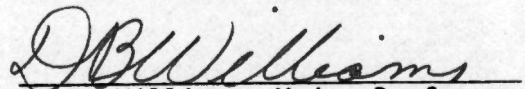
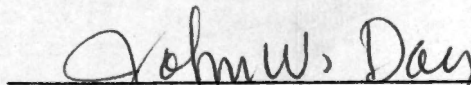
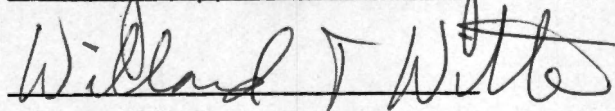


To the Graduate Council:

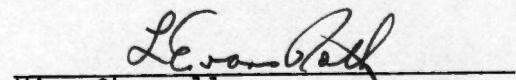
I am submitting herewith a thesis written by Perry Anthony Cope entitled "The Propagation of Tree Seedlings under Continuous Light in Square, Bottomless Containers." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ornamental Horticulture and Landscape Design.


D. B. Williams, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

THE PROPAGATION OF TREE SEEDLINGS UNDER
CONTINUOUS LIGHT IN SQUARE,
BOTTOMLESS CONTAINERS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Perry Anthony Cope

June 1981

3051808

ACKNOWLEDGMENTS

To Dr. Donald B. Williams, Professor and Head of the Ornamental Horticulture and Landscape Design Department, the author expresses his appreciation for his role as his major professor and committee chairman.

The author also expresses appreciation to Dr. John Day, Associate Professor, and Dr. Will Witte, Associate Professor. Department of Ornamental Horticulture and Landscape Design, for their wise and patient advice, encouragement, and support.

The author also wishes to express his gratitude to Dr. G. S. Smith, past Associate Professor of the Ornamental Horticulture and Landscape Design Department, for his role as major professor during the planning and development of this project.

Thanks are due to the author's wife, Carolyn, and parents for their unlimited encouragement and inspiration.

ABSTRACT

Six woody ornamental species were selected to study the effects of continuous light and square, bottomless containers on growth and development during greenhouse propagation phase and after planting to field or 3-gallon container. Species tested were Liquidambar styraciflua, Koelreuteria paniculata, Betula pendula, Magnolia x soulangeana, Quercus palustris, and Prunus caroliniana.

K. paniculata grew tallest when started under continuous light. Continuous light had no effect on caliper, fresh weight, straightness rating, or root rating of K. paniculata. Fresh weight of plants started in bottomless containers was heavier than plants started in containers with bottoms. The root quality rating of K. paniculata seedlings from bottomless container treatments was better than seedlings that were started in containers with bottoms.

Continuous light had a positive effect on the height and fresh weight of Magnolia x soulangeana seedlings. Plants from continuous light treatments were more crooked, however. Magnolia x soulangeana grew more in height, caliper, fresh weight, and had better root quality rating when started in bottomless containers.

Seedlings of B. pendula started in bottomless containers were taller than those started in containers with bottoms. Bottomless containers also produced plants with greater caliper, fresh weight, and better root quality and straightness rating. Photoperiod treatments had no effect on the growth of B. pendula. B. pendula planted in the field had larger caliper and were heavier than seedlings planted in 3-gallon containers.

Liquidambar styraciflua was the most unresponsive species tested to treatments. Photoperiod or container type had no influence on height, caliper, fresh weight, or straightness rating at either growing location. Root quality rating of field plants was better for plants from natural photoperiod treatments. Continuous light and bottomless containers interacted to produce the highest root quality rating of 3-gallon container plants.

Q. palustris seedlings grew tallest when started under continuous light. Continuous light treatments also produced seedlings with greater fresh weight and root quality ratings. Continuous light had no effect on caliper or straightness rating of Q. palustris. Container type had no effect on height, caliper, fresh weight, or straightness rating. Seedlings started in bottomless containers had better root quality rating.

Continuous light treatments produced taller P. caroliniana seedlings but did not influence caliper, fresh weight, straightness or root quality rating. Container type had no effect on height, caliper, fresh weight, or straightness rating of P. caroliniana. Seedlings started in bottomless containers had better root quality ratings than those started in containers with bottoms.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION.	1
II. LITERATURE REVIEW	3
I. PHOTOPERIOD AND THE GROWTH OF TREES	3
II. SQUARE, BOTTOMLESS CONTAINERS AND THE GROWTH OF TREES .	5
III. MATERIALS AND METHODS	8
IV. RESULTS AND DISCUSSION.	19
I. <u>KOELREUTERIA PANICULATA</u> -GOLDEN RAIN TREE.	19
II. <u>MAGNOLIA X SOULANGEANA</u> -SAUCER MAGNOLIA.	22
III. <u>BETULA PENDULA</u> -EUROPEAN WHITE BIRCH	33
IV. <u>LIQUIDAMBAR STYRACIFLUA</u> -SWEET GUM	45
V. <u>QUERCUS PALUSTRIS</u> -PIN OAK	47
VI. <u>PRUNUS CAROLINIANA</u> -CAROLINA LAURELCHERRY.	52
V. SUMMARY AND CONCLUSIONS	60
I. <u>KOELREUTERIA PANICULATA</u> -GOLDEN RAIN TREE.	60
II. <u>MAGNOLIA X SOULANGEANA</u> -SAUCER MAGNOLIA.	60
III. <u>BETULA PENDULA</u> -EUROPEAN WHITE BIRCH	61
IV. <u>LIQUIDAMBAR STYRACIFLUA</u> -SWEET GUM	62
V. <u>QUERCUS PALUSTRIS</u> -PIN OAK	62
VI. <u>PRUNUS CAROLINIANA</u> -CAROLINA LAURELCHERRY.	64
LITERATURE CITED.	65
VITA.	69

LIST OF FIGURES

FIGURE	PAGE
1. Containers on wire bench.	9
2. Tree seedlings under continuous light on raised wire bench.	11
3. Example of Root Rating Standards for container plants. Species pictured is <u>Liquidambar styraciflua</u>	17
4. Example of Root Rating Standards for field plants. Species pictured is <u>Koelreuteria paniculata</u>	18
5. Height of <u>K. paniculata</u> in response to photoperiod treatment and container type at termination of greenhouse phase	20
6. Height of <u>K. paniculata</u> in response to photoperiod treatment at end of growing season.	21
7. Fresh weight of top growth of <u>K. paniculata</u> in response to container type at end of growing season	23
8. Root quality rating of <u>K. paniculata</u> grown in field response to container type	24
9. Root quality rating of <u>K. paniculata</u> grown in container in response to container type.	25
10. Height of <u>Magnolia x soulangeana</u> in response to photoperiod treatment at termination of greenhouse phase.	26
11. Height of <u>Magnolia x soulangeana</u> in response to container type at termination of greenhouse phase	27
12. Height of <u>Magnolia x soulangeana</u> in response to photoperiod treatment at end of growing season.	28
13. Height of <u>Magnolia x soulangeana</u> in response to container type at end of growing season	30
14. Caliper of <u>Magnolia x soulangeana</u> in response to container type at end of growing season	31
15. Fresh weight of top growth of <u>Magnolia x soulangeana</u> in response to photoperiod treatment and container type at end of growing season	32

16.	Straightness quality rating of <u>Magnolia</u> x <u>soulangeana</u> in response to photoperiod treatment at end of growing season.	34
17.	Root quality rating of <u>Magnolia</u> x <u>soulangeana</u> in field response to container type.	35
18.	Root quality rating of <u>Magnolia</u> x <u>soulangeana</u> in container in response to container type	36
19.	Height of <u>B. pendula</u> in response to container type at termination of greenhouse phase	37
20.	Height of <u>B. pendula</u> in response to container type at end of growing season.	38
21.	Caliper of <u>B. pendula</u> in response to growing location. . .	40
22.	Fresh weight of top growth of <u>B. pendula</u> in response to growing location.	41
23.	Straightness quality rating of <u>B. pendula</u> in response to container type at end of growing season	42
24.	Root quality rating of <u>B. pendula</u> grown in field in response to container type	43
25.	Root quality rating of <u>B. pendula</u> in container in response to container type.	44
26.	Increase in height growth of <u>L. styraciflua</u> after planting to field and container in response to greenhouse photoperiod treatment	46
27.	Root quality rating of <u>L. styraciflua</u> at end of growing season in response to photoperiod treatment	48
28.	Root quality rating of <u>L. styraciflua</u> in 3-gallon containers at end of growing season in response to photoperiod treatment and container type.	49
29.	Height of <u>Q. palustris</u> in response to photoperiod treatment at termination of greenhouse phase.	50
30.	Height of <u>Q. palustris</u> in response to photoperiod treatment at end of growing season.	51
31.	Fresh weight of <u>Q. palustris</u> in response to photoperiod treatment at end of growing season.	53

FIGURE	PAGE
32. Root quality rating of <u>Q. palustris</u> in response to container type at end of growing season	54
33. Root quality rating of <u>Q. palustris</u> in response to photoperiod treatment at end of growing season	55
34. Height of <u>P. caroliniana</u> in response to photoperiod treatment at termination of greenhouse phase.	56
35. Height of <u>P. caroliniana</u> in response to photoperiod treatment at end of growing season.	58
36. Root quality rating of <u>P. caroliniana</u> at end of growing season in response to container type.	59

CHAPTER I

INTRODUCTION

Traditionally, the production of tree seedlings has been accomplished by germination in outdoor seedbeds or direct seeding in the field. The nurseryman can adjust growing conditions to some extent by irrigating, adding soil amendments, and improving soil fertility but to a large degree the ability of growers to manipulate growing conditions is limited. Growth of trees in seedbeds can also be effected by crowded conditions, insects, diseases, improper fertilization practices, and adverse weather at the nursery site.

Such production systems leave the nurseryman in a precarious position and his production can vary greatly, affecting the success of his operation on a year to year basis. Compounding these problems most trees require 2-6 years to reach sufficient size for sale or planting to field or container, depending on species. Therefore, the nurseryman is committing himself without knowledge of the future demand for a particular tree species.

Efforts have been made to give the nurseryman more control over growing conditions of tree seedlings. One area that has received considerable attention is the containerized or tube seedling concept developed by the forestry industry (23). The emphasis is placed on deep, narrow containers that lend themselves to mechanization and increased survival after planting.

From this tube seedling concept other work has evolved utilizing containers without bottoms. Preformed paper milk cartons have been used in several experiments (5,6,11,12,22). The air pruning response of taproots to bottomless container culture is discussed in Chapter II, Literature Review.

In efforts to optimize growth of tree seedlings another area receiving attention is the use of supplemental light in greenhouses to extend photoperiod. Several researchers have shown that most tree species respond to continuous light by increased growth (2,8,18,27). In a greenhouse system other growing conditions such as temperature, CO₂ concentration, and water can be controlled but continuous light is the key component in greatly accelerating growth of young seedlings (8).

Several advantages have been realized from the propagation and production of tree seedlings in square, bottomless containers and also from exposure to extended photoperiod. However, the combined effects of these two cultural methods have not been investigated on the ornamental tree species used in this study.

CHAPTER II

LITERATURE REVIEW

I. PHOTOPERIOD AND THE GROWTH OF TREES

Studies regarding photoperiod and the growth of plants have been conducted by numerous investigators. Garner and Allard (3) reported the importance of the length of day and night in controlling growth characteristics and flowering of herbaceous plants. They summarized that long days increased the rate and duration of vegetative elongation and short days decreased the rate of growth and hastened the onset of bud formation (3,4). However, the idea that decreasing day length or increasing night length might be an important factor in inducing dormancy in woody plants was slow in gaining recognition (21,24,25).

Prior to the 1930's investigators generally assumed that low temperature was the most important factor in cessation of growth of many plants (14,15). During this decade, however, several workers in the field of woody plant growth recognized the significance of photoperiod. Moshkov (16) reported that certain tree species from southern Russia, when grown at Leningrad where the maximum length of day is 20 hours, continued to grow until killed by frost instead of becoming dormant at the end of the summer. When the length of day was artificially shortened these species ceased growth earlier in the season and received no damage by cold weather. Kramer (15), working with North American species and utilizing artificial light, reported greatest growth of most species when grown under a continuous, 24 hour photoperiod. He compared the

24 hour photoperiod to a long day photoperiod of 14.5 hours, a normal photoperiod that ranged between 9.5-14.5 hours, and a short day photoperiod of 8.5 hours of light. Kramer concluded that variation in length of day considerably controlled the duration of growing season of most tree species. Similar results were obtained by Jester and Kramer (14) and Phillips (19).

Downs and Borthwick (2) reported the effects of photoperiod on the growth of several tree species. They summarized that short days induced dormancy and long days prolonged growth. However, exceptions to this generalization were documented.

Nitsch (18) produced a classification of woody plants according to their photoperiodic behavior. He identified four different responses in woody plants to photoperiod. Plants such as Weigela florida exhibit continuous growth when exposed to long days while exposure to short days will induce dormancy (Class A). Long days stimulate periodic growth in Quercus borealis while short days induce dormancy (Class B). Juniperus horizontalis will grow continuously under long days but short days will not cause dormancy (Class C). Long days will prolong the growing period of Syringa vulgaris but this species will eventually go dormant regardless of daylength (Class D).

Results of numerous studies show that artificially extending the natural day length will prolong the vegetative growth phase of many tree species, especially very young seedlings (7,17,27). Read and Bagley (20) compared the production of tree seedlings grown under extended or continuous photoperiod to seedlings grown in conventional

seedbed culture. All tree species tested grew faster when the natural photoperiod was lengthened and most grew the fastest under a continuous, 24 hour photoperiod.

Hanover et al. (8) have designed a greenhouse-tree seedling production system for use by commercial nurserymen. In this system, termed accelerated-optimal-growth, temperature, water, nutrition, CO₂, and light are brought to optimal levels in an effort to rapidly produce tree seedlings. All factors interact to stimulate growth acceleration and seedlings attain sufficient size to plant in the field much faster than seedlings grown in outdoor seedbeds. The researchers report that the success of the system is mainly due to the continuous photoperiod.

II. SQUARE, BOTTOMLESS CONTAINERS AND THE GROWTH OF TREES

Milk cartons as growing containers were initially tested for use in reforestation of valuable hardwood species by researchers in forest science (22). The mortality of Juglans nigra seedlings grown in .946 l (1 qt) milk cartons was compared to bareroot seedlings from outdoor seedbeds one growing season after planting to the field. Survival of container grown plants was much greater than bareroot plants.

Conventional containers with bottoms modify root structure and in species with dominant taproots the malformed, contorted root system that is produced causes slower growth and sometimes premature death (1,13).

Investigators have shown that by using a square, bottomless container on a wire bench the roots grow out until reaching the sides,

then turn towards the 90° corner and proceed downwards (5,11). As the roots reach the atmosphere below the wire bench they dessicate. This air pruning of the taproot results in the development of lateral roots and thus a more fibrous root system.

Gibson and Whitcomb (5,6) studied the effect of different diameters of milk cartons on the growth of tree seedlings. Those compared were quart (6.98 cm in dia.), half-gallon (10.16 cm in dia.), and gallon (13.97 cm in dia.) milk cartons all 13.97 cm (5.5 in) deep and bottomless. After 4 months the smaller container performed equally well as the two larger containers. However, after 12 months the tree seedlings in the two larger size containers were superior in growth and development.

Investigations were conducted to determine the optimum depth of square, bottomless containers for tree seedling production. Hathaway and Whitcomb (10) compared containers that were 27.9 cm (11 in), 20.95 cm (8.25 in), and 13.97 cm (5.5 in) deep, all being 6.98 cm (2.75 in) x 6.98 cm (2.75 in) square. At the end of 90 days, seedlings produced in the shortest containers were equally as good as those in the deeper containers.

Hathaway and Whitcomb (9) reported on the survival after planting to the field of trees grown in square, bottomless containers. Three species planted in the field in August when the air temperature was 102°F had a 100% survival rate one month after planting.

Quercus macrocarpa seedlings grown in square, bottomless containers and in round containers with bottoms were compared by Hathaway and Whitcomb (12). Both type containers were of the same height and volume.

After one growing season, the square, bottomless containers produced taller seedlings with much greater stem caliper than those grown in round containers with bottoms.

CHAPTER III

MATERIALS AND METHODS

Six woody ornamental species were selected to study the effects of continuous light and square, bottomless containers on growth and development during greenhouse propagation phase and after planting to field or container. The species studied were Liquidambar styraciflua (Sweet Gum), Betula pendula (European White Birch), Koelreuteria paniculata (Golden Rain Tree), Magnolia x soulangeana (Saucer Magnolia), Prunus caroliniana (Carolina Laurelcherry), and Quercus palustris (Pin Oak).

Containers were constructed from .946 l (1 qt) milk cartons. One-half of the containers had the bottoms folded into an intact position. One-half had this extra paper removed, resulting in a bottomless container. Holes were punched in containers with intact bottoms to facilitate drainage. Containers were cut to 13.97 cm (5.5 in) tall to make all containers equal size. Container dimensions were 6.98 cm (2.75 in) x 6.98 cm (2.75 in) x 13.97 cm (5.5 in). The volume of soil held by each was 680.62 cm³ (41.6 in³).

The growing medium was 3:1:1 pine bark to sand to peat. Incorporated into this was 6.81 kg (15 lb) 18-5-11 Osmocote, 1.82 kg (4 lb) Perk, 1.82 kg (4 lb) 0-20-0 regular superphosphate, and 3.63 kg (8 lb) dolomitic limestone per .765 m³ (1 yd³).

Containers were placed in the greenhouse on raised wire benches measuring 1.2 m x 3 m (4 ft x 10 ft) (Figure 1). Four, 1.2 m (4 ft)



Figure 1. Containers on wire bench.

lighting fixtures with two bulbs per fixture were suspended over one-half of the twelve benches used in the study. The six benches receiving continuous light were selected randomly. Each fixture contained two cool-white fluorescent bulbs and at night delivered 3-500 footcandles at container top level (Figure 2). The light fixtures were initially stationed 45.7 cm (18 in) above the top of containers and were adjusted upward as the seedlings grew. To shield benches receiving no supplemental light, curtains of black polyethylene plastic were attached to the sides of the lighting fixtures along the length of the bench. These curtains were raised and lowered daily at 8:00 a.m. and 5:00 p.m., respectively.

The L. styraciflua, Q. palustris, K. paniculata, and B. pendula seeds were obtained from a commercial source that was unable to supply the exact location of collection. Seeds of Magnolia x soulangeana were collected from a specimen at the southeast entrance of the Ellington Plant Science Building, University of Tennessee Agricultural Campus, Knoxville. Seeds of P. caroliniana were collected at the Bearden Junior High School Campus, Knoxville.

After sufficient stratification period in damp sand held at 1-3° C (33-38° F) in a cooler, seeds of K. paniculata, Q. palustris, L. styraciflua, and B. pendula were planted directly in containers on March 25, 1980. Q. palustris was seeded at two seeds per container, K. paniculata and L. styraciflua at 3-4, and B. pendula at 10-12 seeds per container and after germination were thinned to one strong seedling. Magnolia x soulangeana and P. caroliniana were sown in fall of 1979 in outdoor seedbeds and after germination the following spring were transplanted to containers in the greenhouse on May 22, 1980.



Figure 2. Tree seedlings under continuous light on raised wire bench.

This phase of the experiment was conducted in a glass greenhouse shaded with whitewash during summer. The greenhouse was cooled during summer months by an evaporative pad and fan cooling system which kept the temperature in a range of 24-35⁰ C (75-95⁰ F) during the day.

Treatments in the greenhouse included four combinations of continuous or natural photoperiod and bottomless or intact bottom container. Greenhouse treatments are given in Table 1. Treatments for each species except P. caroliniana and Q. palustris were replicated six times with ten subsamples per replication arranged in a split-plot design. Treatments for P. caroliniana and Q. palustris were replicated three times with ten subsamples per replication arranged in a split-plot design. The smaller number of replications for these species was due to insufficient number of samples and were therefore planted in field only and not in container.

All species were grown until sufficient top growth and root development had occurred to plant to field or container. The number of days each species was in the greenhouse is give in Table 2.

After seedlings had reached sufficient size in the greenhouse to plant, the subsamples in each treatment were divided as follows: the three worst specimens were culled. Of the remaining seven, four were planted in the field and three were planted in 3-gallon containers. Samples in field and container culture were arranged in a randomized complete block design. Height measurements were recorded at this time.

Water was supplied as needed to containers, usually every third day. Field samples were irrigated, using a trickle hose system, at the time of planting and again 10-12 days later.

TABLE 1. Treatment combinations of photoperiod and container type during greenhouse phase.

treatment code	greenhouse treatment
1	24 hour photoperiod bottomless container
2	24 hour photoperiod container with bottom
3	natural photoperiod bottomless container
4	natural photoperiod container with bottom

TABLE 2. Number of days each species was in greenhouse phase.

species	number of days
<u>Koelreuteria paniculata</u>	112
<u>Magnolia x soulangeana</u>	84
<u>Betula pendula</u>	105
<u>Liquidambar styraciflua</u>	116
<u>Quercus palustris</u>	126
<u>Prunus caroliniana</u>	84

The growing medium used in the 3-gallon containers was a commercial blend of 2.5:1.5:1 pine bark to peat to sand. The medium was amended with 5.45 kg (12 lb) dolomitic limestone, 2.72 kg (6 lb) gypsum, 2.72 kg (6 lb) 12-6-6 Beaty fertilizer, and 85.8 g (3 oz) of FTE 555 per cubic yard.

Field soil was of the Etowah series, well-drained with a dark brown silt loam topsoil 12.7-30.5 cm (5-12 in) thick. Field soil was analyzed for nutrient availability and found to be deficient in potassium and phosphorus, thus 9.1 kg (20 lb) of actual phosphate and 122.8 kg (270 lb) of potassium were added pre-plant to field on a per acre basis. No additional fertilizer was supplied to either field or container plants during the remainder of the growing season.

At the end of the growing season analysis of top growth and root development was initiated. Straightness rating for each species was determined on a visual scale of 1-3. One was equal to no or very little apical dominance and lying on or close to ground level; two was equal to average straightness with some apical dominance; and three was equal to a straight tree with strong apical dominance.

After straightness ratings were recorded each tree in field and container was cut off at 6 cm above ground level. These samples of top growth were then transferred to a work area for measuring height, caliper, and fresh weight of top growth.

Height was determined by placing the plants on a table and measuring from the apical growing point to the point the plant was severed from its root system. Six cm were then added to this measure to adjust the value to the true height of the plants.

Caliper measurements were recorded 1 cm above the point plants were severed from root system. Therefore, caliper of plants was determined 7 cm above what would have been the soil level.

Fresh weight of top growth was also recorded at this time using Mettler top-loading scales.

Root quality rating for each species in container was determined on a visual scale of 1-4. An example of root quality ratings for container plants is given in Figure 3. Plants were removed from container and the growing medium was dislodged from the root system. Root systems were then compared to standards and assigned a root quality rating.

Root quality rating for each species in field culture was determined on a visual scale of 1-3. An example of root quality ratings for field plants is given in Figure 4. Plants in field were dug with a 30.5 cm (12 in) root ball for each plant. Soil was shaken loose, the root systems compared to standards for field plants, and finally a root quality rating was assigned.

All data were statistically analyzed by the Statistical Analysis System (SAS) at The University of Tennessee Computing Center. An analysis of variance (ANOVA) was run to determine significance of main treatment effects. Treatment means were separated by Duncan's Multiple Range Test.

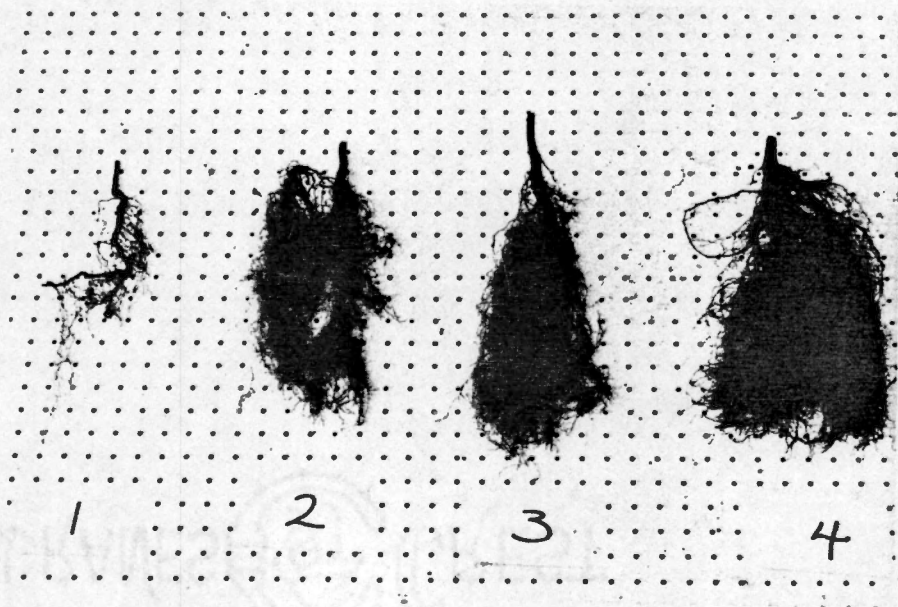


Figure 3. Example of Root Rating Standards for container plants.
Species pictured is Liquidambar styraciflua.

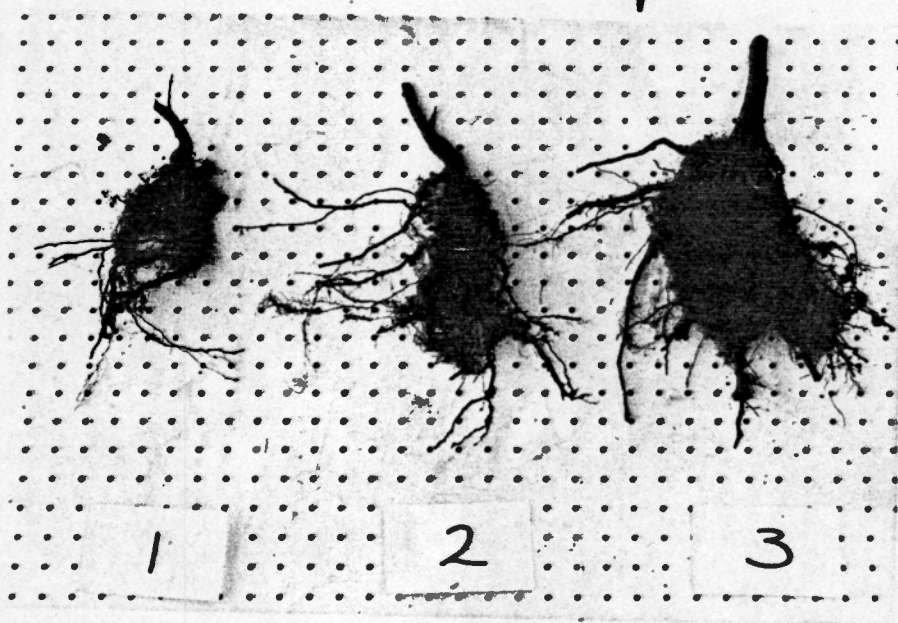


Figure 4. Example of Root Rating Standards for field plants.
Species pictured is *Koeleria paniculata*.

CHAPTER IV

RESULTS AND DISCUSSION

Response of six woody ornamental species will be discussed separately since no comparison between species will be made.

I. KOELREUTERIA PANICULATA-GOLDEN RAIN TREE

1. Greenhouse Phase

Seedlings started under continuous light were taller than those started under a natural photoperiod (Figure 5). Container type had no effect on height growth. An interaction occurred between these main treatment effects with the most height growth in the bottomless container, 24 hour photoperiod treatment (Figure 5).

2. Field and Container Phase

Seedlings started under continuous photoperiod were taller at the end of the growing season than seedlings started under natural photoperiod in both field and container plants (Figure 6). Container type, or interaction of container type and photoperiod treatment, had no influence on height growth. In this phase, K. paniculata grew more in the field (4.0 cm) than in containers (1.1 cm).

No meaningful difference occurred between the caliper of field (9.9 mm) and container (9.3 mm) grown plants. Photoperiod treatment, container type, or interaction of photoperiod and container type had no effect on caliper of K. paniculata at either growing location.

Fresh weight of plants started in bottomless containers was greater than plants started in containers with bottoms in both field and

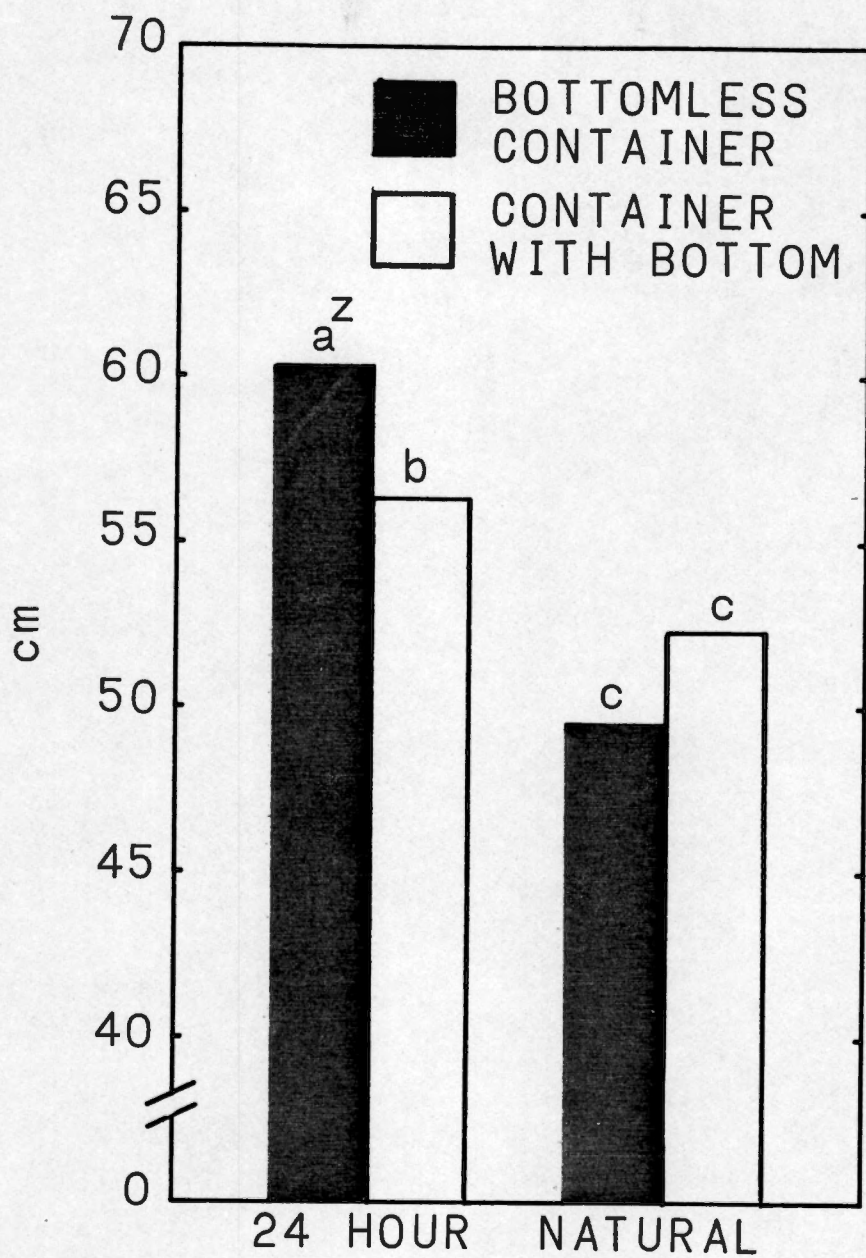


Figure 5. Height of *K. paniculata* in response to photo-period treatment and container type at termination of greenhouse phase.

^zMean separation by Duncan's Multiple Range test, 5% level.

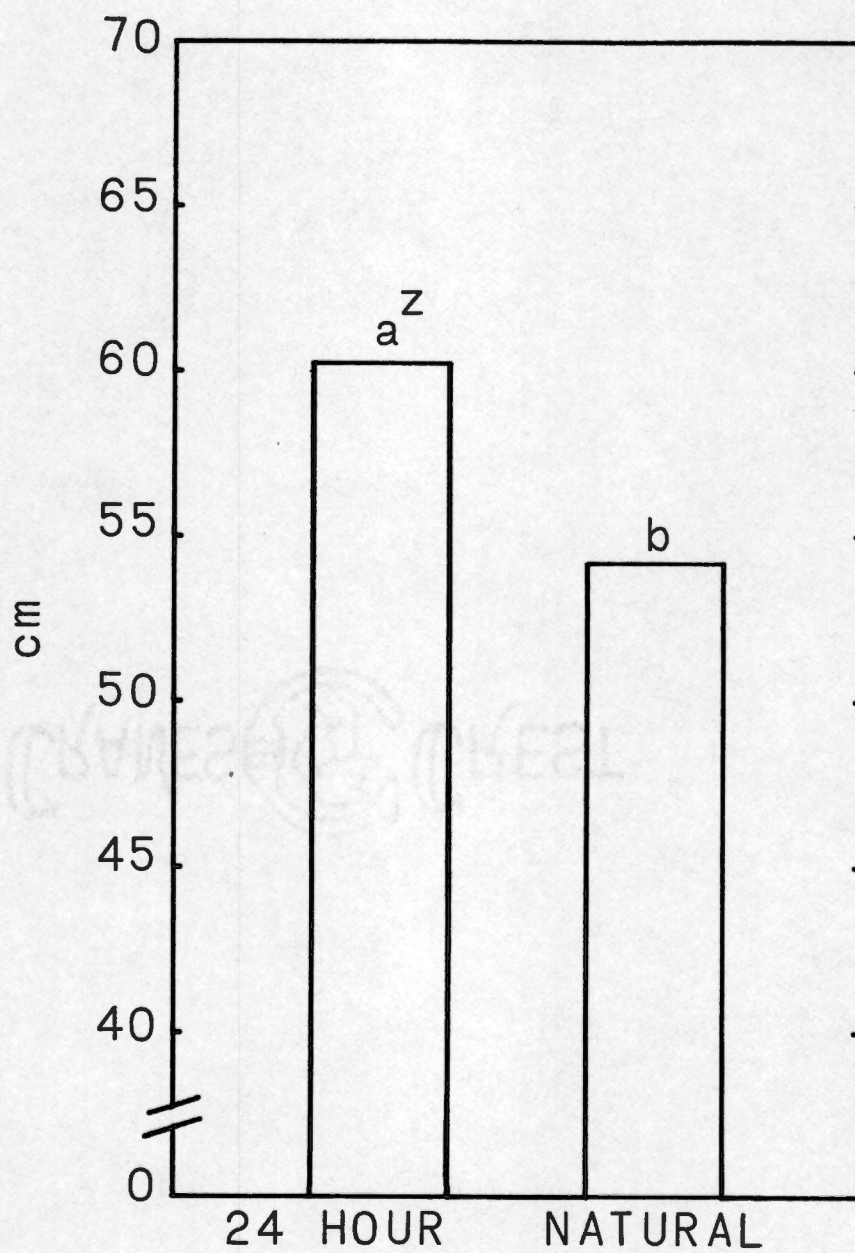


Figure 6. Height of *K. paniculata* in response to photo-period treatment at end of growing season.

^zMean separation by ANOVA test, 5% level.

container growing locations (Figure 7). Photoperiod treatment, or interaction of photoperiod and container type, had no effect on fresh weight.

Neither treatments nor location had any effect on the straightness ratings, with all means being 2.5 ± 0.1 .

Field plants had a better root quality rating when started in bottomless containers when compared to plants started in containers with bottoms (Figure 8). Photoperiod treatment had no effect on root quality ratings of K. paniculata. These main treatment effects did not interact to influence root quality ratings.

Three gallon container plants had a higher root quality rating when the seedlings were started in bottomless containers as opposed to seedlings started in containers with bottoms (Figure 9). Photoperiod treatment, or interaction of photoperiod and container type, had no effect on root quality ratings of container plants.

II. MAGNOLIA X SOULANGEANA-SAUCER MAGNOLIA

1. Greenhouse Phase

Seedlings started under continuous light were taller than seedlings started under natural photoperiod (Figure 10). Magnolia x soulangeana grew taller in bottomless containers than in containers with bottoms (Figure 11). No interaction between photoperiod treatment and container type occurred.

2. Field and Container Phase

Height measurements indicated a positive response to 24 hour photoperiod when compared to a natural photoperiod (Figure 12). Magnolia

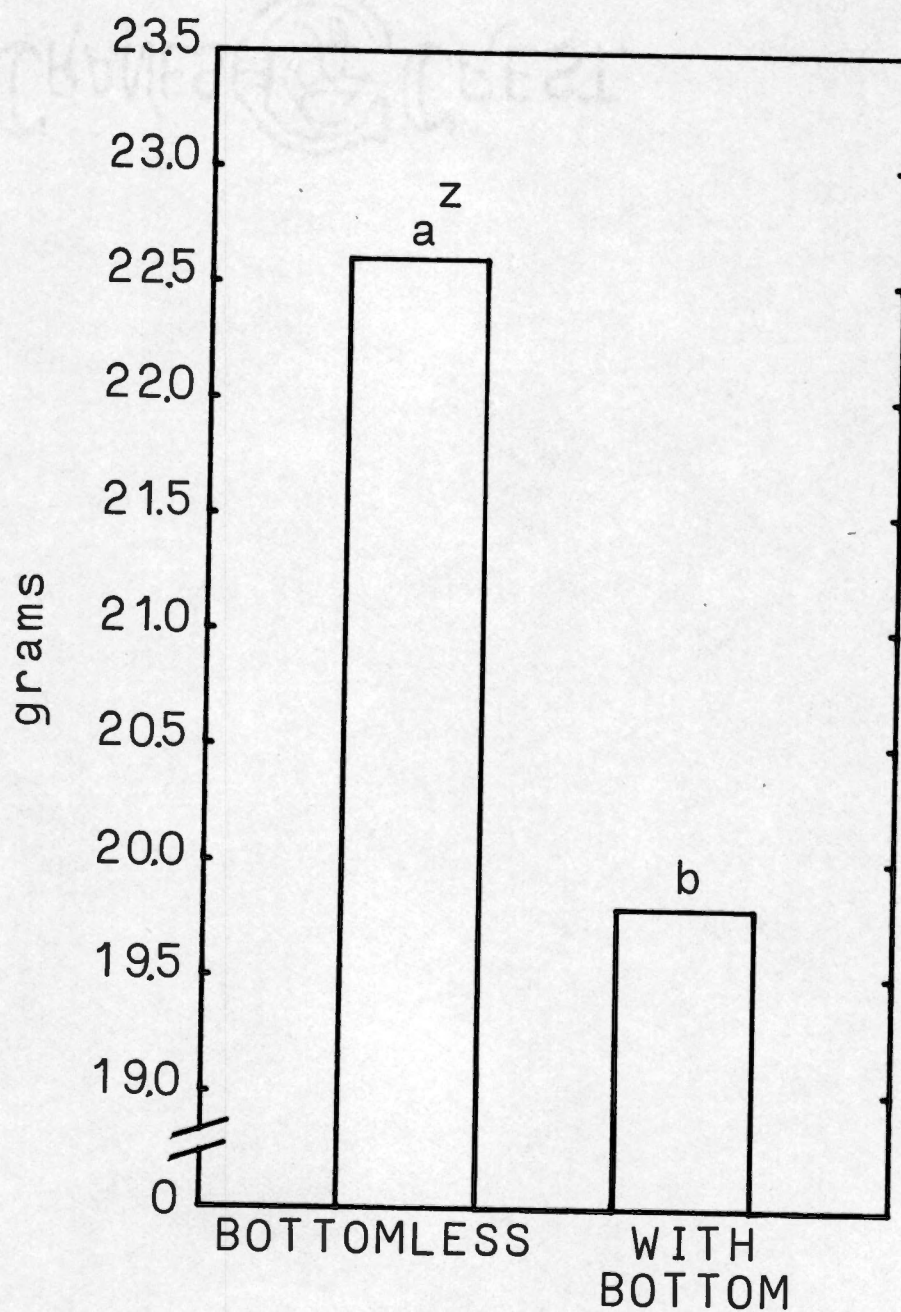


Figure 7. Fresh weight of top growth of *K. paniculata* in response to container type at end of growing season.

^z Mean separation by ANOVA test, 5% level.

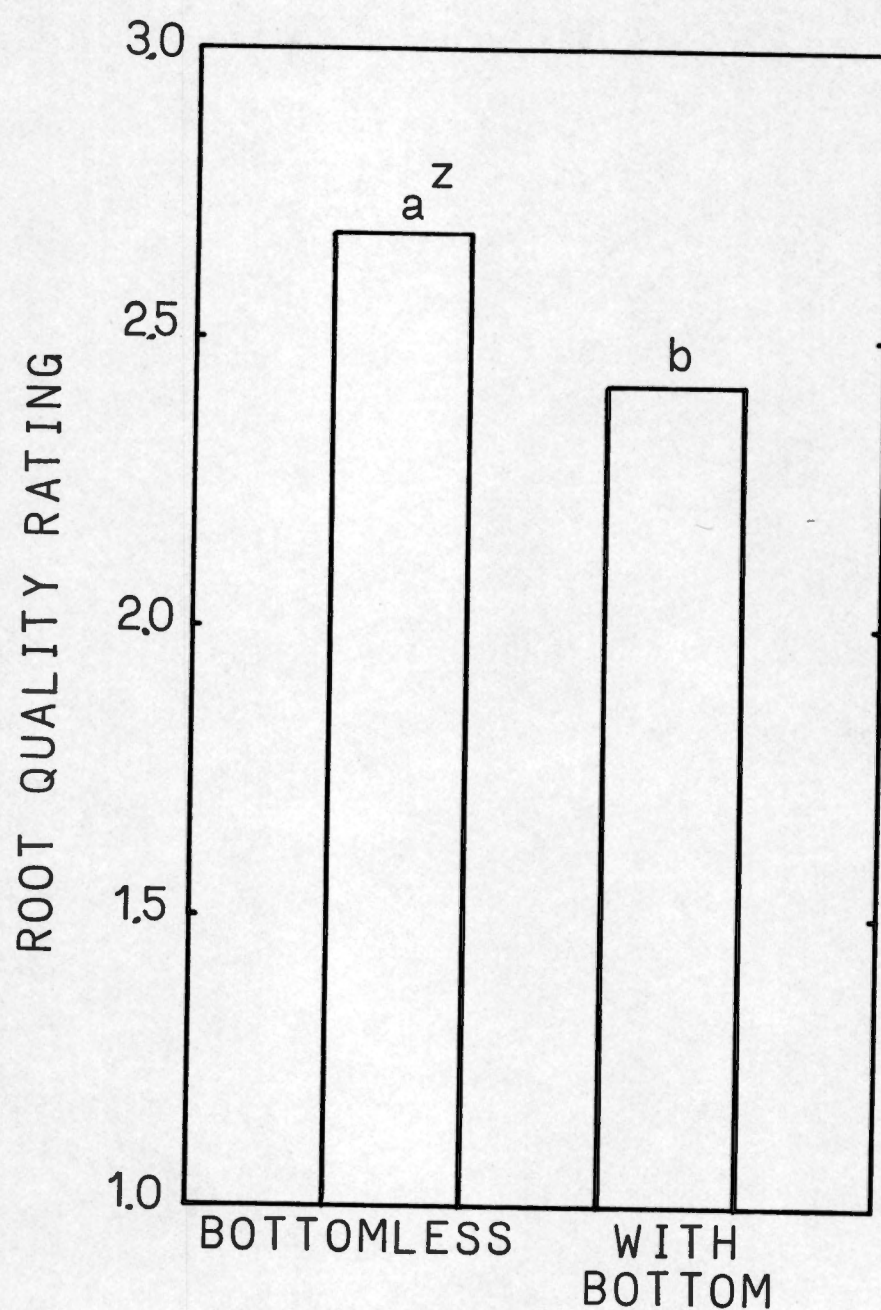


Figure 8. Root quality rating of *K. paniculata* grown in field response to container type.

^zMean separation by ANOVA test, 5% level.

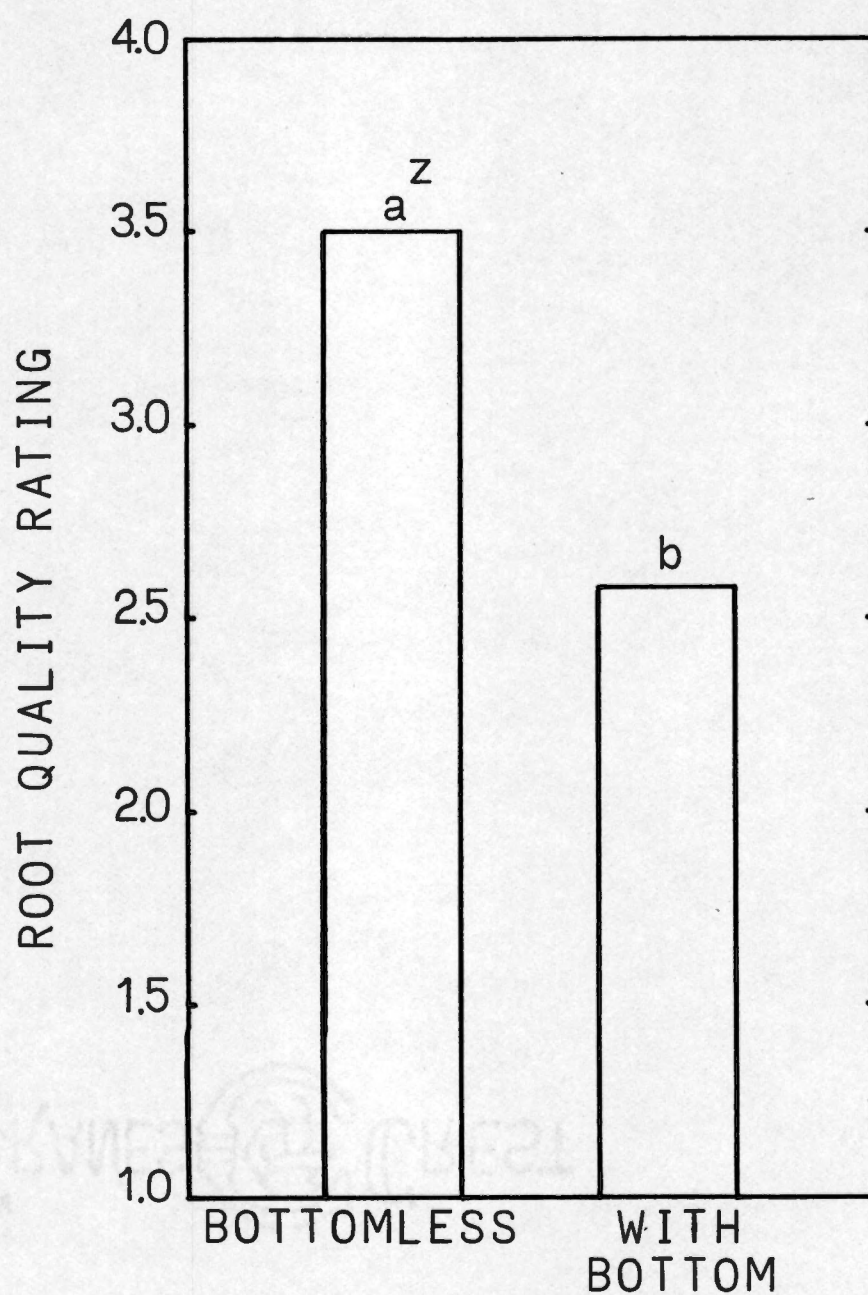


Figure 9. Root quality rating of *K. paniculata* grown in container in response to container type.

^zMean separation by ANOVA test, 5% level.

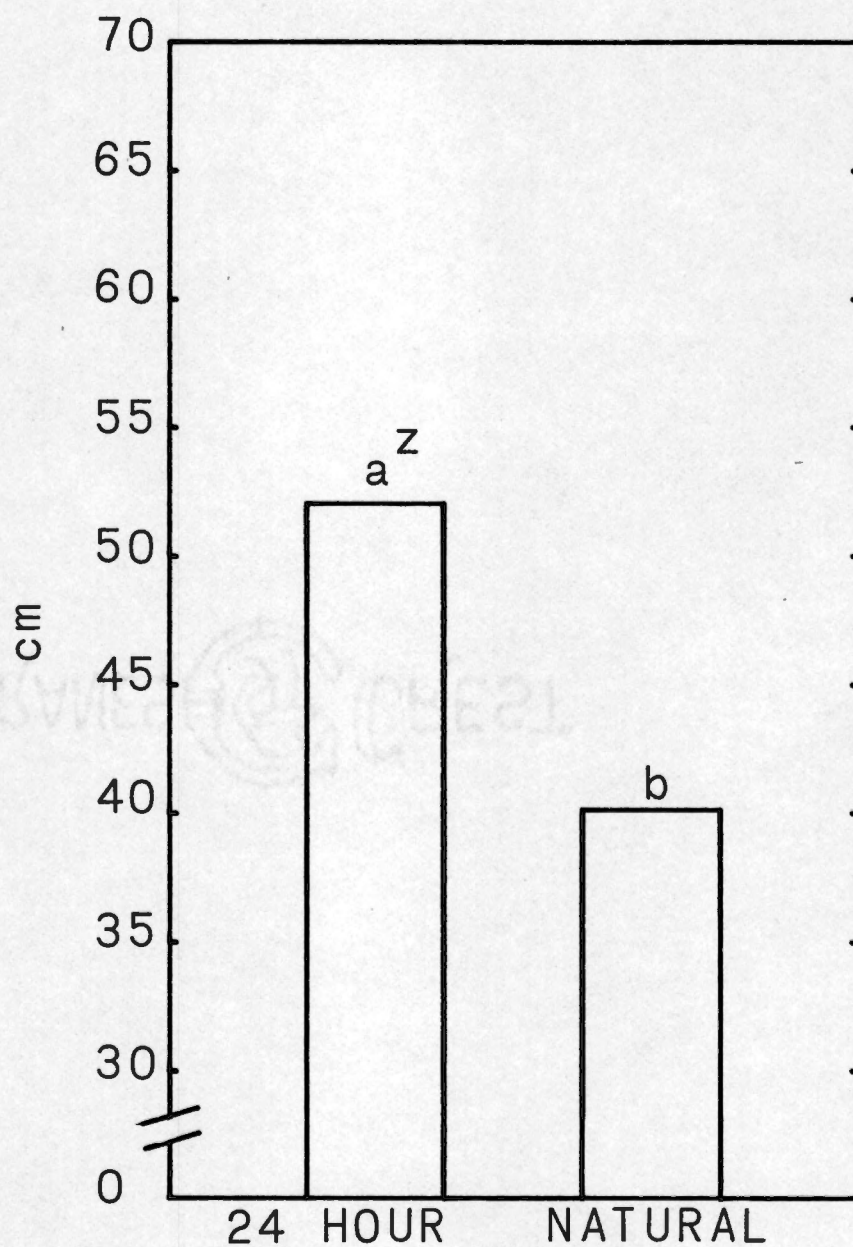


Figure 10. Height of *Magnolia x soulangeana* in response to photoperiod treatment at termination of greenhouse phase.

^zMean separation by ANOVA test, 5% level.

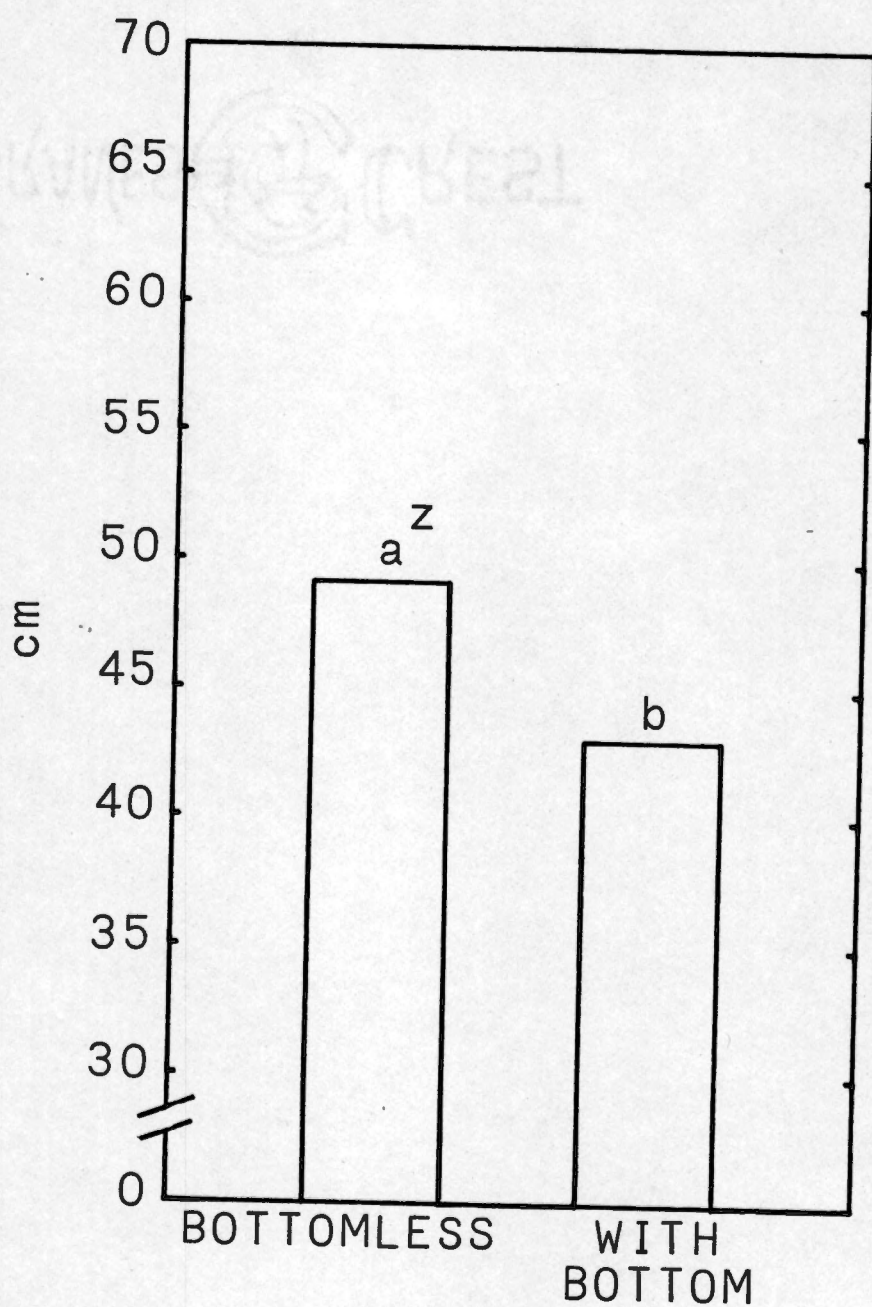


Figure 11. Height of *Magnolia x soulangeana* in response to container type at termination of greenhouse phase.

^zMean separation by ANOVA test, 5% level.

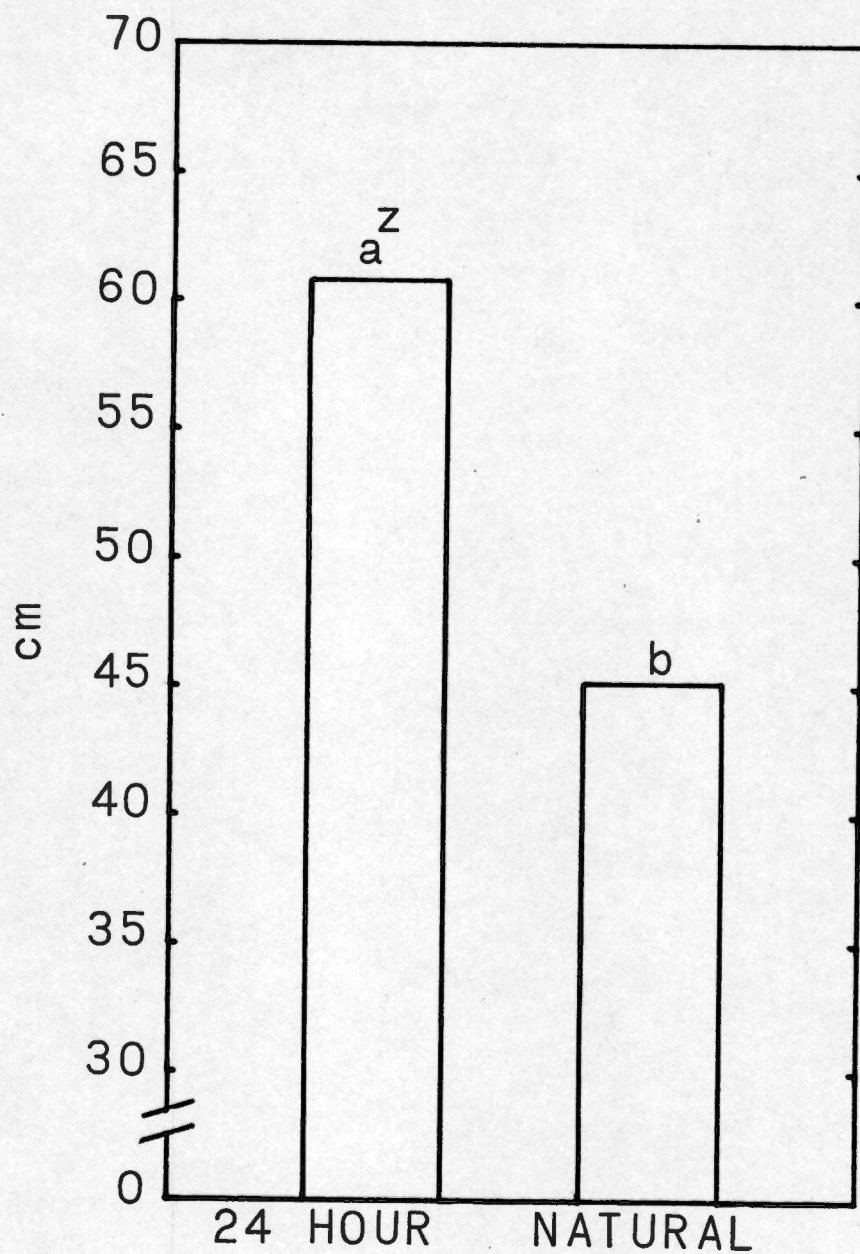


Figure 12. Height of *Magnolia x soulangeana* in response to photoperiod treatment at end of growing season.

^zMean separation by ANOVA test, 5% level.

x soulangiana grew taller in field and 3-gallon container when started in bottomless containers compared to containers with bottoms (Figure 13). No interaction between these main treatment effects was observed.

Plants from continuous light treatments grew faster (8.8 cm) after planting to field or container than plants started under a natural photoperiod (4.9 cm). Magnolia x soulangiana started in bottomless container during the greenhouse phase grew more (8.1 cm) than plants in containers with bottoms (5.5 cm) after planting to field or container. These main treatment effects did not interact to accelerate growth. Plants reached approximately the same height in containers and field at the conclusion of the growing season, with all means being $52.5 \text{ cm} \pm 1.0 \text{ cm}$.

The caliper of Magnolia x soulangiana seedlings started in bottomless containers was greater than seedlings started in containers with bottoms (Figure 14). No meaningful difference in caliper occurred between plants started under 24 hour photoperiod and plants started under a natural photoperiod. There was no interaction of main treatment effects as well as no difference between caliper of field and container plants.

Fresh weight of top growth of Magnolia x soulangiana was greater in plants from 24 hour light, bottomless container treatments (Figure 15). The trend was the same for natural daylength, bottomless container treatments but excessive variation determined the difference to be nonsignificant.

Magnolia x soulangiana started under natural photoperiod were straighter than plants from continuous light treatments in both field

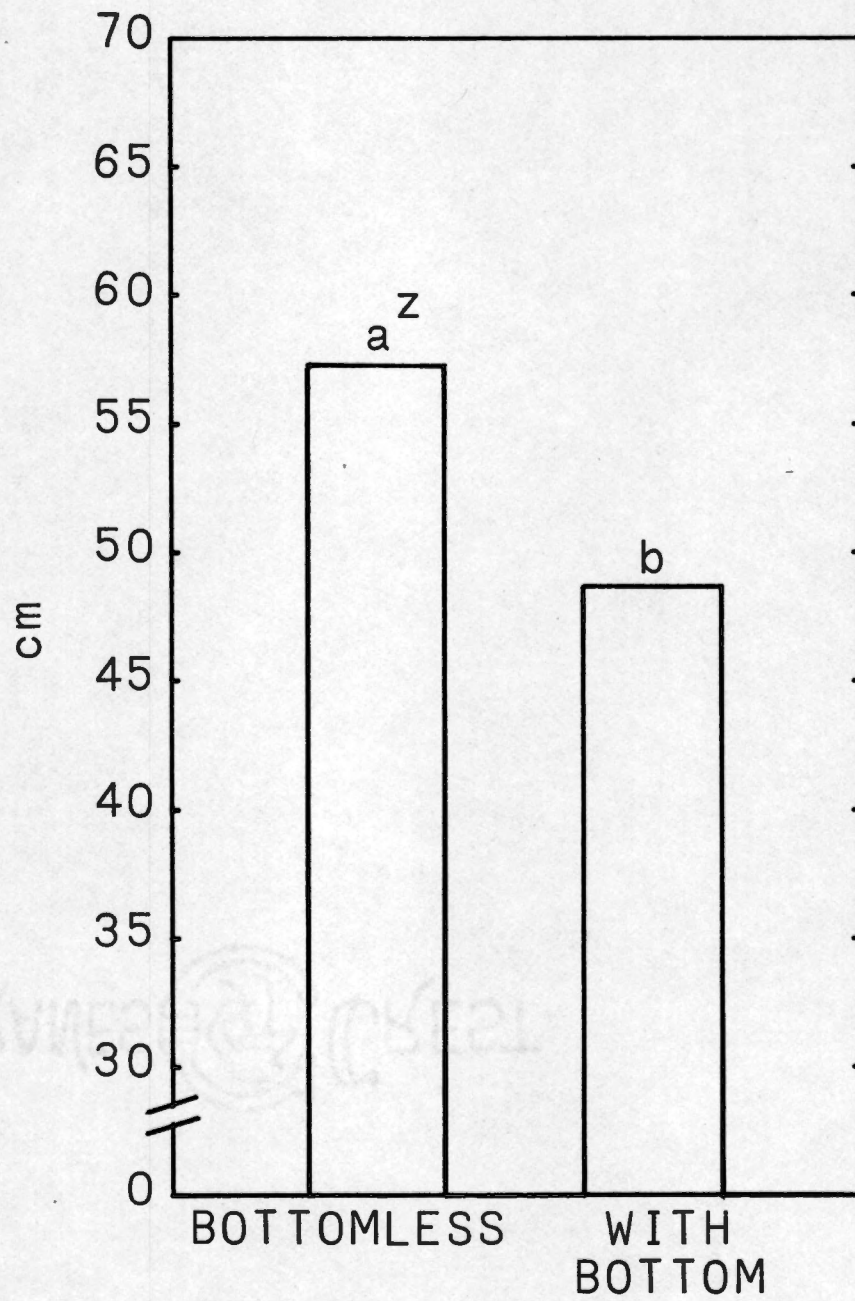


Figure 13. Height of *Magnolia x soulangeana* in response to container type at end of growing season.

^z Mean separation by ANOVA test, 5% level.

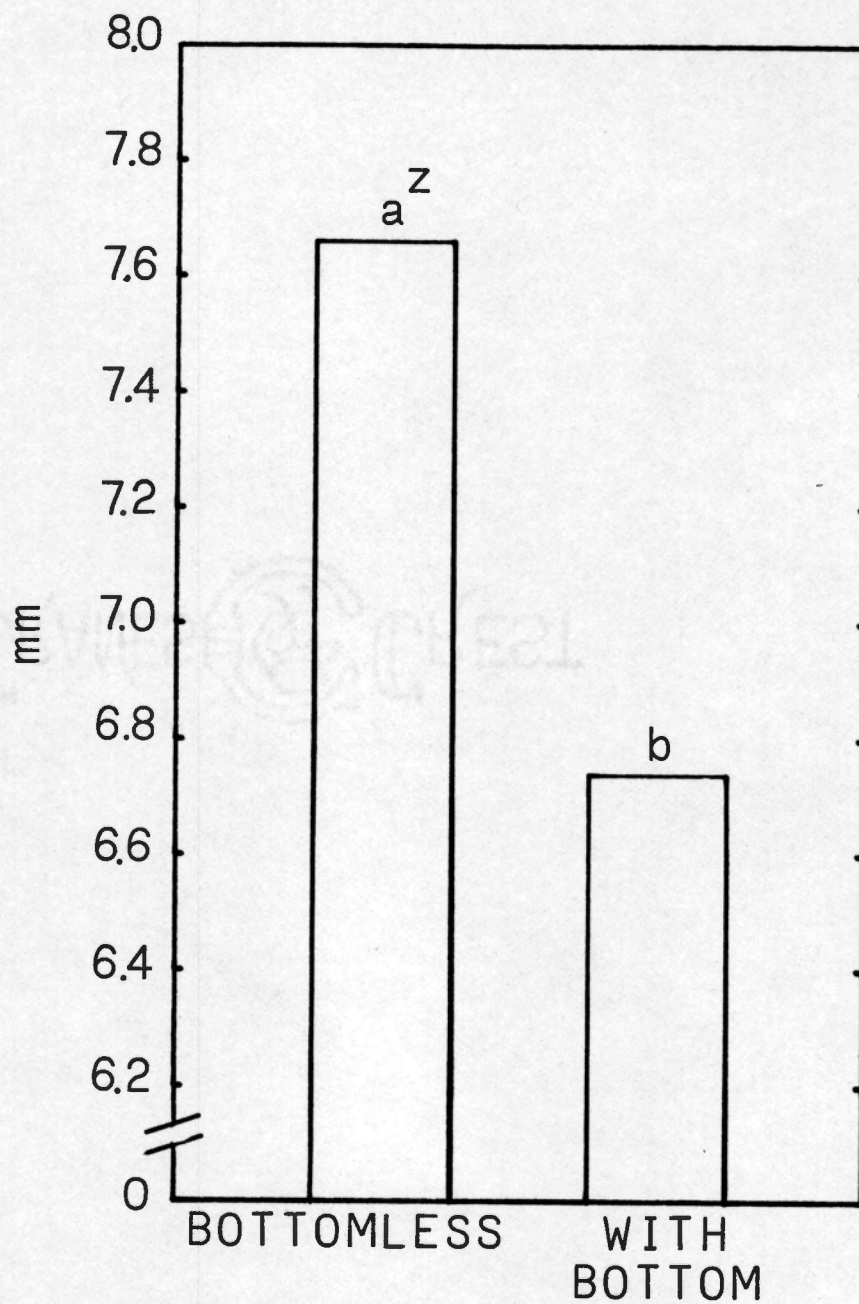


Figure 14. Caliper of *Magnolia x soulangeana* in response to container type at end of growing season.

^zMean separation by ANOVA test, 5% level.

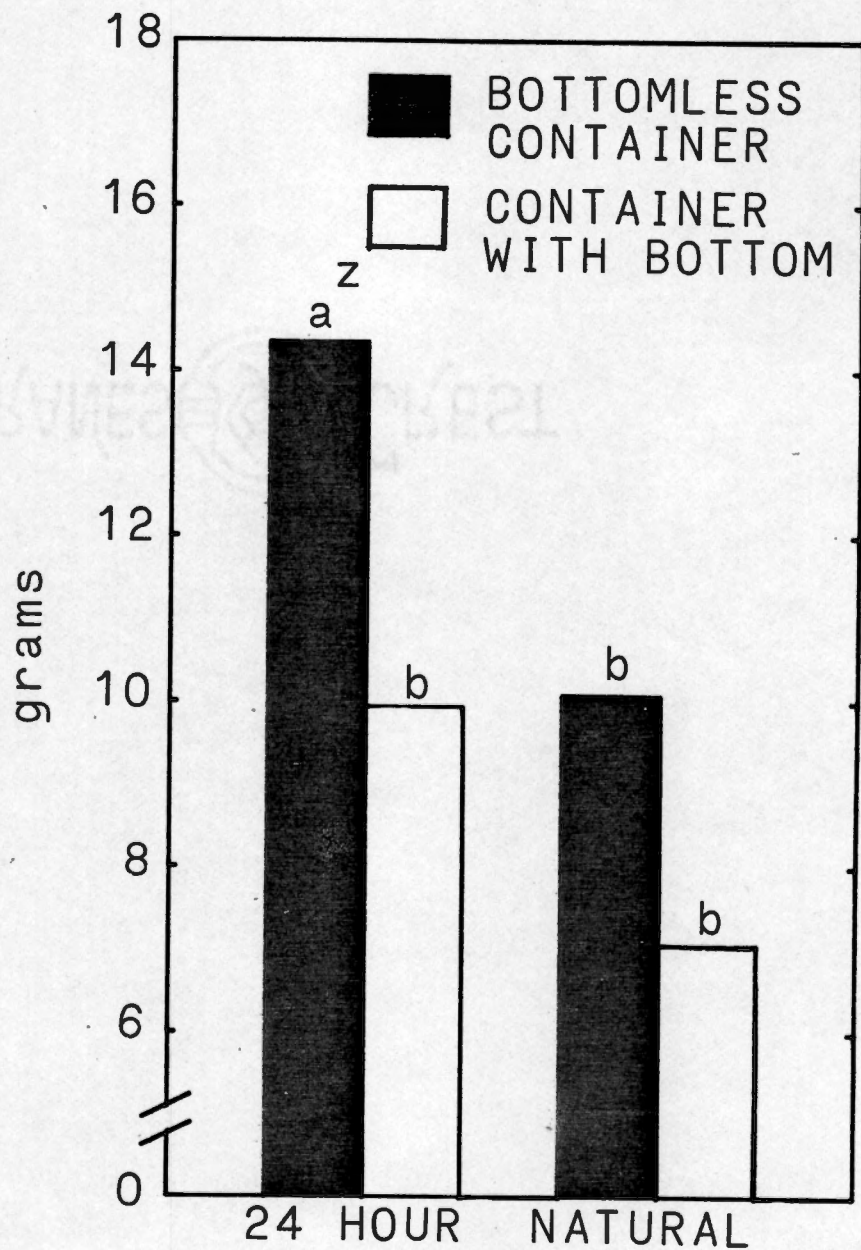


Figure 15. Fresh weight of top growth of *Magnolia x soulangeana* in response to photoperiod treatment and container type at end of growing season.

^z Mean separation by Duncan's Multiple Range test, 5% level.

and container growing locations (Figure 16). Container type, or interaction of container type and photoperiod treatment, had no effect on straightness ratings. No meaningful difference in straightness ratings was observed when field and container plants were compared.

Seedlings started in bottomless containers produced better root quality ratings than those started in containers with bottoms in both field (Figure 17) and container plants (Figure 18). Photoperiod treatments, or interaction of photoperiod treatment and container type, had no effect on root quality ratings at either growing location.

III. BETULA PENDULA-EUROPEAN WHITE BIRCH

1. Greenhouse Phase

Seedlings started in bottomless containers were taller than those started in containers with bottoms at termination of greenhouse growing phase (Figure 19). Photoperiod treatment, or interaction of photoperiod treatment and container type, had no effect on height growth.

2. Field and Container Phase

Measurements taken at the conclusion of the growing season indicated bottomless containers produced taller seedlings than containers with bottoms (Figure 20). Continuous light had no meaningful effect on the height growth of B. pendula seedlings. Photoperiod treatment and container type did not interact to effect height growth.

No meaningful difference in height growth of B. pendula seedlings occurred after planting to field (6.78 cm) or container (6.80 cm). No difference in height growth was observed when field plants (70.1 cm) were compared to container plants (71.0 cm).

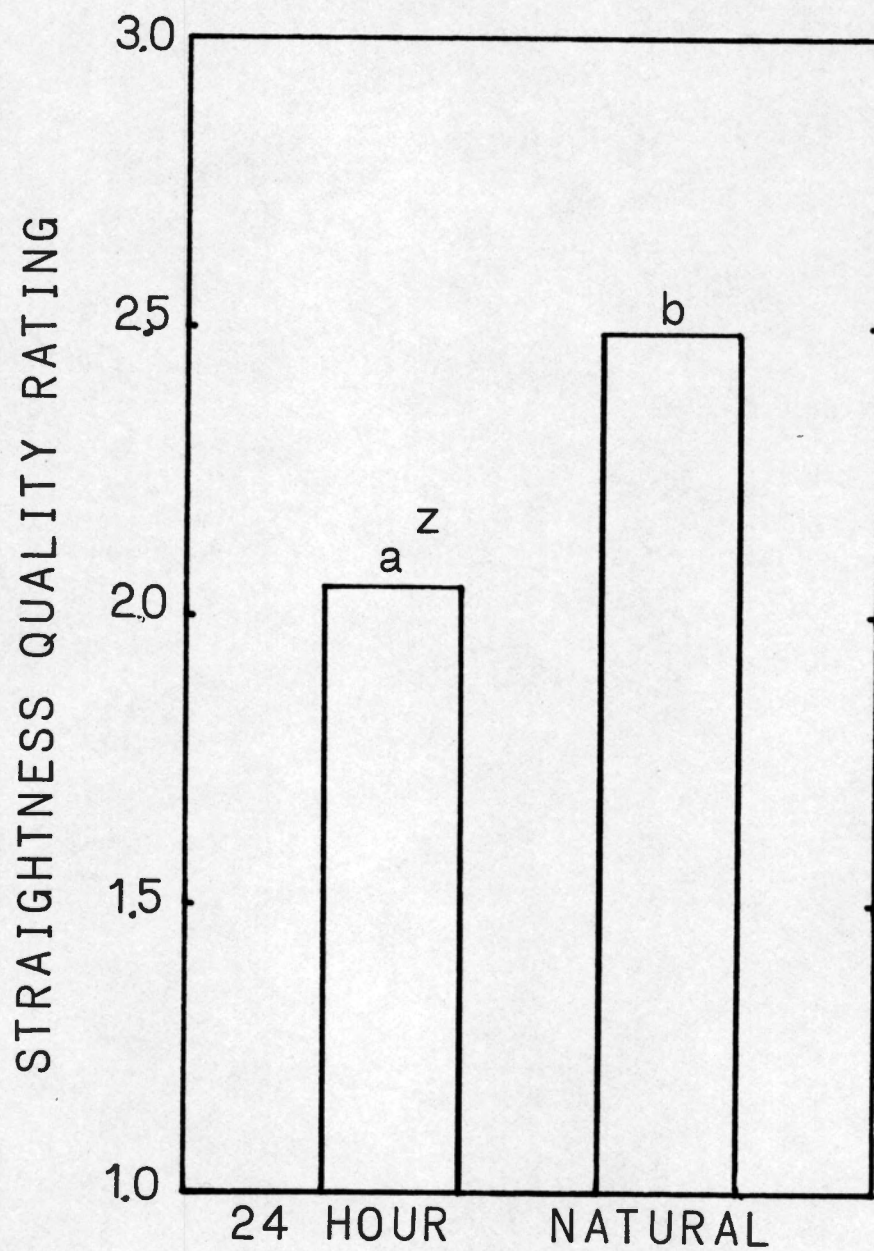


Figure 16. Straightness quality rating of Magnolia x soulangeana in response to photoperiod treatment at end of growing season.

^zMean separation by ANOVA test, 5% level.

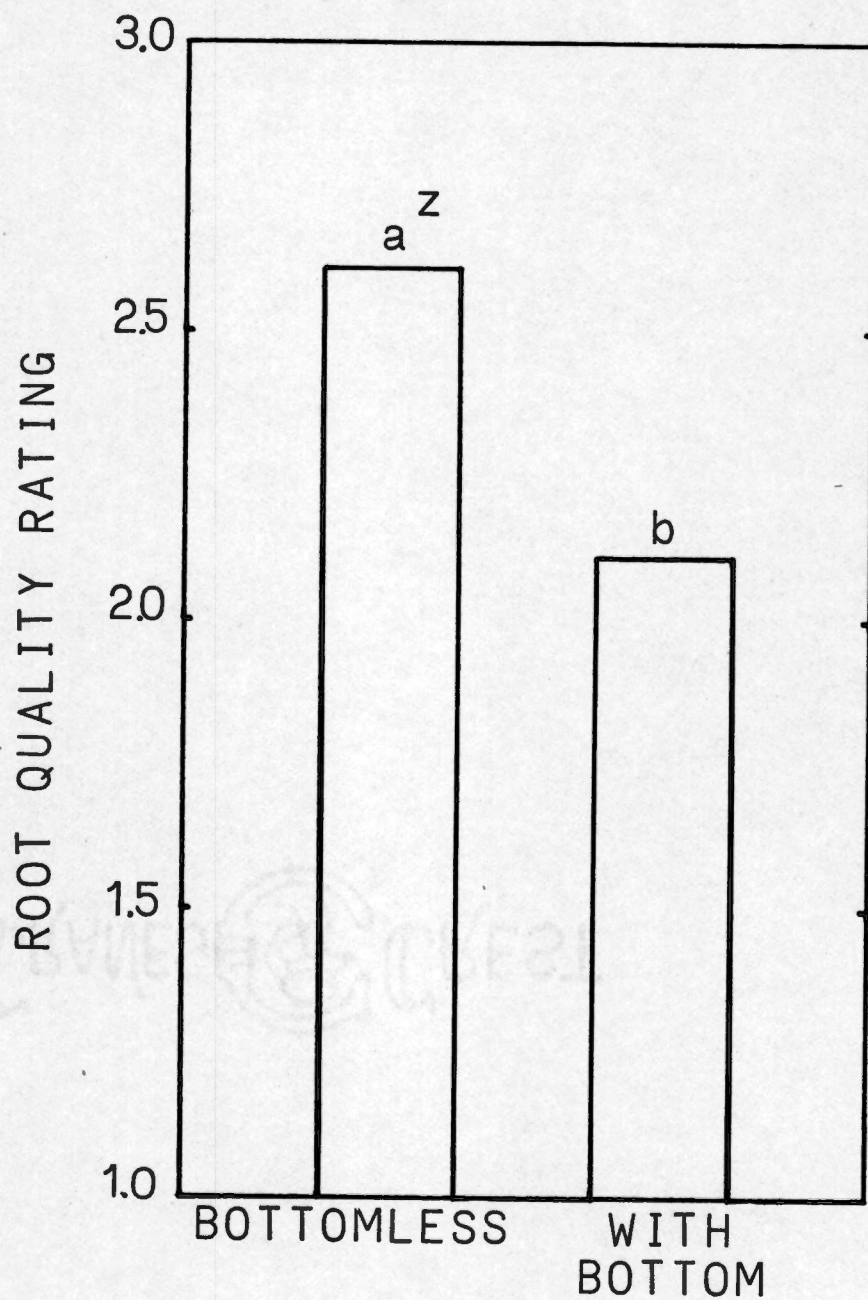


Figure 17. Root quality rating of *Magnolia x soulangeana* in field response to container type.

^zMean separation by ANOVA test, 5% level.

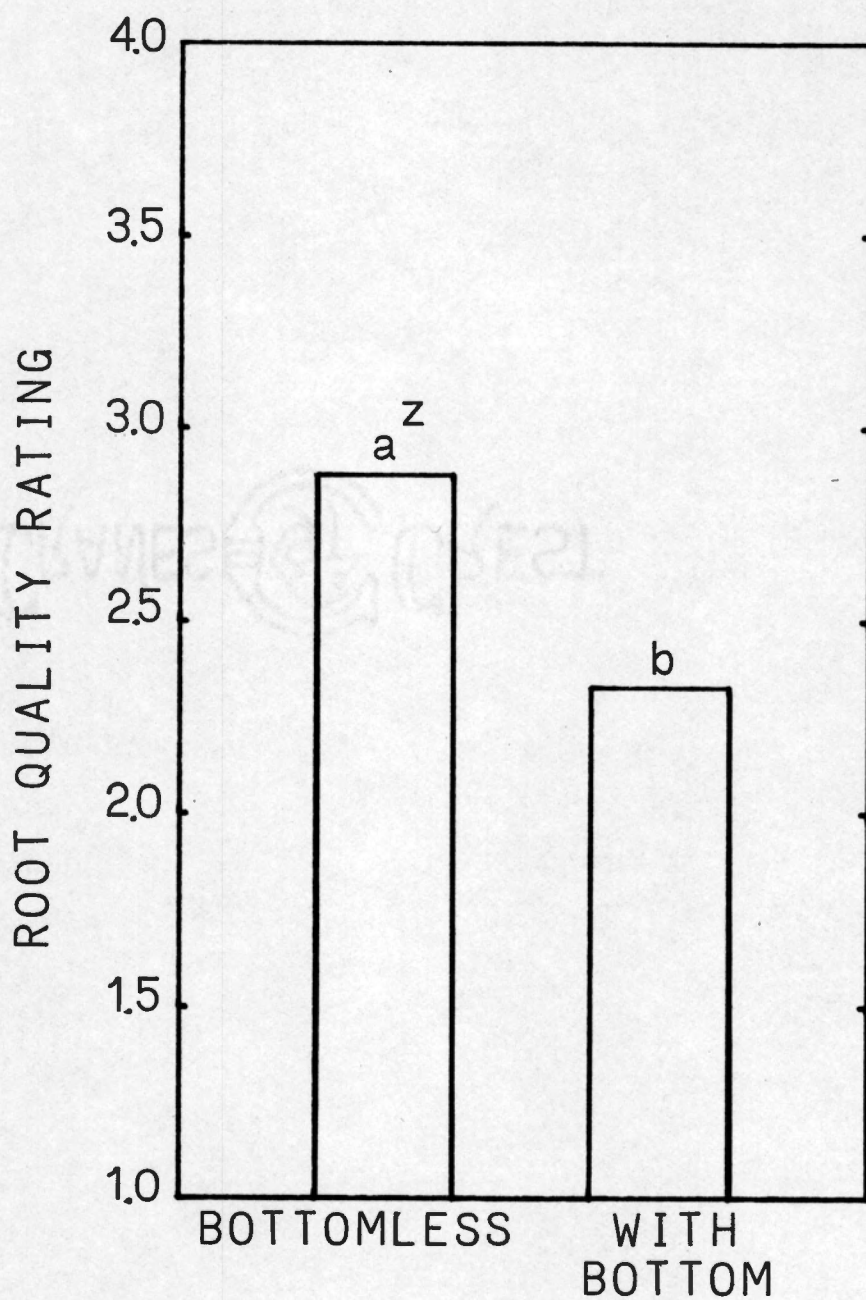


Figure 18. Root quality rating of *Magnolia x soulangeana* in container in response to container type.

^zMean separation by ANOVA test, 5% level.

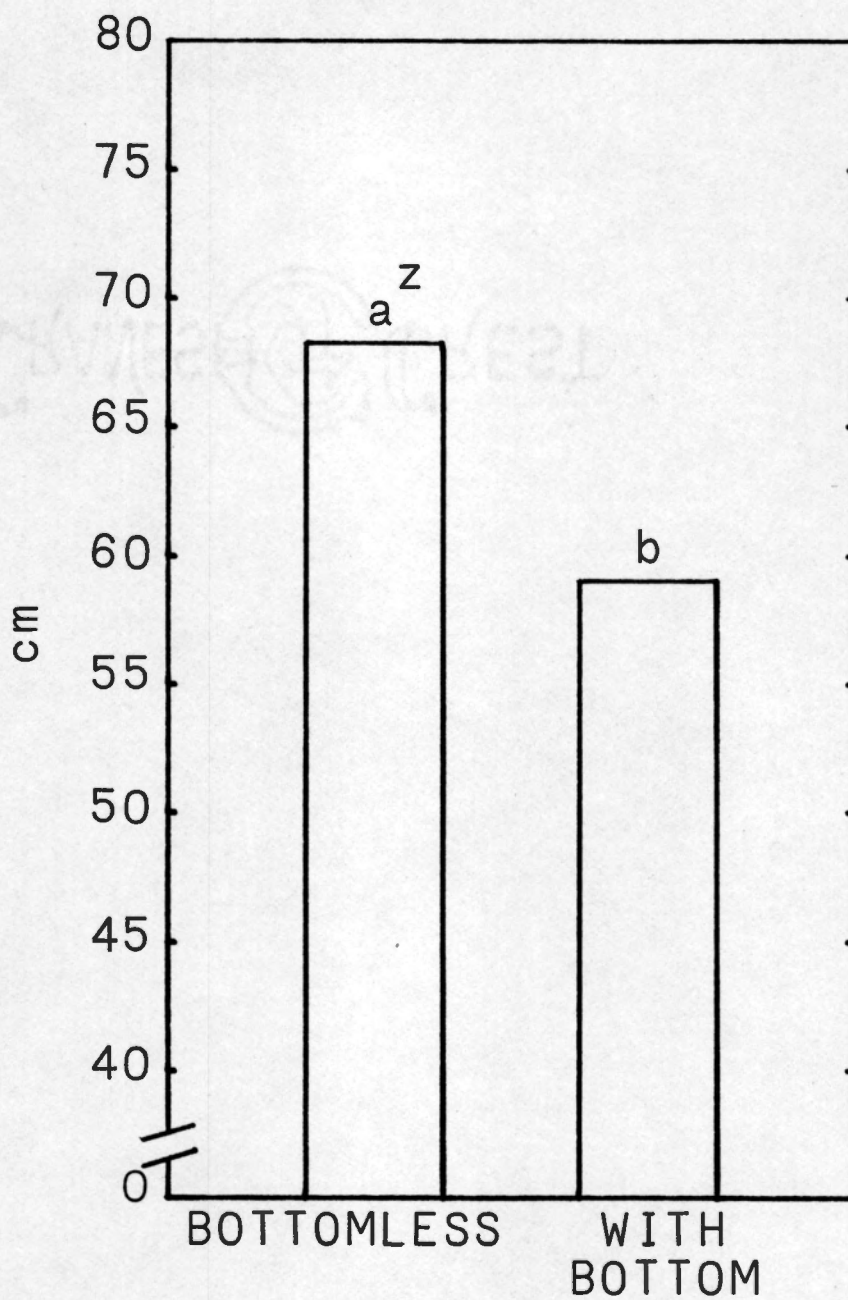


Figure 19. Height of *B. pendula* in response to container type at termination of greenhouse phase.

^zMean separation by ANOVA test, 5% level.

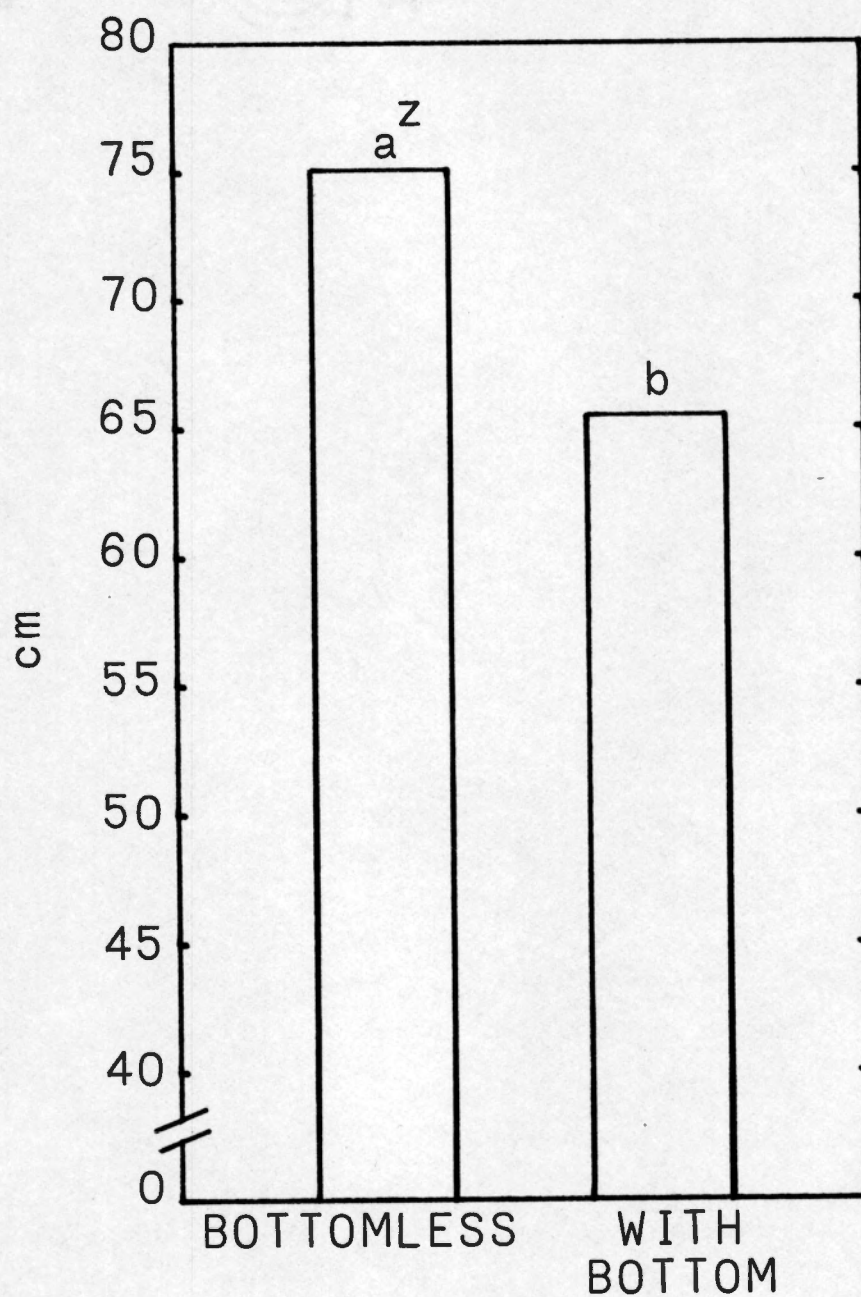


Figure 20. Height of *B. pendula* in response to container type at end of growing season.

^zMean separation by ANOVA test, 5% level.

Seedlings of B. pendula started in bottomless containers during the greenhouse phase had greater caliper (9.09 mm) than plants started in containers with bottoms (8.09 mm). B. pendula planted in field had a much larger caliper than those planted in container (Figure 21). Photoperiod treatment, or interaction of photoperiod and container type, had no effect on seedling caliper in field or container.

Fresh weight of top growth of B. pendula started in bottomless containers was greater (23.11 gm) than that of seedlings started in containers with bottoms (17.65 gm). Seedlings planted in field were heavier than those in container (Figure 22). Photoperiod treatment, or interaction of photoperiod and container type, had no effect on fresh weight at either growing location.

B. pendula seedlings started in bottomless containers during greenhouse phase were straighter than those started in containers with bottoms at conclusion of growing season (Figure 23). Photoperiod treatment, or interaction of photoperiod and container type, had no effect on straightness ratings. Growing location, either field or container, had no influence on straightness ratings.

B. pendula started in bottomless containers during the greenhouse phase had better root quality ratings at the end of the season than seedlings started in containers with bottoms. This was observed in both field (Figure 24) and container (Figure 25) plants. Photoperiod treatment, or interaction of photoperiod and container type, had no effect on root quality ratings at either growing location.

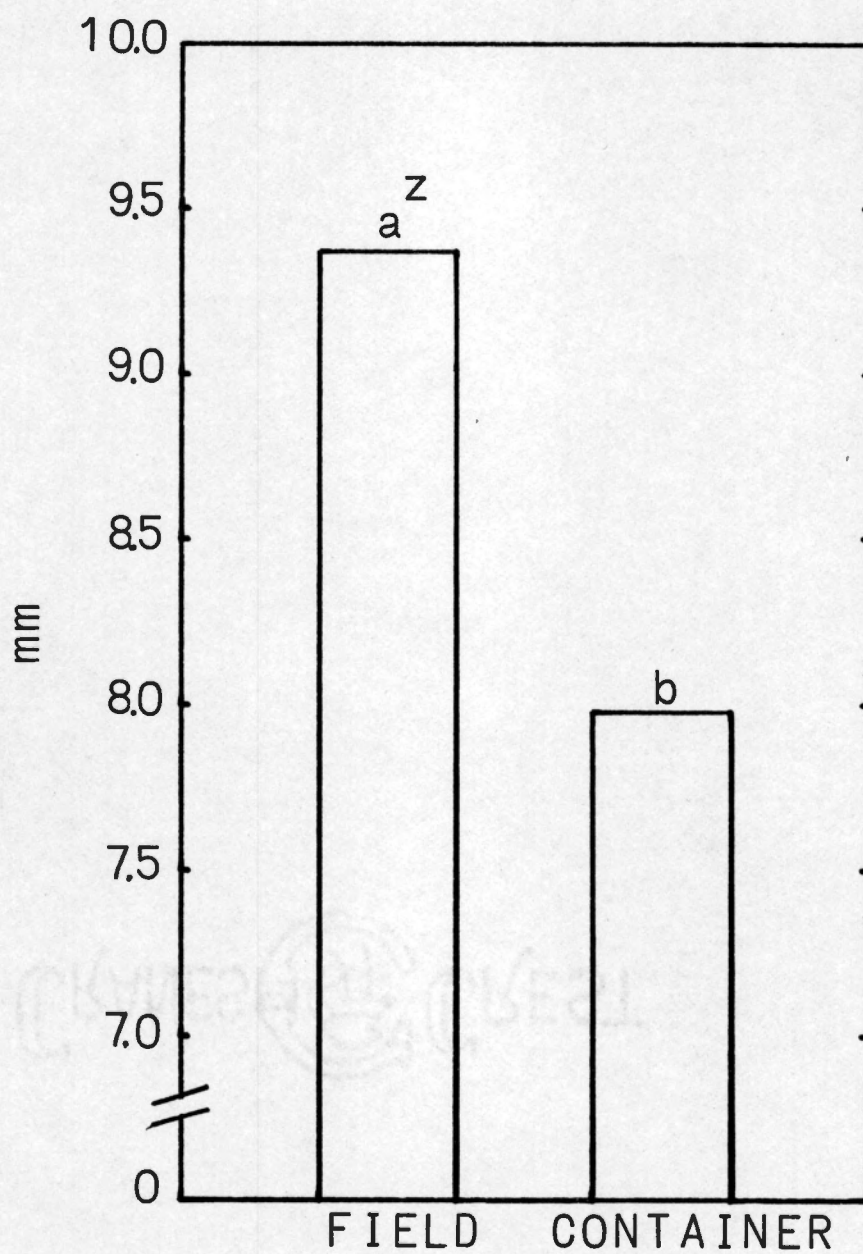


Figure 21. Caliper of *B. pendula* in response to growing location.

^ZMean separation by ANOVA test, 5% level.

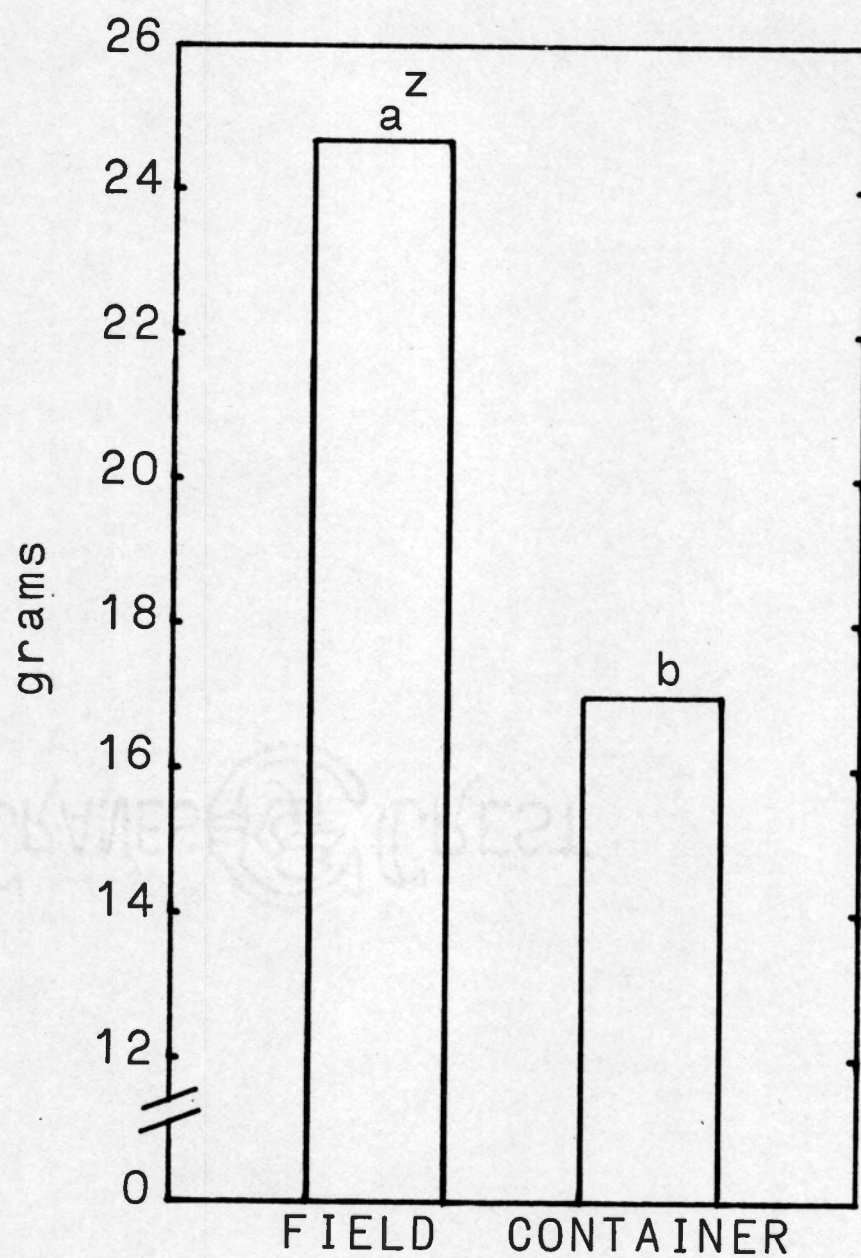


Figure 22. Fresh weight of top growth of *B. pendula* in response to growing location.

^zMean separation by ANOVA test, 5% level.

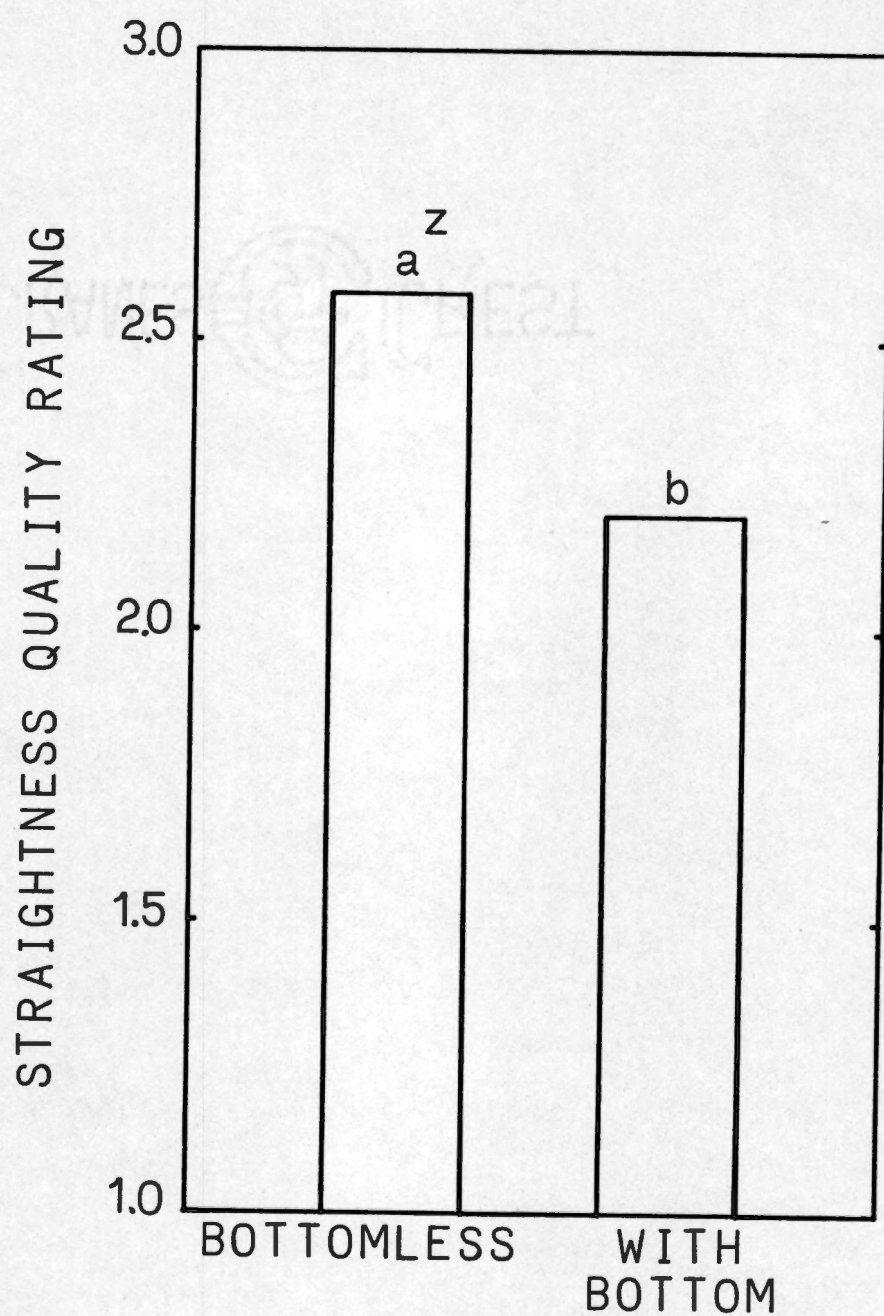


Figure 23. Straightness quality rating of B. pendula in response to container type at end of growing season.

^zMean separation by ANOVA test, 5% level.

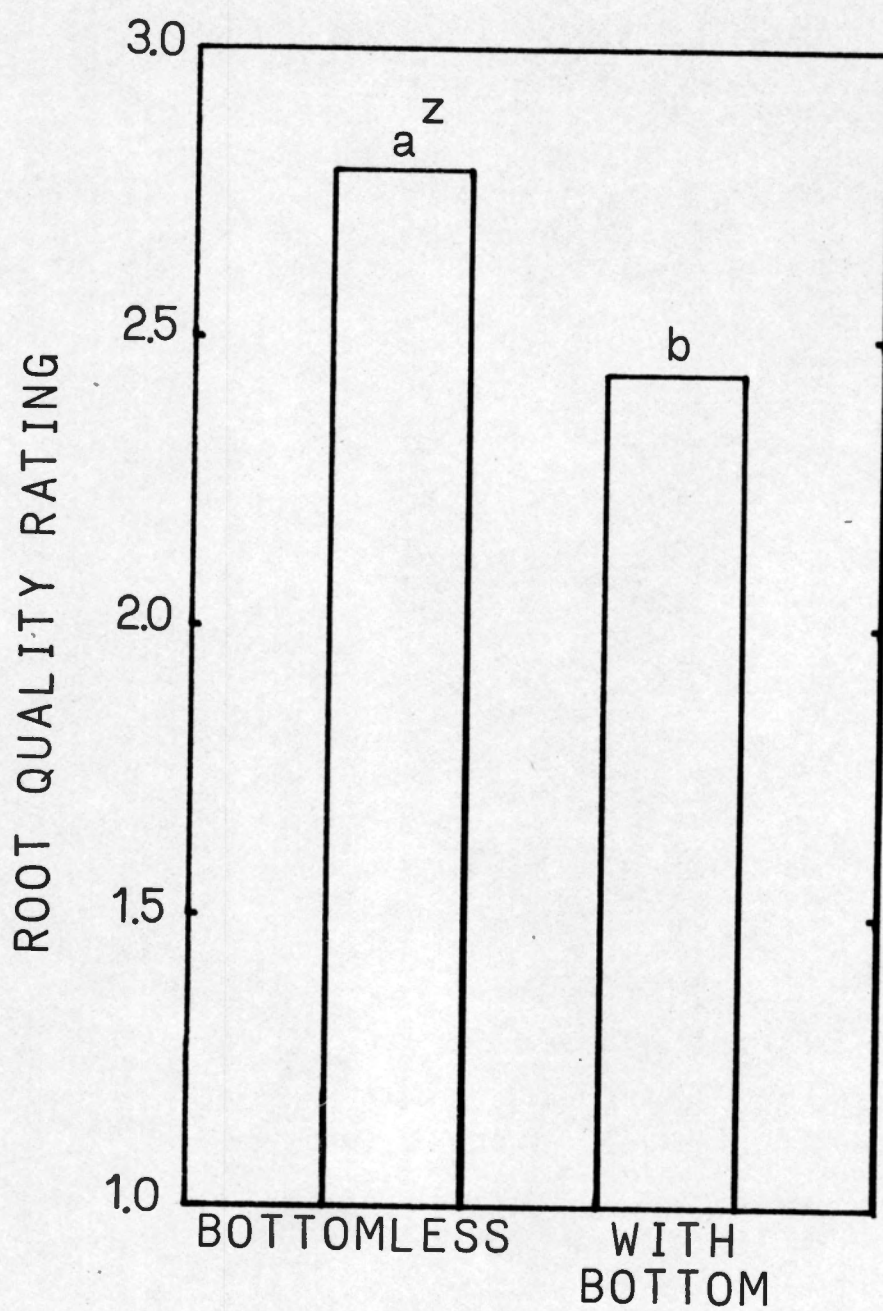


Figure 24. Root quality rating of *B. pendula* grown in field in response to container type.

^zMean separation by ANOVA test, 5% level.

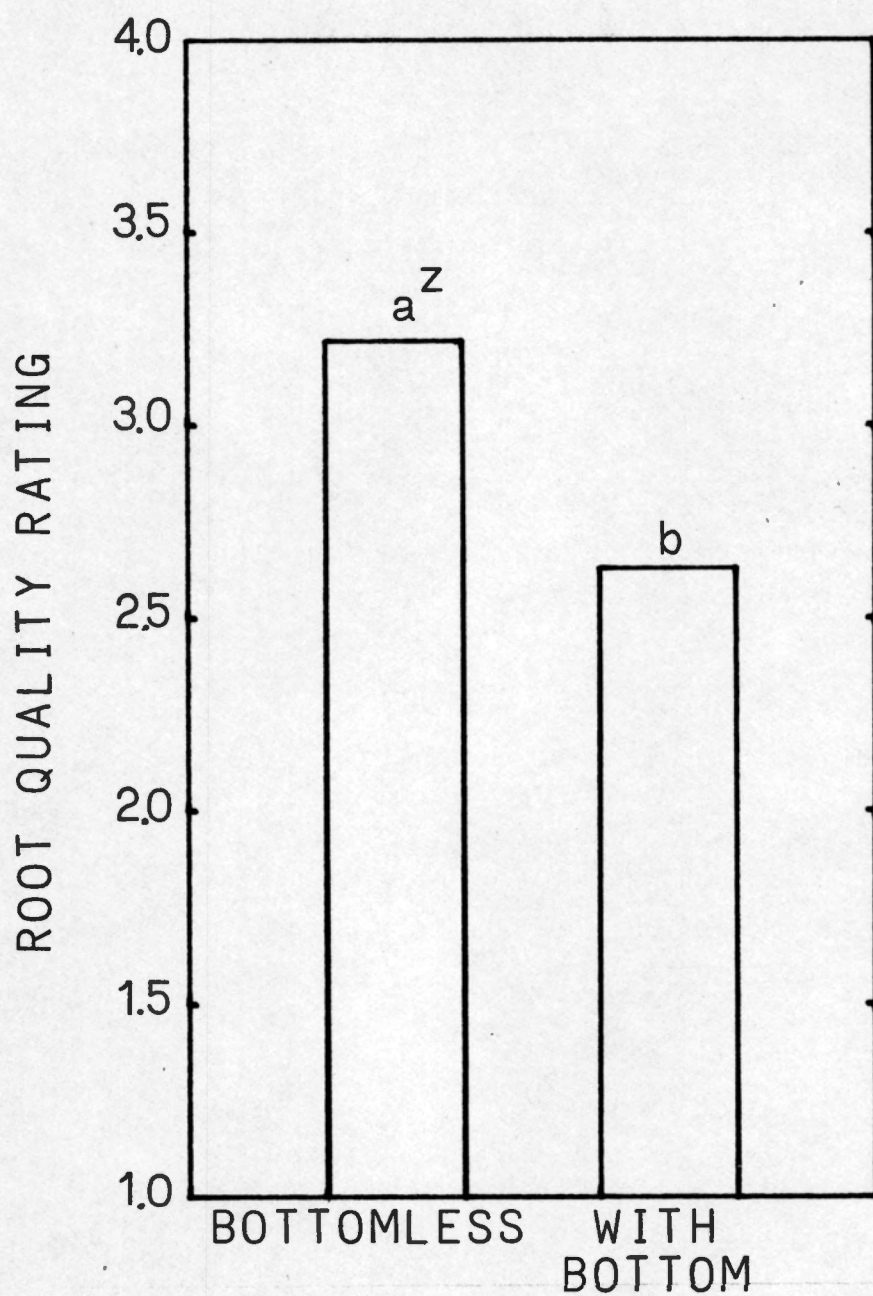


Figure 25. Root quality rating of *B. pendula* in container in response to container type.

^zMean separation by ANOVA test, 5% level.

IV. LIQUIDAMBAR STYRACIFLUA-SWEET GUM

1. Greenhouse Phase

Photoperiod treatment, container type, or interaction of photoperiod and container type had no significant influence on height growth of L. styraciflua seedlings, with all means being equal to $40 \text{ cm} \pm 5.0 \text{ cm}$.

2. Field and Container Phase

Height measurements taken at the end of the growing season indicated no response to photoperiod treatment or container type, with all means equal to $47 \text{ cm} \pm 2.0 \text{ cm}$. These main treatment effects did not interact to influence growth. After planting L. styraciflua to field or container, seedlings from natural daylength treatments grew a greater amount in height than seedlings from continuous light treatments (Figure 26). No meaningful difference was observed between the height of seedlings in field (49.4 cm) and container (46.5 cm) culture.

No difference in caliper resulting from treatment effects was observed at the end of the growing season with all means being equal to $9.3 \text{ mm} \pm .3 \text{ mm}$. The caliper of field plants (9.4 mm) was approximately the same as container plants (9.1 mm).

Fresh weight of tops of L. styraciflua taken at the end of the season indicated no response to photoperiod treatment, container type, or interaction of photoperiod and container type with all means being equal to $16.4 \text{ gm} \pm 1.4 \text{ gm}$. No meaningful difference occurred between the fresh weight of tops of field (16.0 g) and container (16.4 g) plants.

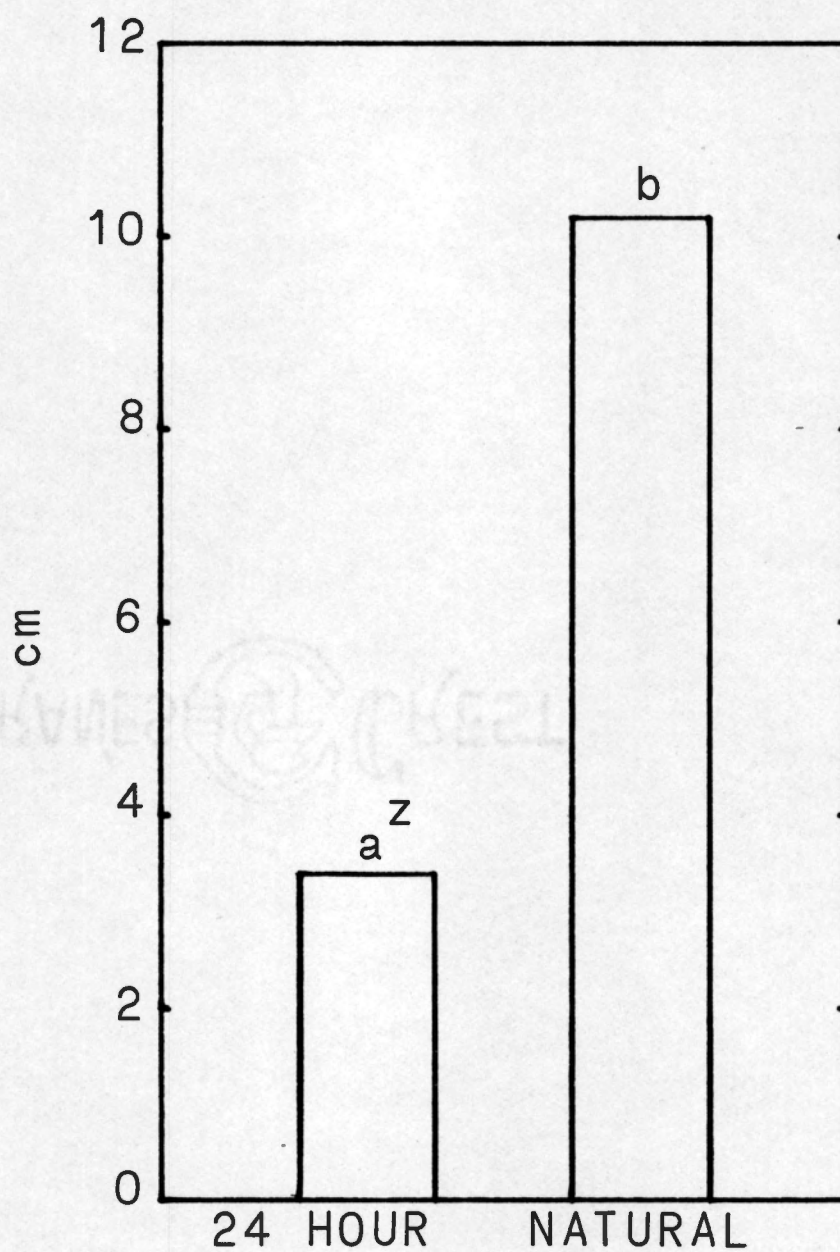


Figure 26. Increase in height growth of *L. styraciflua* after planting to field and container in response to greenhouse photoperiod treatment.

^zMean separation by ANOVA test, 5% level.

L. styraciflua seedlings were equally straight in all treatments and in both growing locations, with all means being $2.97 \pm .03$.

Root quality rating of field plants was better for plants from natural photoperiod treatments (Figure 27). Container type and photoperiod treatment did not interact to influence root quality ratings of field plants.

Continuous light and bottomless containers interacted to produce a higher root quality rating in container plants (Figure 28).

V. QUERCUS PALUSTRIS-PIN OAK

1. Greenhouse Phase

Seedlings started under 24 hour photoperiod were taller than those started under natural photoperiod (Figure 29). Container type, or interaction of container type and photoperiod treatment, had no influence on height growth.

2. Field Phase

Q. palustris started under continuous light in the greenhouse phase were taller at the end of the growing season than seedlings started under natural photoperiod (Figure 30). Negligible height growth occurred between termination of greenhouse phase and end of growing season, with all means being $2 \text{ cm} \pm 1 \text{ cm}$. Container type, or interaction of container type and photoperiod treatment, had no effect on height growth.

Container type, photoperiod treatment, or interaction of container type and photoperiod treatment had no effect on caliper of Q. palustris, with all means being $6.0 \text{ mm} \pm 0.75 \text{ mm}$.

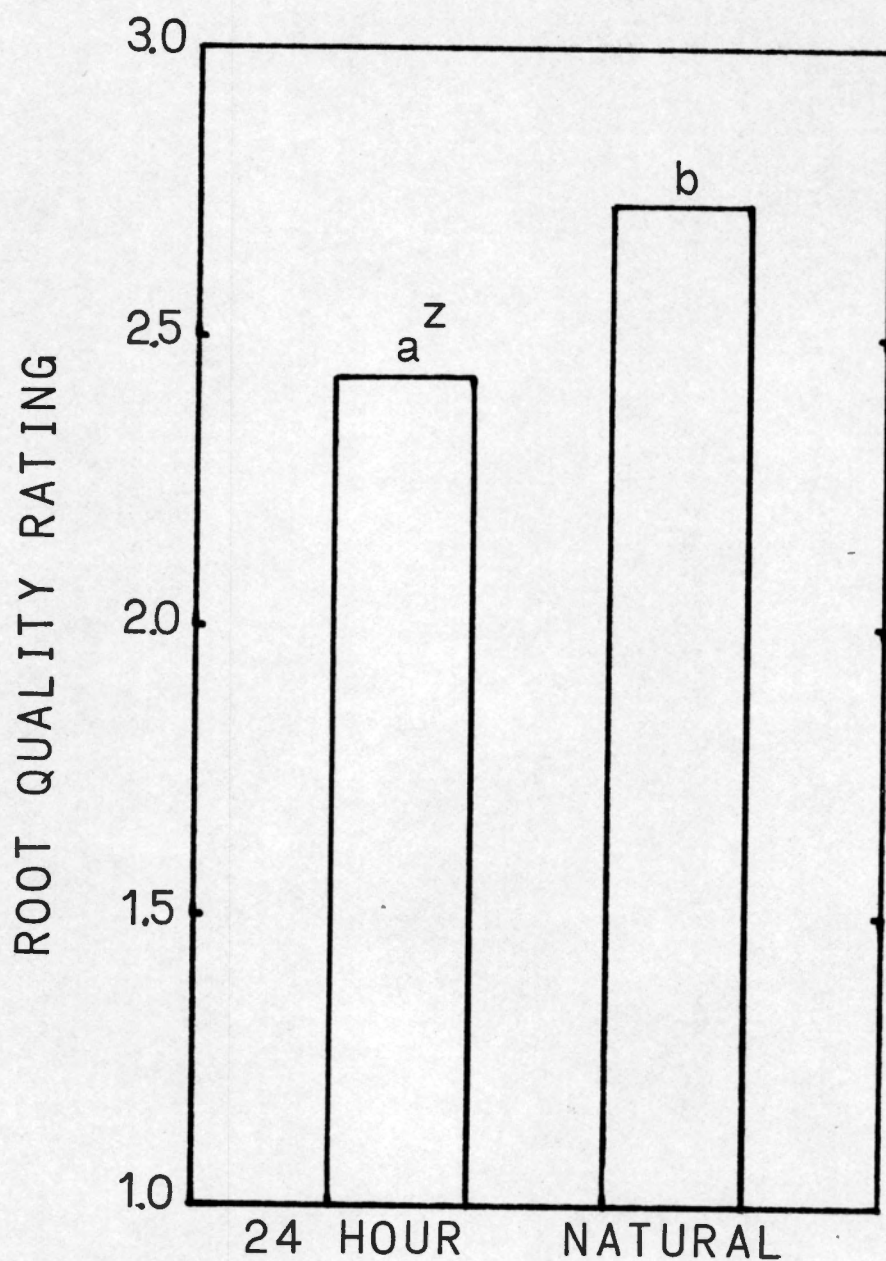


Figure 27. Root quality rating of *L. styraciflua* at end of growing season in response to photoperiod treatment.

^zMean separation by ANOVA test, 5% level.

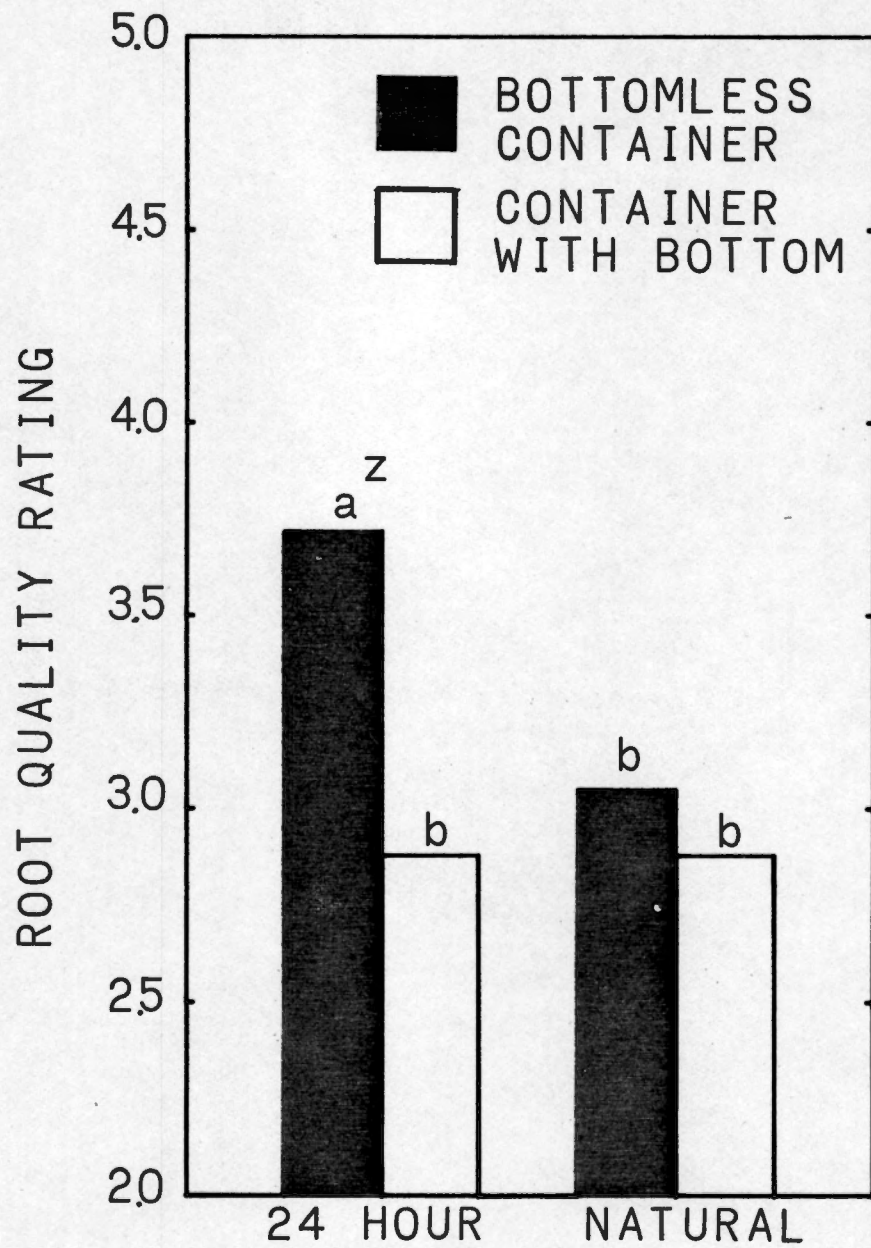


Figure 28. Root quality rating of L. styraciflua in 3-gallon containers at end of growing season in response to photoperiod treatment and container type.

^zMean separation by Duncan's Multiple Range test, 5% level.

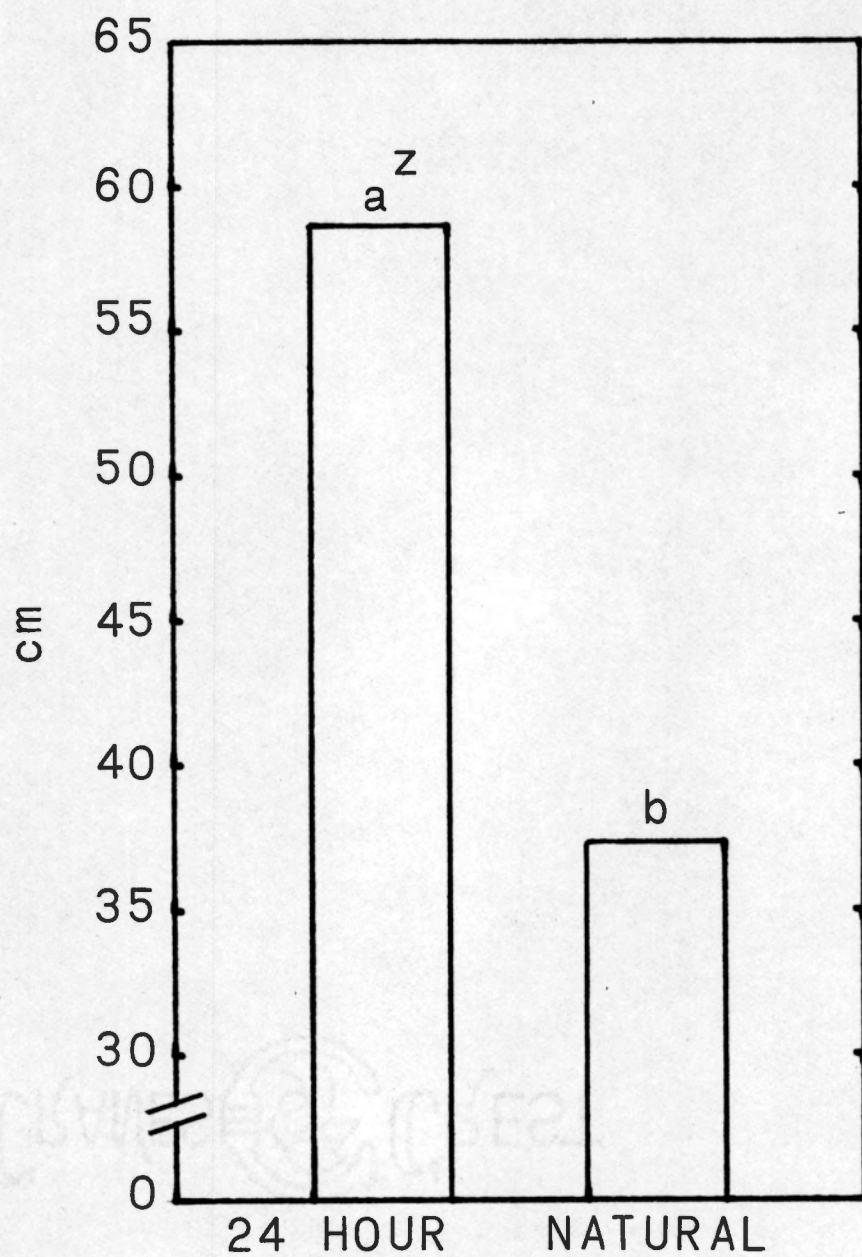


Figure 29. Height of *Q. palustris* in response to photoperiod treatment at termination of greenhouse phase.

^zMean separation by ANOVA test, 5% level.

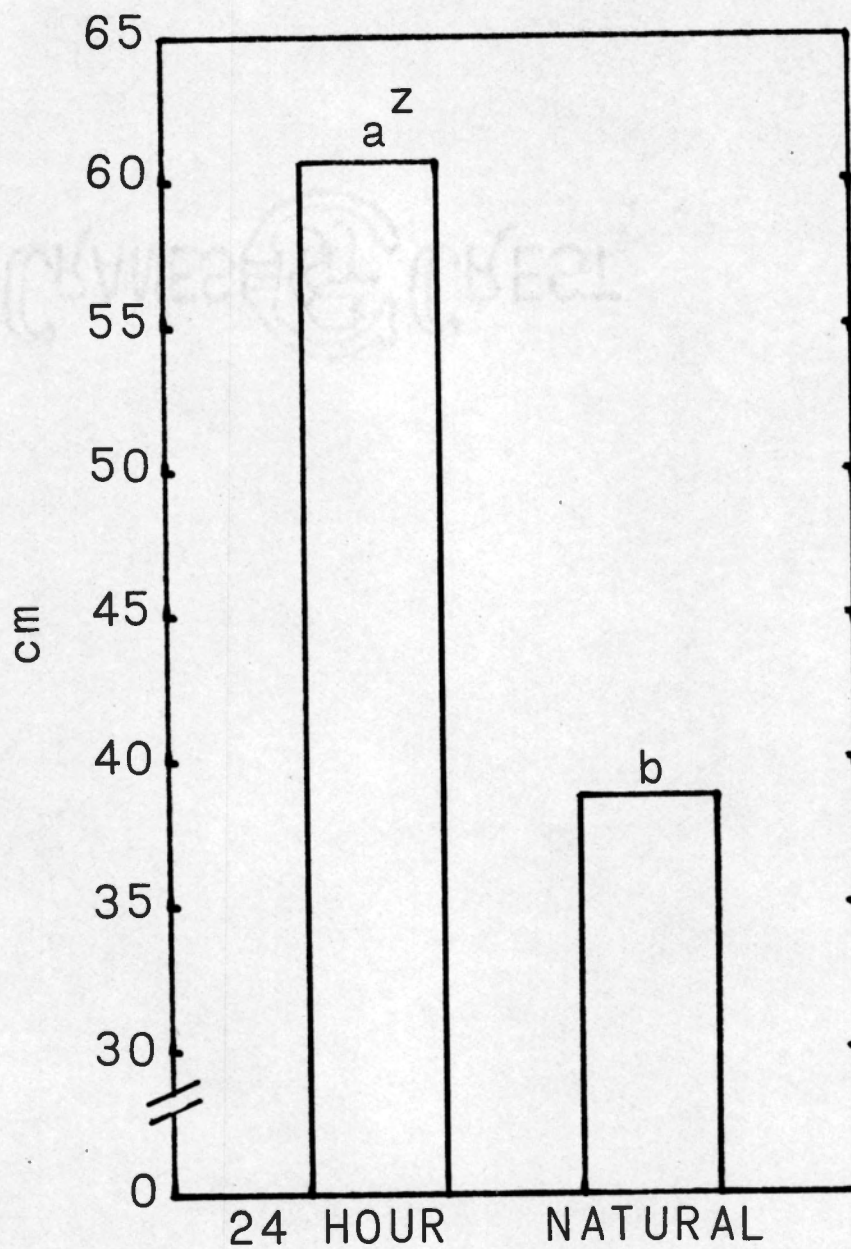


Figure 30. Height of *Q. palustris* in response to photoperiod treatment at end of growing season.

^zMean separation by ANOVA test, 5% level.

Top growth of seedlings started under 24 hour photoperiod during the greenhouse phase was heavier than top growth of seedlings from natural photoperiod treatments (Figure 31). Container type, or interaction of container and photoperiod treatment, had no effect on fresh weight of Q. palustris.

Container type, photoperiod treatment, or interaction of container type and photoperiod treatment had no influence on straightness quality rating of Q. palustris seedlings, with all means being 2.75 ± 0.25 .

Seedlings started in bottomless containers had better root quality ratings than seedlings started in containers with bottoms (Figure 32). Seedlings from continuous light treatments had better root quality ratings than those from natural photoperiod treatments (Figure 33). Bottomless containers and continuous light did not interact to stimulate an added response.

VI. PRUNUS CAROLINIANA-CAROLINA LAURELCHERRY

1. Greenhouse Phase

P. caroliniana seedlings started under continuous light were taller than seedlings started under natural photoperiod (Figure 34). Container type, either bottomless or intact bottom, had no effect on height growth. There was no interaction of photoperiod and container type resulting in increased height of P. caroliniana seedlings.

2. Field Phase

Seedlings started under 24 hour photoperiod were greater in height to those started under natural photoperiod when compared at the end of the

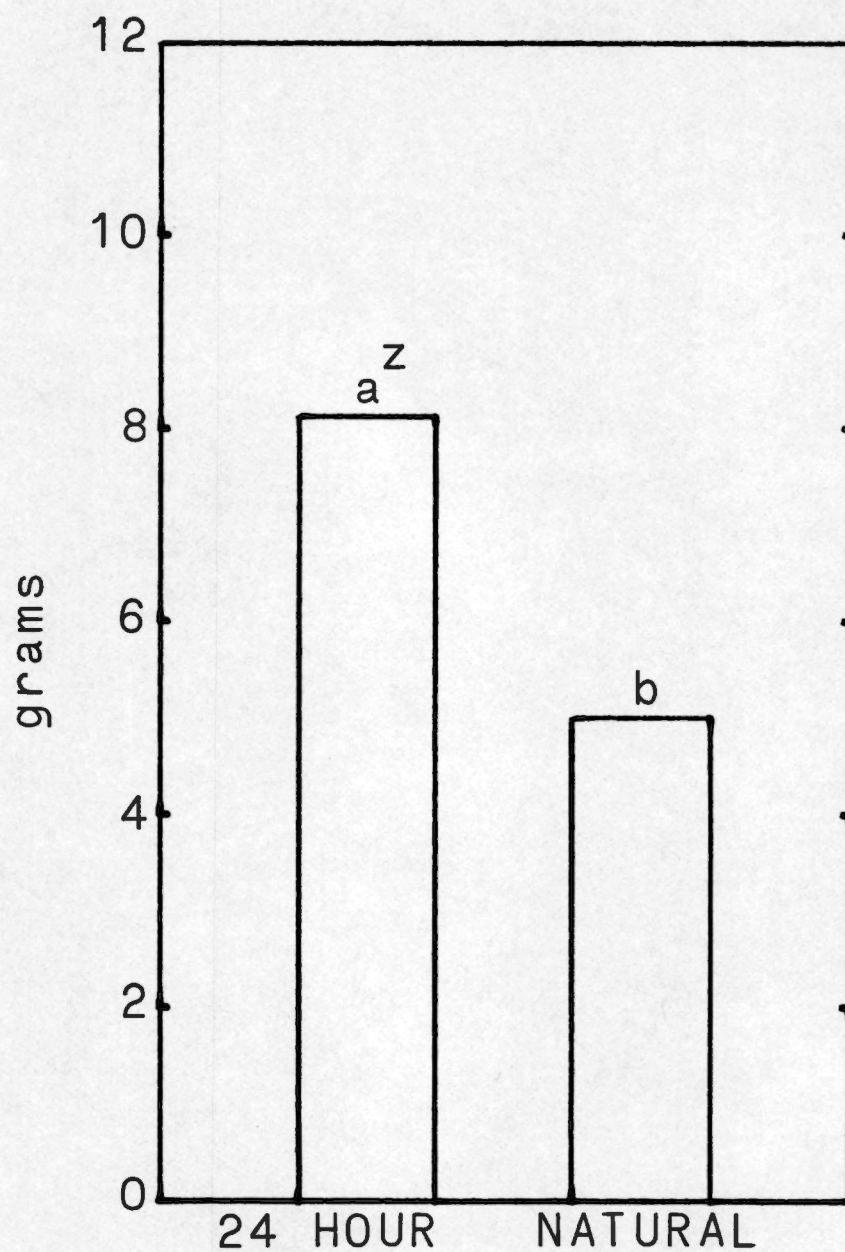


Figure 31. Fresh weight of *Q. palustris* in response to photoperiod treatment at end of growing season.

^ZMean separation by ANOVA test, 5% level.

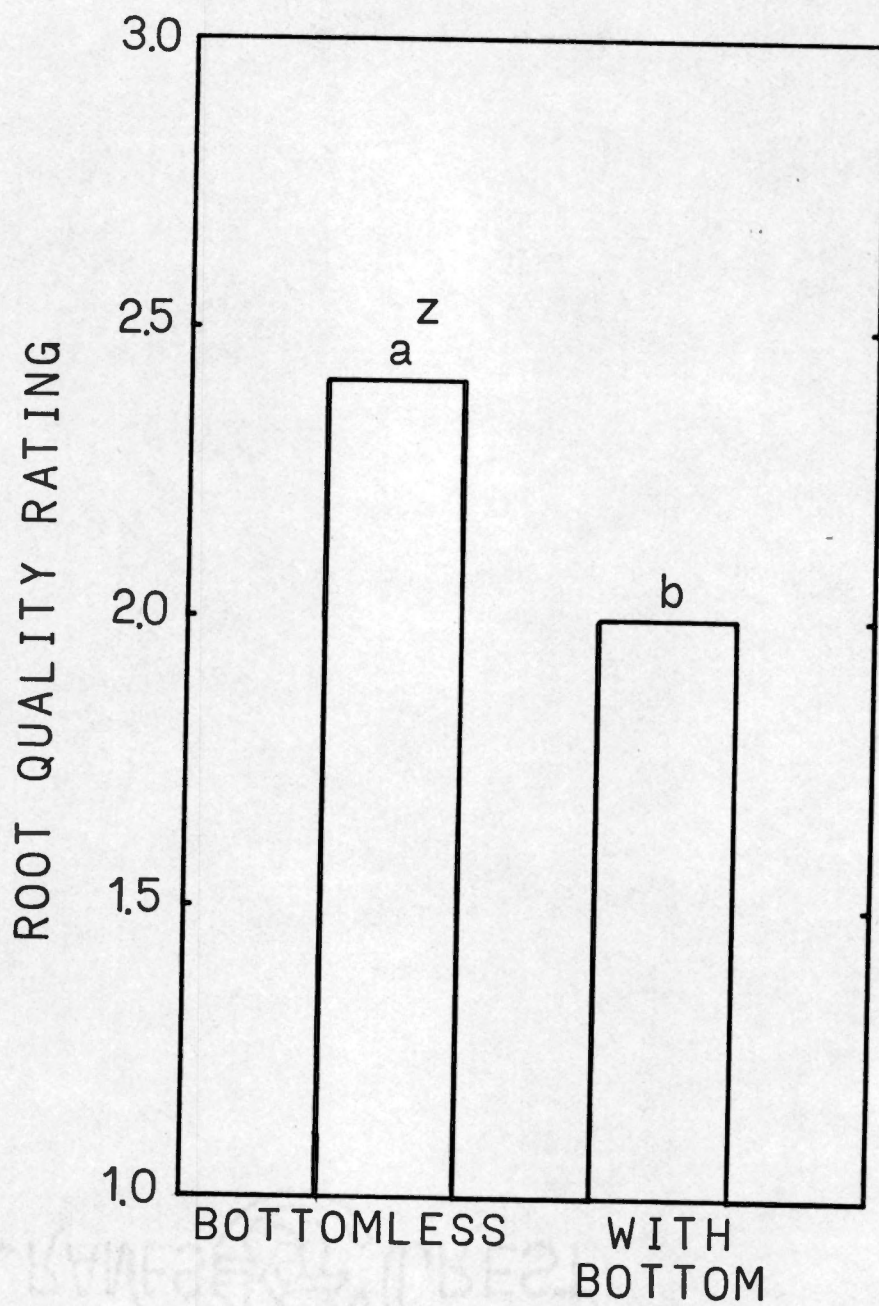


Figure 32. Root quality rating of *Q. palustris* in response to container type at end of growing season.

^zMean separation by ANOVA test, 5% level.

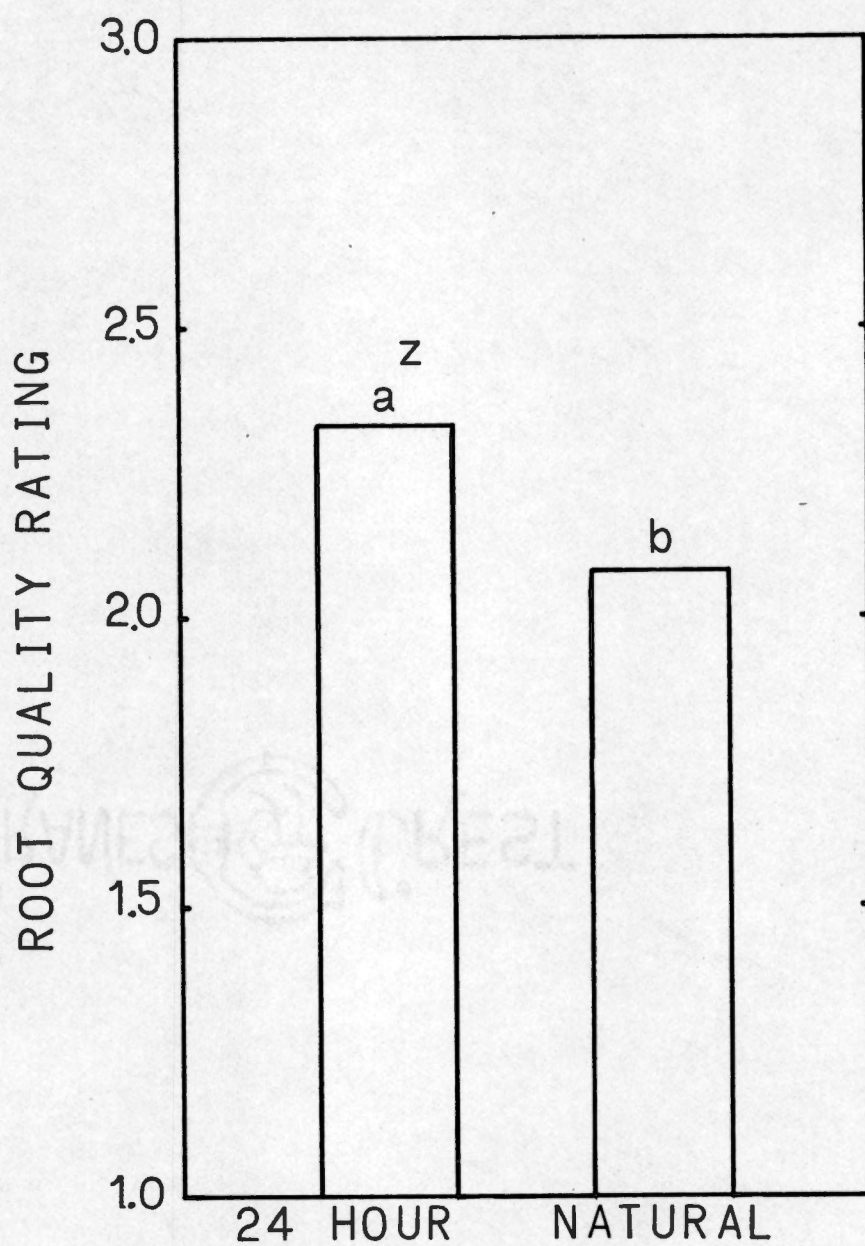


Figure 33. Root quality rating of Q. palustris in response to photoperiod treatment at end of growing season.

^zMean separation by ANOVA test, 5% level.

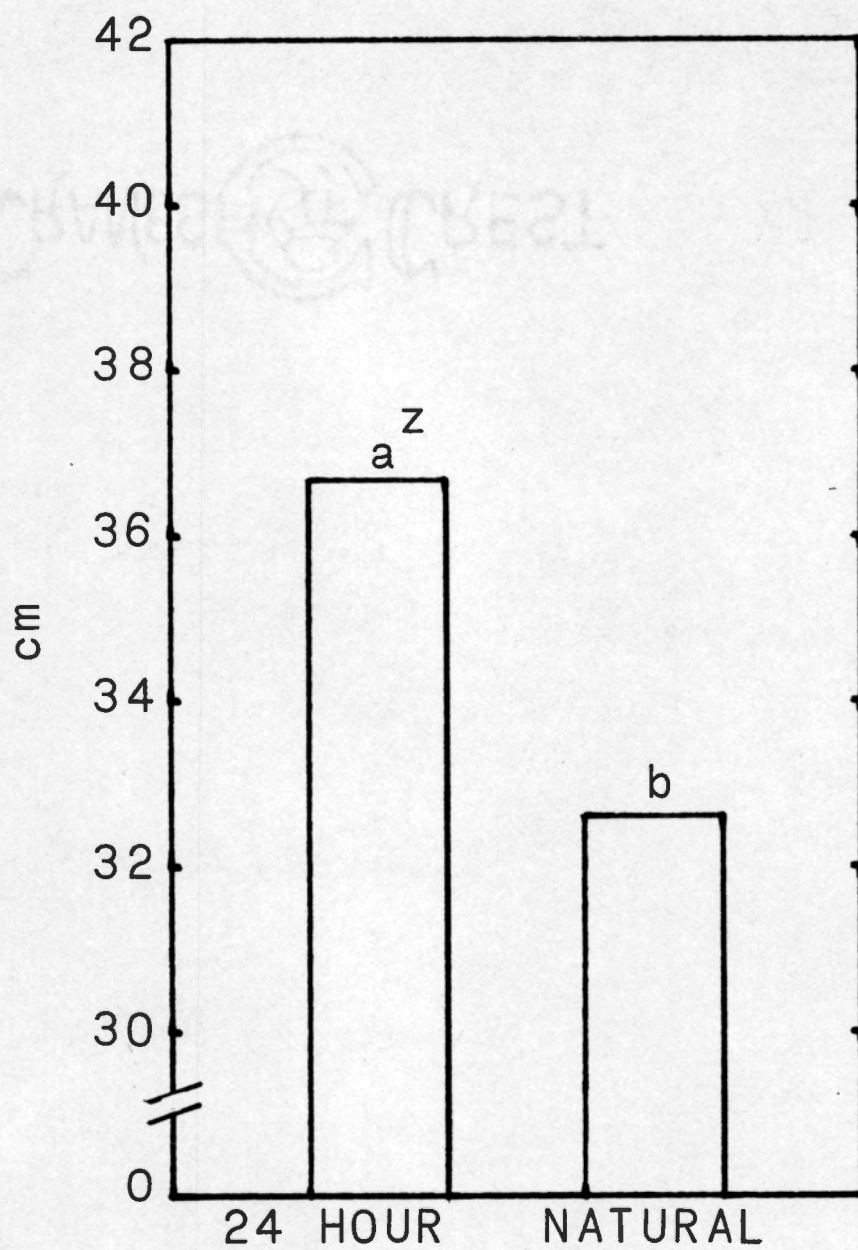


Figure 34. Height of *P. caroliniana* in response to photoperiod treatment at termination of greenhouse phase.

^zMean separation by ANOVA test, 5% level.

growing season (Figure 35). Container type, or interaction of container type and photoperiod treatment, had no effect on the height growth of P. caroliniana. Seedlings grew approximately the same for all treatments after planting to field, with all means being $2.7 \text{ cm} \pm 1.1 \text{ cm}$.

There was no meaningful difference in caliper of P. caroliniana seedlings due to treatment effects, with all means being $3.9 \text{ mm} \pm 0.3 \text{ mm}$. No meaningful variation in fresh weight of seedlings due to treatment effects occurred, with all means being $9.5 \text{ g} \pm 1.0 \text{ g}$.

Treatments had no effect on straightness ratings of P. caroliniana seedlings, with all means equal to 3.0.

Seedlings started in bottomless containers had better root quality ratings than those started in containers with bottoms (Figure 36). Photoperiod treatment had no effect on root quality ratings. No interaction occurred between photoperiod and container type that related to better root quality ratings.

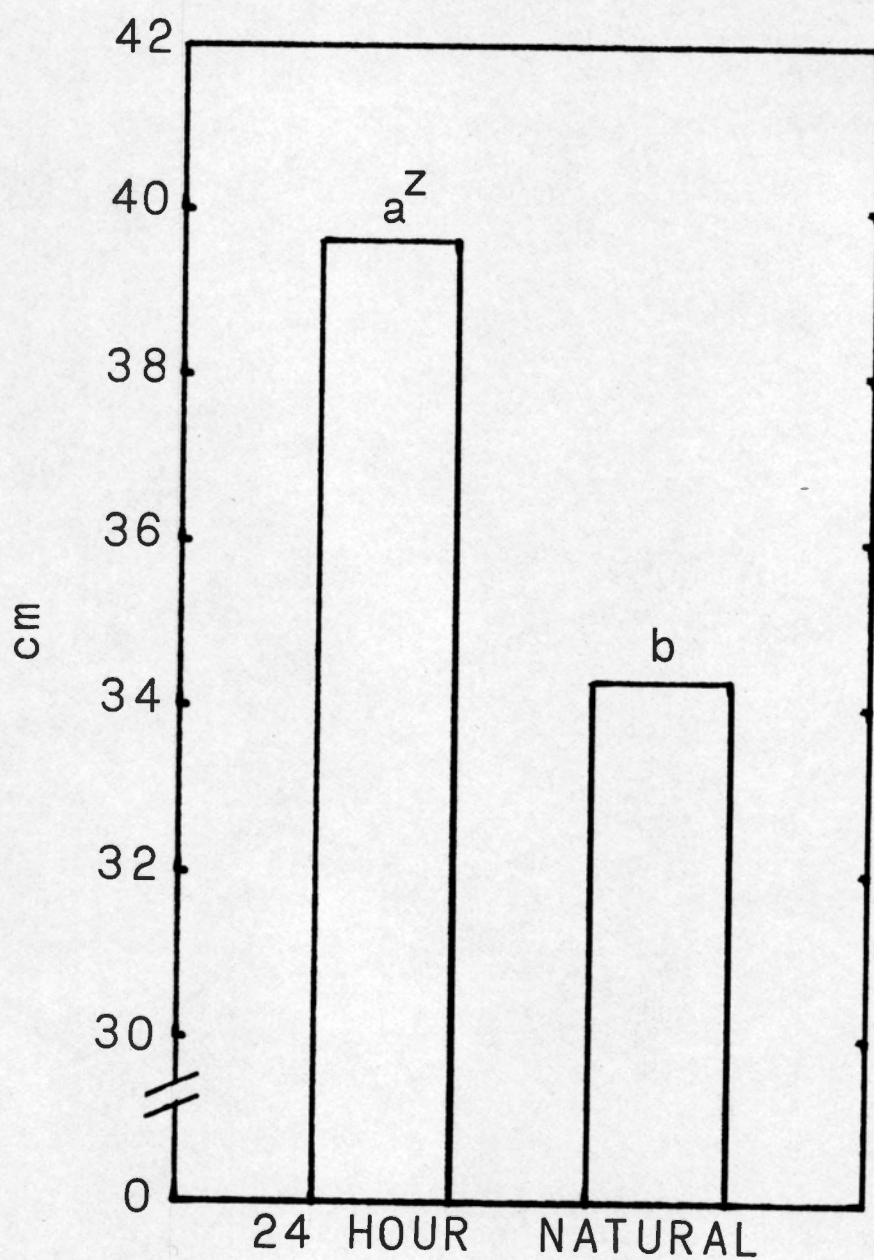


Figure 35. Height of *P. caroliniana* in response to photoperiod treatment at end of growing season.

^ZMean separation by ANOVA test, 5% level.

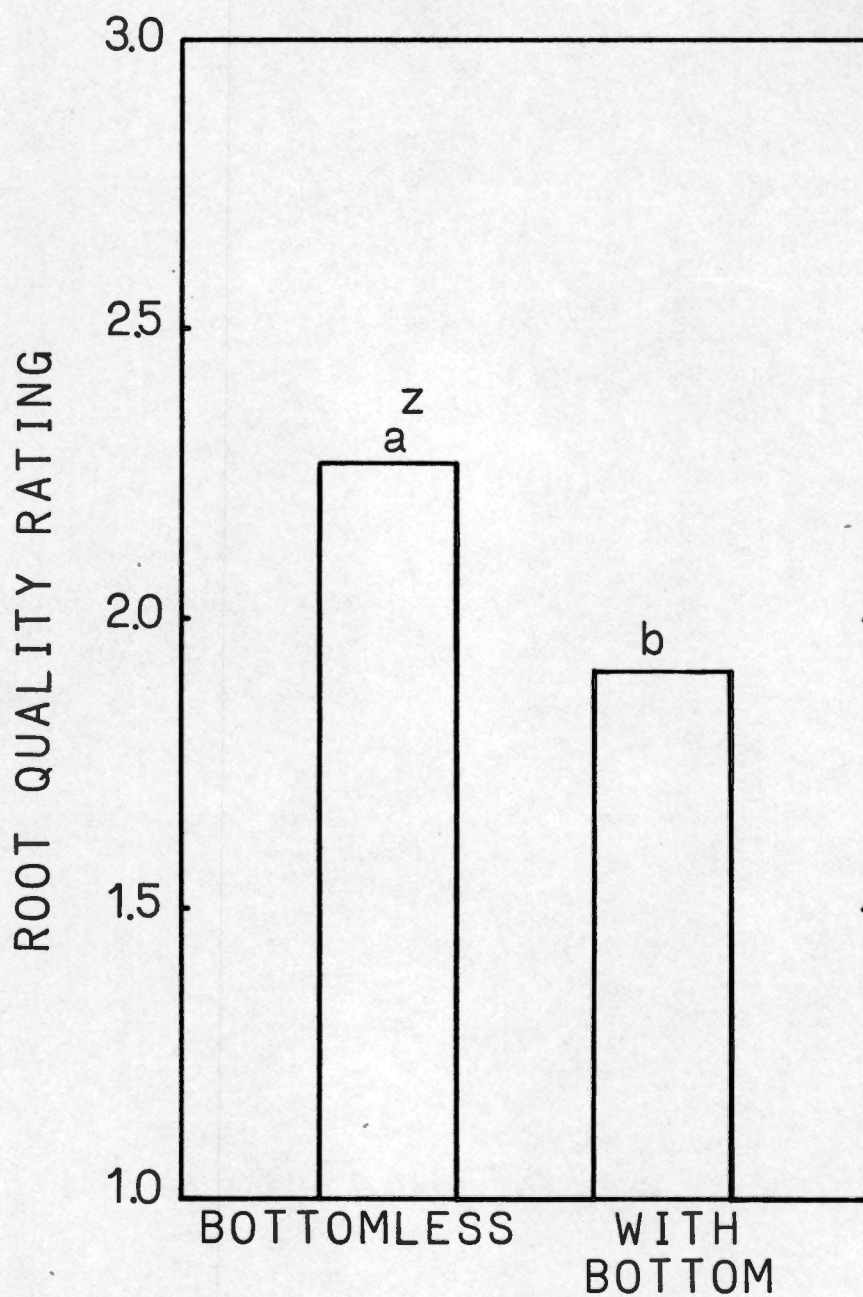


Figure 36. Root quality rating of *P. caroliniana* at end of growing season in response to container type.

^zMean separation by ANOVA test, 5% level.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. KOELREUTERIA PANICULATA-GOLDEN RAIN TREE

Seedlings of K. paniculata responded to continuous light by increased height growth over seedlings from natural photoperiod treatments. The most height growth occurred in the bottomless container, 24 hour photoperiod treatment.

Bottomless container culture influenced root production and fresh weight of top growth. Seedlings started in bottomless containers had higher root quality ratings and were also heavier than seedlings started in containers with bottoms. The root pruning effect of bottomless containers as discussed by Whitcomb et al. stimulated increased lateral branching of roots (6,10). This increased the nutrient absorption capacity of the root system, resulting in heavier top growth of seedlings.

In summary, every treatment produced good one-year seedlings. The best seedlings, however, came consistently from 24 hour photoperiod and bottomless container treatments. The production of K. paniculata seedlings under continuous light in square, bottomless containers appears feasible.

II. MAGNOLIA X SOULANGEANA-SAUCER MAGNOLIA

Magnolia x soulangeana seedlings from 24 hour photoperiod and bottomless container treatment were superior in height, amount of height growth after planting, and fresh weight of top growth than seedlings started in other treatments.

Bottomless containers also influenced other parameters. Plants started in bottomless containers had greater caliper than plants started in containers with bottoms. Also, seedlings started in bottomless containers had better root quality ratings at both growing locations.

A negative response to continuous light occurred in Magnolia x soulangeana seedlings upon analysis of straightness ratings. Plants from natural photoperiod treatments were straighter than plants from continuous light treatments.

The lower straightness rating of seedlings from continuous light treatments may be a limiting factor in suggesting that Magnolia x soulangeana seedlings be started under extended photoperiods. However, seedlings from all treatments were not as straight as desired and would require considerable pruning of top growth to promote a satisfactory straight trunk. Propagation in bottomless containers is an effective method of Magnolia x soulangeana seedling production.

III. BETULA PENDULA-EUROPEAN WHITE BIRCH

Several parameters suggested that bottomless containers produced superior seedlings compared to those produced by containers with bottoms. Those started in bottomless containers were taller, straighter, had greater caliper and fresh weight of top growth and better root quality ratings.

Continuous photoperiod did not effect growth of B. pendula. This may be due to the long days of the natural photoperiod, up to 14.5 hours of sunlight, that occurred during the course of this experiment and were used to compare with continuous photoperiod. If a shorter day photoperiod was used for comparison, the influence of continuous light might be more pronounced.

Field production of B. pendula produced better seedlings than 3-gallon container production. Field plants had greater caliper and fresh weight of top growth. Container plants were not as sturdy and were spindly in appearance when compared to field grown plants.

Utilization of square, bottomless containers during propagation period and then planting seedlings to field culture is the most feasible application of results.

IV. LIQUIDAMBAR STYRACIFLUA-SWEET GUM

L. styraciflua was the most unresponsive species tested as no significant effect in height, caliper, fresh weight, or straightness rating from treatments occurred. Seedlings grew approximately the same in all treatment combinations and at both growing locations.

Seedlings from natural photoperiod treatments did produce plants that grew faster after planting to field or container than plants from continuous light treatments. Also, the root quality rating of plants from natural photoperiod treatments was better than those from continuous light treatments.

L. styraciflua is easily propagated and grown by conventional nursery methods. Because of this and since the species was so unresponsive to treatments of photoperiod and container type, there is no advantage in growing L. styraciflua by methods tested.

V. QUERCUS PALUSTRIS-PIN OAK

While in the greenhouse, seedlings under continuous light responded with increased height growth when compared with seedlings from natural

photoperiod treatments. Essentially, Q. palustris ceased height growth after planting to field. As described by Romberger (21), height growth of Quercus spp. is by periodic flushes of new growth. Obviously, Q. palustris did not generate another flush of growth after removal from the greenhouse phase and transplanting to field.

Twenty-four hour photoperiod treatments influenced other growth parameters. The fresh weight of top growth of seedlings from continuous light treatments was heavier than those from natural photoperiod treatments. The root quality rating of seedlings from continuous light and bottomless container culture was better than for other treatments.

Container type did not influence Q. palustris in any other parameter other than root quality ratings. This is contrary to research by Hathaway and Whitcomb who reported significant growth increases in height and caliper of Q. shumardii seedlings started in bottomless containers (11,12). However, studies have shown the timing of planting out from propagation phase to field or container is critical to subsequent development (26). Optimum root development in the square, bottomless containers must be realized prior to transplanting to field culture. Results indicate adequate root development may not have occurred in the propagation containers at time of transplanting.

Continuous light is effective in stimulating increased growth of Q. palustris seedlings. Bottomless containers may be effective if transplanting date were timed to coincide with optimum root development in the containers. More work on this species needs to be done.

IV. PRUNUS CAROLINIANA-CAROLINA LAURELCHERRY

During the greenhouse phase, P. caroliniana responded to continuous light by increased height over seedlings from natural photo-period treatments. Growth after planting to field was negligible and approximately the same for all treatments.

Seedlings from bottomless containers had better root quality ratings than seedlings from containers with bottoms. The root pruning effect of bottomless containers did produce a more fibrous root system but did not effect other growth parameters. The benefits of increased growth as a result of this root pruning of P. caroliniana, if any, may be delayed to subsequent years of growth.

The production of P. caroliniana seedlings under continuous light may be feasible although seedlings from all treatments were comparatively small in height.



LITERATURE CITED

LITERATURE CITED

1. Ben Salem, B. 1971. Root strangulation: A neglected factor in container grown nursery stock. M.S. Thesis in Forestry, University of California, Berkeley. 50 pp.
2. Downs, R. J. and H. A. Borthwick. 1956. Effect of photoperiod on growth of trees. Botanical Gazette 117:310-326.
3. Garner, W. W. and H. A. Allard. 1920. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Journal of Agricultural Research 18:553-606.
4. Garner, W. W. and H. A. Allard. 1923. Further studies in photoperiodism, the response of the plant to relative length of day and night. Journal of Agricultural Research 23:871-920.
5. Gibson, J. and C. E. Whitcomb. 1978. Effect of container size and fertility levels on the growth of tree seedlings in square, bottomless containers. 40-41. In Oklahoma Agricultural Experiment Station Research Report P-777. Oklahoma State University, Stillwater.
6. Gibson, J. and C. E. Whitcomb. 1980. Producing tree seedlings in square, bottomless containers. Ornamentals South 2(5):12-15.
7. Hanover, J. W. and D. A. Reicosky. 1972. Accelerated growth for early testing of spruce seedlings. Forest Science 18:92-94.
8. Hanover, J. W., E. Young, W. A. Lemmien, and M. van Slooten. 1976. Accelerated-optimal-growth: A new concept in tree production. In Michigan Agricultural Experiment Station Research Report 317. 15 pp.
9. Hathaway, R. D. and C. E. Whitcomb. 1976. Nutrition of container grown tree seedlings. 41-45. In Oklahoma Agricultural Experiment Station Research Report P-741. Oklahoma State University, Stillwater.
10. Hathaway, R. D. and C. E. Whitcomb. 1976. Growth of tree seedlings in containers. 33-38. In Oklahoma Agricultural Experiment Station Report P-741. Oklahoma State University, Stillwater.
11. Hathaway, R. D. and C. E. Whitcomb. 1977. Propagation of Quercus seedlings in bottomless containers with Osmocote. Journal of Arboriculture 3(11):208-212.

12. Hathaway, R. D. and C. E. Whitcomb. 1978. The effects of root malformation during propagation on growth and survival of bur oak. 33-34. In Oklahoma Agricultural Experiment Station Research Report P-777. Oklahoma State University, Stillwater.
13. Hiatt, H. A. and R. W. Tinus. 1974. Container shape controls root system configuration of ponderosa pine. 194-196. In Proceedings of North American Containerized Forest Tree Seedlings Symposium, Denver, Colorado. Great Plains Agricultural Council Pub. No. 68.
14. Jester, J. R. and P. J. Kramer. 1939. The effect of the length of day on the height growth of certain forest tree seedlings. Journal of Forestry 37:797-803.
15. Kramer, P. J. 1936. Effect of variation in length of day on growth and dormancy in trees. Plant Physiology 11:127-137.
16. Moshkov, B. S. 1930. Photoperiodicity of certain woody species. (In Russian with English summary.) Bulletin of Applied Botany, Genetics, and Plant Breeding, xxiii (2). 479-510. (Biological Abstracts, vii 20678, 1932).
17. Nienstaedt, H. 1966. Dormancy and dormancy release in white spruce. Forest Science 12:374-384.
18. Nitsch, J. P. 1957. Photoperiodism in woody plants. Proceedings of the American Society for Horticultural Science 70:526-544.
19. Phillips, J. E. 1941. Effect of day length on dormancy in tree seedlings. Journal of Forestry 39:55-59.
20. Read, R. A. and W. T. Bagley. 1967. Response of tree seedlings to extended photoperiod. U.S. Department of Agriculture Forest Service Research Paper RM-30. 16 pp.
21. Romberger, J. A. 1963. Meristems, Growth, and Development in Woody Plants. U.S. Department of Agriculture Technical Bulletin No. 1293. p. 84.
22. Shreve, L. W. 1974. The use of preformed paper milk cartons for containerized black walnut seedlings, grafts, and rooted cuttings. 137-138. In Proceedings of North American Containerized Forest Tree Seedlings Symposium, Denver, Colorado. Great Plains Agricultural Council Pub. No. 68.
23. Tinus, R. W. 1973. Conifer seedling nursery in a greenhouse. Journal of Soil and Water Conservation 29:122-125.
24. Wareing, P. F. 1948. Photoperiodism in woody species. Forestry 22:211-221.

25. Wareing, P. F. 1956. Photoperiodism in woody plants. Annual Review of Plant Physiology 7:191-214.
26. Whitcomb, C. E., A. Storjohann, and J. Gibson. 1977. Effects of time of transplanting container grown tree seedlings on subsequent growth and development. 37-39. In Oklahoma Agricultural Experiment Station Research Report. P-777. Oklahoma State University, Stillwater.
27. Young, E. and J. W. Hanover. 1976. Accelerating maturity in Picea seedlings. Acta Horticulturae 56:105-114.

VITA

Perry Anthony (Tony) Cope was born in McMinnville, Tennessee on October 3, 1953. He received the Bachelor of Science degree in Agriculture with a major in Ornamental Horticulture and Landscape Design from The University of Tennessee, Knoxville, in 1977.

After two years working for the North Carolina Agricultural Extension Service in Macon County, North Carolina, he entered The Graduate School at The University of Tennessee, Knoxville. In June 1981 he was granted the Master of Science degree with a major in Ornamental Horticulture and Landscape Design. While working toward the degree he was employed by The University of Tennessee Agricultural Experiment Station as a Graduate Research Assistant in Ornamental Horticulture and Landscape Design.

He is married to the former Carolyn Troutman of Knoxville, Tennessee.