EFFECTS OF CONTAINER SIZE AND FERTILITY LEVELS ON THE GROWTH OF TREE SEEDLINGS IN SQUARE BOTTOMLESS CONTAINERS

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CHAPTER I

INTRODUCTION

The production of seedlings in containers is a relatively new concept. The primary objection to container seedlings is one of increased costs; however, advances in technology and techniques are making them more competitive with bed grown seedlings. Survival and performance of container grown seedlings is generally superior to those grown in ground beds.

Root pruning to induce lateral branching is accomplished in ground beds by removing a portion of existing roots. Although secondary roots are forced, substantial growth is wasted. Furthermore, the practice of lifting seedlings from beds and planting bare-root in the field compounds the loss of vitality through shock.

Air root-pruning in bottomless containers produces lateral root branches without loss of existing roots and accompanying physiological shock. Containers allow the transplanting of an undisturbed root system intact.

The use of slow-release fertilizers allows a continuous supply of nutrients at a controlled predictable rate without excessive applications or sporadic availability.

CHAPTER II

LITERATURE REVIEW

Bed Grown Seedlings

Most tree seedlings are grown in ground beds out-of-doors. This practice is so pervasive that a review of the literature shows thousands of variations of sowing seeds en masse in a common plot. The main argument for ground culture is economics. Container seedlings cost 25 to 40% more to produce than bare-root material (39). Disadvantages of ground beds include disease problems, nutrient regulation, and problems arising from competition for light, moisture, nutrients, and CO_2.

Growing douglas-fir seedlings at four different densities, Timmis and Tanaka (44) found that with progressively lower densities, top and root weights increased, the plant became shorter but thicker at the base, and had increased cold hardiness. Baron and Schubert (8) found lower seedbed densities produced larger more vigorous seedlings with increased stem diameter and topweight. Those grown at lower densities also survived better in the field. Wakely (47) suggests that on any given volume of soil, only a fixed number of healthy seedlings may be produced, and by increasing density, the amount of unacceptable seedlings increases.

Other studies also support the view that low seedbed densities produce better seedlings (17) (41).

Average seedbed densities are 28 per square foot for conifers and 12 per square foot for hardwoods (1). Root and top pruning to produce secondary roots and branches is a common practice in ground bed culture. Harris (25) in a study comparing root pruning practices in combination with post-transplanting performance, found that root pruning more than doubled the number of acceptable root systems in comparison with no root pruning. In order to balance the shoot-root ratio, top pruning is also commonly done (53). Larson (32) and Woessner (52) suggest that these practices in severity are very detrimental.

Container Grown Seedlings

Containers for seedling production are of two basic designs, those allowing free root emergence and those restricting root emergence with roots assuming the shape of the container. Those of the first type include compressed peat pots into which a growing medium is added; Jiffy 7's, where container and mix are compressed into a flattened disc which expands when watered; Gro-blocks (BR-8's), an integrated wood fiber block; and Polyloam, a synthetic low density medium complete with nutrients. Polyloam can be integrated into a block or used as a growing medium for containers. These containers are usually inexpensive and can be transplanted without root disturbance. However, they are unsuitable for mechanical planting.

Containers of the second type include those with biodegradable sides or with non-biodegradable sides which must be removed or destroyed on planting. Those with biodegradable sides are of recent development. Japanese paper pots have multiple interconnected cavities for growing seedlings in a folded accordian-like structure. The honeycomb shaped containers are stretched and filled with growing media and when planted out the container dissentegrates (13). Recently, the fiber vinylon has been incorporated to give added strength during production (28).

A recent development is Union Carbide's biodegradable plastic polycaprolactone, an aliphatic polyester subject to microbiological attack and thus biodegradation. It can be injector molded, compression molded, or sheet extruded into bullet shapes or larger containers. After 12 months, the compound has completely degraded, but additional incorporated elements can extend container life to any predictable point (14).

Other containers include a wax coated clay container that allows some root emergence with the softening of the clay and erosion of the wax (20), and the Research Council of Alberta "Peat Sausage", a thin-walled tubular polyethylene casing filled by extruding moist peat moss into the casing through a die (13). The body is slit upon transplanting, and biodegrades slowly.

Non-biodegradable root restrictive containers are numerous. The "Walter's Bullet" is a plastic bullet-shaped container, 6.3-14.6 cm. long (2.5-5.5 in.) with a top diameter of 1.9 cm. (.75 in.) and a wall thickness of .15 cm. (.06 in.). Various improvements in design have resulted in the implementation of a longitudinal slit from the bottom of the container to the lip of the collar, allowing for expansion of the root system. Longitudinal ribs direct roots downward and prevent spiraling. A planting "gun" injects the bullet into the ground and shatters the casing, allowing mostly free root emergence. Recently, a biodegradable plastic has been used for the "Walter's Bullet" (13).

The Ontario tube is an extruded styrene tube open at both ends, 7.6 cm. long (3 in.), 1.4 cm. in top diameter (0.56 in.), with the same longitudinal slit as in the "Walter's Bullet". A variation made in Alberta doubles the volume of growing medium (13).

The British Columbia/Canadian Forest Service styroblock was developed in 1970. It is a polystyrene product of varying dimensions with pyramidal or round cavities of various seedling densities per block. Seedlings, called styroplugs, are removed from the block for planting (13).

Spencer-Lemaire book planters are seedling cavities created by having one-half of each cavity molded into one of the two sides of a folding plastic "book". Each sheet is six cavities, 2.5 cm. (1 in.) X 1.9 cm. (0.75 in.) at the top of the rectangular cavity, and 10.2 cm. in length (4 in.). Planting is accomplished by unfolding the book and removing seedlings (13).

Swedish multi-pots are similar in design and concept to the styroblocks. Flats of individual yet linked cavities are made of rigid plastic and are reusable. Multi-pots come in many various dimensions and densities. Planting is accomplished by seedling removal (13).

Forestry oriented seedling containers are of limited volume for greater economy in production. Seedling densities compare favorably with average seedbed densities of 28 per square foot recommended by Abbott (1).

Research has been done by Whitcomb and others (27) (42) (50) using bottomless milk carton containers. Lengths of 7.62, 15.24, 22.86, 30.48 and 38.1 cm. (3, 6, 9, 12 and 15 in.), and widths of 3.81, 5.08 and 6.35 cm. (1.5, 2, and 2.5 in.) were studied by Davis and Whitcomb (16). They found containers 6.35 cm. (2.5 in.) in width and 15.24 to 30.48 cm. (6 to 12 in.) deep to be the most promising for tree seedling production. Planting is accomplished by the removal of the non-biodegradable poly band from the plant.

Growing Media

Several growing media have been used in container seedling production. Characteristics of a good medium are:

1.) Sufficiently firm and dense to hold seedlings.

2.) Fairly constant in volume wet or dry.

3.) Sufficient water holding capacity to avoid excessively frequent watering.

4.) Enough air-space to prevent root suffocation (26).

Edgren (19) and White (51), compared soil with peat moss for container grown seedlings and found the lightweight water retentive, high cation exchange capacity peat moss mix superior to mineral soils. Phipps (38) studied peat mixed with vermiculite, vermiculite with arcillite (calcined montmorrillonite clay), sand with loam soil (all 1:1 ratio), and arcillite and peat alone. After 16 weeks, differences in stem length and diameter of red pine seedlings showed the peat-vermiculite mix significantly superior to all others. In addition, mixes of peat-vermiculite and peat alone remained intact better during transplanting.

Struck and Whitcomb (42) compared peat and perlite (1:1) against ground pine bark, peat, and sand (2:1:1) in bottomless milk carton containers. Germination of Cedrus deodara seed was 53% in the well aerated peat-perlite mix, and 36% in the less well aerated bark-peat-sand mix.

Ferguson and Monsen (23) used various combinations of peat moss, sand, and horticultural vermiculite. They found peat moss and vermiculite (1:2) gave the best results in producing curlleaf mountain-mahogany.

In container seedling production the need for a lightweight, water-retentive, yet well-aerated mix is evident. Peat moss in soilless mixes is almost universal with, primarily, one other component usually vermiculite or perlite.

Seedling Nutrition

Literature reveals most container seedlings are produced using a liquid fertilizer program of N,P,K,Mg,Ca, and S. Application rates vary widely among producers (Table I). Liquid, soluble dry chemicals, and slow-release fertilizers constitute the three main categories of release mechanisms. Due to application schedules, liquid feed systems have an up and down relationship with plant growth. Top dressing with highly soluble dry chemicals are potentially most harmful to plants from excessive applications. Because of the mechanism of release, slow-release fertilizers are most naturally attuned to plant growth. Aljibury (2) cites three distinct advantages of controlled release fertilizers:

1.) They are applied at rates that are necessary for plant growth without causing excessive nutrient loss by leaching.
2.) The mode of release allows for reasonable mistakes and over-application without phytotoxicity.
3.) Frequent applications are not required.

Slow-release fertilizers include; a.) IBDU (Isobutyldiene diurea), a condensation product of urea and isobutyaldehyde with an ammoniacal nitrogen content of approximately 31%, b.) Urea-formaldehyde (ureaforms), synthetic non-protein slow-release sources of nitrogen produced by the polymerization reaction of urea with formaldehyde, a 38% availability of ammoniacal nitrogen, available through soil microbial

TABLE I

SUMMARY OF SOME RECENT SAND CULTURES

N	P	K ppm	Ca	Mg	S	Irrigation Frequency	Species
100	10	20	50	10	20	2 hours	Picea glauca
							Picea rubens
100	1	126	40	24		1 hour	Pinus taeda
							Pinus virginiana
280	93	273	200	73		7 to 28 days	Pinus strobus
250	250	50	100	100		8 hours	Pinus radiata
300	100	50	75	50	50	24 hours	Pinus serotina
							Pinus taeda
28	23.5	44	40	18	30	6 hours	Pseudotsuga mensiesii
							Tsuga heterophylla
							Thuja plicata
							Pinus contorta
50	15	20	150	50	149	3 hours	Pseudotsuga menziesii
							Picea stichcnsis
112	31	156	80	48	150	24 hours	Pinus contorta
							Picea glauca
56	186	78	320	97	128	2X per week	Pinus contorta
203	151	320	244	173	280	2X per week	Pinus banksiana

Source: (12)

action, and c.) multiple plastic-coated products (Osmocote), capable of many release rates in many analyses (7).

Osmocote (manufactured by Sierra Chemicals, Milpitas, California) releases nutrients by osmotic pressure and diffusion. The high water potential of the nutrient ball or "prill" draws water from the surrounding growing medium through a semi-permeable membrane, increasing the osmotic pressure inside the sphere. This swelling and pressure results in the evacuation of the now liquified nutrient solution. The increasing concentration of fertilizer salts outside the coating equalizes the pressure within the sphere and provides an available source of nutrients to the roots. Further leaching draws fertilizer salts away from the sphere, and the osmotic process occurs again. The cycle repeats itself until the polymer sphere is empty. Different thicknesses of the polymer resin allow for different rates of release. Combinations of different coatings provide for even more flexibility in release rate.

The release rate determined by the coating is predictably constant except for two variables, moisture availability and temperature. Increased temperature results in increased rates of nutrient release. Reduced temperature counteracts this effect, while freezing crystalizes the liquid. Complete drying also stops the process due to the extreme high water potential of the air. These phenomenon tend to match the biological cycle with accuracy. With reduced moisture, extreme cold, or extreme dry, there is a reduction of plant growth or dormancy, and nutrients are withheld. With the resumption of available soil moisture, plant growth resumes and nutrient release commences. The release rate of osmocote is more uniform when it is mixed with the soil medium because the release is enhanced by the positive soil temperature-water vapor relationship absent in top-dress treatments.

Sierra Chemical Company recommends the following application rates of 18-5-11 (standard long-term container nursery stock fertilizer source); 3.98 kg/m^3 (6.75 lb./$yard^3$), 7.38 kg/m^3 (12.5 lb./$yard^3$), and 9.74 kg/m^3 (16.5 lb./$yard^3$), as low, medium and high, respectively.

Washington and Self (49) using five rates of osmocote 18-5-11 on three species, found euonymus grew best at 14.75 kg/m^3 (25 lb./$yard^3$), photinia at 11.8 kg/m^3 (20 lb./$yard^3$), but azaleas at only 5.9 to 8.85 kg/m^3 (10 to 15 lb./$yard^3$).

Laiche (31) used Osmocote 18-6-12 at 2.36, 4.72, and 9.44 kg/m^3 (4, 5, and 16 lb./$yard^3$). He found optimum growth for *Camellia sasanqua* at 2.36 kg/m^3 (4 lb./$yard^3$), and for *Araucaria excelsa* at 4.72 kg/m^3 (8 lb./$yard^3$).

Rates of osmocote needed for best growth are determined, at least partially, by the species grown. Further consideration must be given to environment and coating in determining rates.

Accelerated-Optimal-Growth Seedlings

Ground bed production of seedlings allows for a natural complex of growth influencing factors. In container production, however, growth factors are more finely controlled by the producer. Accelerated-optimal growth seeks to find the theoretical "absolute upper limit of growth", or more practically, seeks "maximization of growth" (33).

During germination and early seedling development, once growth has been arrested for any reason, the seedling responds much more slowly to renewed favorable growth conditions (37). Blackman's "Compound Interest of Plant Growth" theory states that growth proceeds exponentially only when all events and conditions are increased in synchronization (9).

The rhythmic growth of roots and shoots may be seen as a series of feedback oscillations that maintain a functional root-shoot ratio (11). This homeostatic mechanism is for maintaining a balanced root-shoot ratio and for restoring it following either a disturbance or exposure to a stress situation. (48).

Of the controllable environmental factors, light is the single most important factor, and is instrumental in hastening the appearance and increasing the size of foliar organs (33). Increases in photoperiod length and light intensities can be artificially supplied but usually at great expense.

Bonner (10) theorized the upper limit of utilization of light for photosynthesis at 20%, with the practical limit at 5%. Field conditions average only 2-3%. By increasing CO_2 concentrations, the efficiency can be pushed beyond the

5% level. CO_2 enrichment increases the photosynthetic rate and is manifested in increased plant height. Practically speaking, CO_2 enrichment is not economically feasible in most seedling production.

Accelerated growth is best achieved under greenhouse conditions where light, temperature, and environmental extremes are best controlled. In general, overall seedling growth increases with increasing temperatures to about 20-25°C and after that point declines (45).

Container seedling production out-of-doors can produce maximized growth when temperature is not limiting, and sunlight is abundant. Out-of-door production has the added benefit of producing stem strength by the production of collenchyma cells when stems are manipulated by winds. Certainly with all other factors maximized, appropriate nutrition and increased water is essential.

Transplanting and Survival

The transplanted seedling is the direct result of cultural treatment received in production. Tinus (46) states three criteria to be met prior to transplanting for good performance in the field:

1.) Species and seed source must be adapted to site.
2.) Seedlings must be in the proper physiological state.
3.) Root-soil contact must be established quickly.

Besides the proper selection and pre-germination treatment of seed, other factors, easily manipulated, can be employed to maximuze seedling performance. Research into maximizing nutrition can aid individual species. By growing in bottomless containers on raised benches to facilitate air root-pruning, a fibrous root system with increased nutrient and water absorptive capacity can be achieved (16) (27) (42) (50). A good growing medium allows aeration, reasonable water holding capacity, good root growth, and ease in transplanting.

Whitcomb, Storjohann and Gibson (50) grew four species of deciduous trees in bottomless milk carton containers. When transplanted into larger containers at two-week intervals, dramatic increases in height and caliper were observed as a result of earlier transplanting dates. Conversely, one coniferous species grew better when transplanted on the last date. Differences in the ability of the root systems to regenerate at various stages of seedling development are believed to be responsible for the variance.

Despite the fact that forest seedling production centers around smaller containers, and thus, smaller seedlings, some researchers have reported the superiority of larger seedling in survival and performance. Hunt and Gilmore (29) showed that large loblolly pine seedlings grew at a consistently faster rate than smaller ones over a long period of time. Arnott (5) found a distinct correlation between a large seedling and good survival. Many others report the same positive correlation (40) (36) (22) (24).

Tinus (24) grew Quercus macrocarpa in $80cm.^3$ containers, and attained heights of 20 cm. in two and a half months, 50 cm. in four months. Johnson (30) reports that oaks produced in greenhouses in winter were 6 to 12 inches tall with calipers of 4/32 to 5/32 inches in sixteen weeks. In twelve weeks eucalyptus seedlings 18 inches tall were produced in quart pots 57 $in.^3$ (35). Many reports on conifer production state heights of approximately 4-5 inches in about 12-15 week periods.

A major influence on survival and growth in the field is seasonal temperature, rainfall fluctuations and other climatological factors. Scarratt (40) has noted a mid-August planting-out time limit for conifers in Ontario. Swanson reports that of 25 species of deciduous shrubs planted in either spring or fall 85% did better when planted in spring. Of those planted in fall 53% showed severe cold injury in north central Colorado (43). A study in Louisiana stated that seedlings planted in early winter grew more slowly than those planted early the next spring (6). In a five-year study in Minnesota, Alm and Schatz-Hanson (3) using jack and red pine transplanted on June 1, July 1, August 1, September 1, and September 25, found good survival for all dates except September 1 and 25 when survival was dramatically low. Dickinson and Whitcomb (18) compared fall and spring planting of one gallon container nursery stock. They noted that after one growing season in the field, Japanese black pine planted in the fall had more new roots, increased top weight, stem caliper and height than those transplanted in spring. Bur and sawtooth oaks also had increased total roots, top weight, caliper and height when fall planted. Burford holly planted in the fall suffered 50% mortality from cold injury when planted in the fall, however, and was attributed to moisture stress. Tinus (12) has condensed physiological condition and growth responses as a function of planting season (Table II).

Plant dormancy is achieved in two stages. The first occurs before frost and is short-day activated. This dormancy protects plant tissue to 0^{o} C. The second stage occurs after frost, and protects the plant to very low temperatures. In red-osier dogwood, for example, this frost activated stage protects to -18^{o} C., but this varies from species to species. Rapid drops in temperature, however, can result in injury and death at temperatures not normally injurious (21).

Various nutrient elements have been found to affect cold hardiness. Levitt (34) found that late applications of nitrogen reduced cold hardiness in trees and is attributed to its effect of prolonging plant growth and delaying the onset of dormancy. Anderson and Gessel (4), however, found that late applications of nitrogen helped winter survival. Tinus (46) maintains that cold hardiness is aided by low nitrogen and high potassium and phosphorus along with some moisture stress and reduced photoperiod. Coultas (15)

TABLE II

PHYSIOLOGICAL CONDITION AND GROWTH RESPONSE REQUIRED AS A FUNCTION OF PLANTING SEASON

Time of year	Usual planting success	Seedling condition needed	Growth response needed after planting
winter	good in climates that permit	deep dormancy fully cold hardy	1. active root growth 2. top remain dormant until spring 3. break bud and flush
early spring	best	post dormant cold hardy	1. active root growth 2. break bud and flush
late spring early summer	good to poor	post dormant, but not flushing	1. active root growth 2. flush
late summer	poor	non-dormant, flush completed buds set	1. active root growth 2. may or may not flush that year
fall	good	flush completed buds set dormant cold hardiness	1. active root growth 2. enter deep dormancy 3. develop full cold hardiness

Source: (47)

reported high rates of potassium beneficial, but that high phosphorus and nitrogen was detrimental to cold hardiness.

CHAPTER II

METHODS AND MATERIALS

Seeds of Pistacia chinensis, Chinese pistache, Quercus rubra, northern red oak, and Pinus thunbergi, Japanese black pine, were sown into square bottomless milk carton containers on May 6, 1977. Chinese pistache and Japanese black pine were seeded two or three per container. Red oaks were seeded one acorn per container.

Treatments consisted of three container sizes, three fertility levels, and four planting-out dates in the field. There was a seedling production phase, and a field establishment phase of the study. In the seedling production phase each treatment was replicated five times with six sub-samples per treatment. Of the six sub-samples, four were selected for uniformity and randomly assigned a planting-out date.

The seedling containers were all 14.6 cm. deep (5.75 in.) but varied in their widths. The three container sizes used were:

Quart- 14.6 X 7.62 X 7.62 cm. (5.75 X 3 X 3 in.)
848 $cm.^3$ (52 $in.^3$).

½ Gallon- 14.6 X 10.2 X 10.2 cm. (5.75 X 4 X 4 in.)
1519 $cm.^3$ (92 $in.^3$).

Gallon- 14.6 X 12.7 X 12.7 cm. (5.75 X 5 X 5 in.)
2355 $cm.^3$ (174 $in.^3$).

Low, medium, and high fertility levels were 7.1, 9.4, or 11.8 kg. Osmocote 18-5-11 per cubic meter (12, 16, and 20 pounds per cubic yard). The growing medium was ground pine bark, sphagnum peat and coarse sand in a 2:1:1 ratio. Perk, dolomite and single superphosphate were added to each treatment at 2.36, 4.7, and 2.36 kg/m^3 (4, 8, and 4 lb./$yard^3$).

The containers were placed on raised wire benches of expanded metal, about three feet high to facilitate air root pruning. Containers were grouped by species and arranged in a randomized complete block design. A border row of containers surrounded the design to protect from excessive heat build-up. Seedlings were watered by hand.

On August 16, 1977, two of the six sub-samples of pistache in each replication were sacrificed for fresh top and root weight. Due to poor seedling germination of the oaks and pines, there were not enough sub-samples to allow for top and root weight sacrifice. Of the four remaining sub-samples each was randomly assigned a planting-out date of October 1, November 1, December 1, 1977, or March 1, 1978. Each treatment was replicated five times in the field. Before planting-out commenced, height was taken on all species, visual grade on the oaks and pines, and stem caliper on oaks and pistache.

Planting-out was done into a cultivated field of Kirkland Loam, of moderate fertility and drainage. After transplanting, each tree was thoroughly watered in by hand. No supplemental fertilizer was added to the field. Soil conditions were moist and friable on all dates. Treflan (trifluralin) was applied in April, 1978, at the rate of 3.7 kg. active ingredient per hectare (4 lb. per acre), unincorporated, and watered in by rainfall. A second application at the same rate was applied in July.

On May 21, 1978, die-back due to winter injury on pistache was observed and recorded; and on August 2, height and stem caliper were obtained. Also on August 2, spring flushes on pines were measured. Final observations were made October 3, 1978. This included height and caliper on all species, and number of branches on pines. Several plants of each species were excavated and examined to note the long-term results of seedling production root modification.

CHAPTER IV

RESULTS AND DISCUSSION

Seedling Production

Pines

Japanese black pine grew significantly taller and had a higher visual grade when grown in the two smaller containers (Table III). The production of Japanese black pine in the large container (2355 $cm.^3$) does not appear feasible for a one season production cycle.

Pines grown with low fertility had a higher visual grade than plants from the medium or high levels. The visual grade rated pines on total height and number of lateral branches. Low fertility stimulated good height and branching, whereas with higher fertility levels, height was good but branching was poor.

Oaks

Stem caliper and visual grade were greatest when oaks were grown in the medium or large containers (Table IV). Significant responses in height and caliper show the low fertility levels superior to the medium or high. At higher levels the seedlings appeared stunted.

TABLE III

PINES: SEEDLING PRODUCTION PERFORMANCE

Container Size	Visual Grade[1]	Height (in cm.)
small-	6.67 b[2]	8.75 b
medium-	6.32 b	8.62 b
large-	4.78 a	6.48 a

Fertility Level	Visual Grade[1]	Height (in cm.)
low-	6.55 b	
medium-	5.63 a	N.S.
high-	5.63 a	

[1] 1=poorest, 10=best

[2] Means followed by the same letter are not significantly different at the 0.05 level.

TABLE IV

OAKS: SEEDLING PRODUCTION PERFORMANCE

Container Size	Visual Grade[1]	Height (in cm.)	Caliper (in cm.)
small-	5.53 a[2]		0.24 a
medium-	7.72 c	N.S.	0.27 ab
large-	5.87 b		0.29 b

Fertility Level	Visual Grade[1]	Height (in cm.)	Caliper (in cm.)
low-	6.8 b	32.7 b	0.293 b
medium-	5.7 a	26.2 a	0.265 ab
high-	5.9 a	24.7 a	0.243 a

[1] 1=poorest, 10=best

[2] Means followed by the same letter are not significantly different at the 0.05 level.

Chinese Pistache

Chinese pistache response to container size was dramatic. As container size increases, height, caliper, fresh top and root weight increased significantly (Table V). Heights averaging 60 cm. (25 in.) were achieved in 13 weeks in large containers, compared to 45 and 49 cm. (18 and 19 in.) for the small and medium sizes respectively. Fertility levels produced no significant differences.

Field Performance

Pines

When considering the length of current season growth there was no significant interaction between container size and transplanting date on the October 1 date. However, seedlings grown in small containers and transplanted November 1 had significantly longer flushes than seedlings grown in either the medium or large containers (Figure 1). Growth of seedlings produced in the small container declined over the next three planting dates. Seedlings transplanted March 1 from the middle size container out performed either the seedlings from small or large containers. The increasingly poor performance of the small container is attributed to root binding and reduced root regeneration potential (RRP). Increased growth for the seedlings from the middle size transplanted on March 1, is a reflection of increase in time that the pine needed to occupy the larger volume of soil.

TABLE V

CHINESE PISTACHE: SEEDLING PRODUCTION PERFORMANCE

Container Size	Height (cm.)	Caliper (cm.)	Topweight (gm.)	Rootweight (gm.)
small-	45.1 a[1]	0.26 a	19.8 a	11.8 a
medium-	49.6 b	0.31 b	36.5 b	20.9 b
large-	64.0 c	0.36 c	77.1 c	41.0 c

[1]Means followed by the same letter are not significantly different at the 0.05 level.

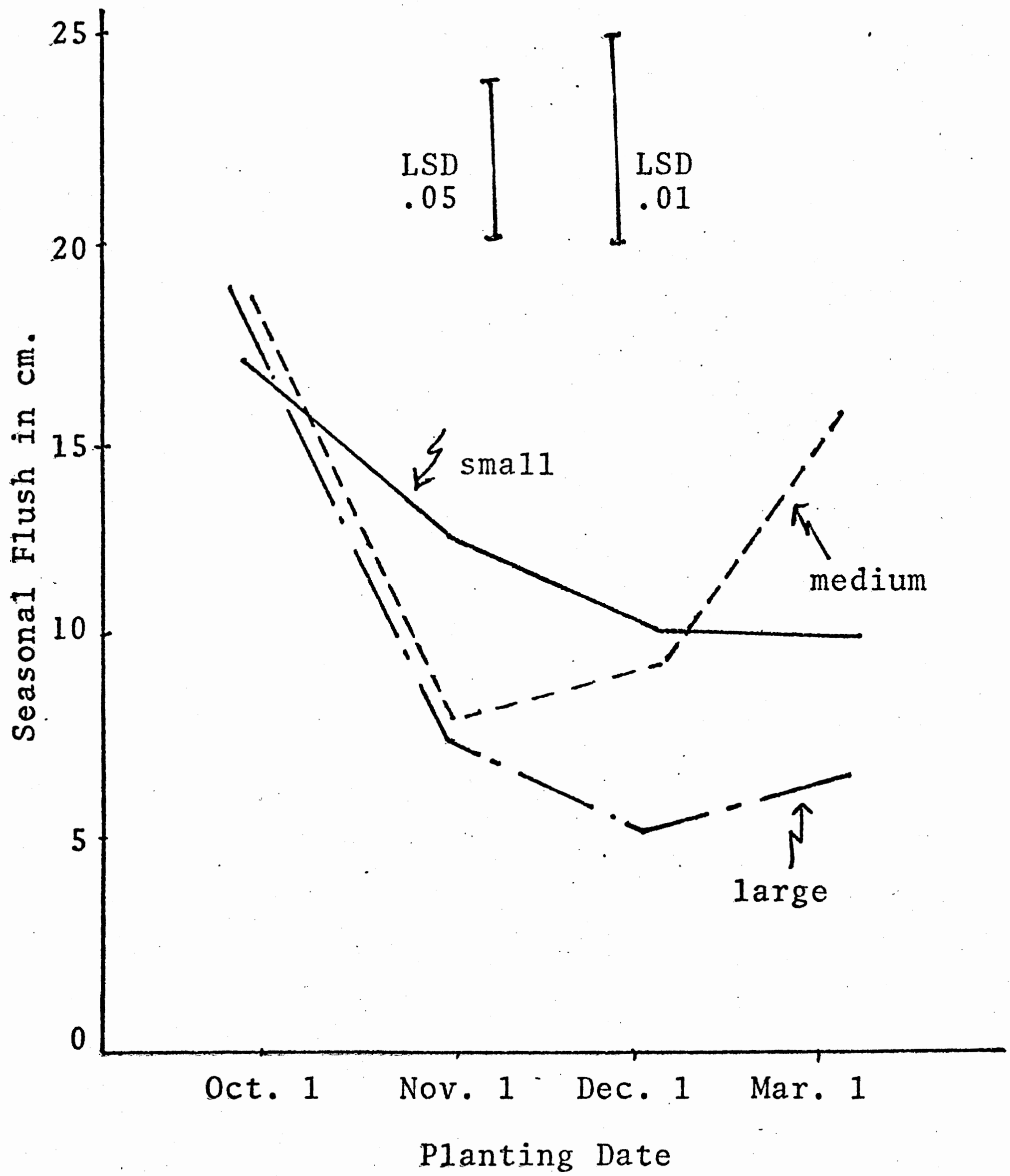

Figure 1. Effects of Container Size and Planting Date on seasonal flush of Japanese Black Pine

Fertility level during seedling production had no effect on performance of Japanese black pine in the field.

The general trend points towards the superiority of smaller containers and earlier planting dates (Table VI). This supports the findings of Scarratt (40), and Alm and Schatz-Hansen (3). Containers much larger than those in reforestation programs can produce large vigorous conifer seedlings.

Oaks

Oaks produced in the medium and large containers had greater stem caliper when transplanted October 1 than those in small containers (Figure 2). With the November 1 planting-out date, no differences in stem caliper were detected between container size. However, seedlings in the middle size were superior to those in large containers on December 1, and the small containers on March 1. After the December 1 date, the trend suggests increasingly better growth of seedlings in middle and large containers, and poorer growth of those in small containers. Seedlings in small containers had become root bound and stunted after November 1, whereas seedlings in larger containers over-wintered and performed well.

The interaction of fertility and planting date on height and stem caliper (Figures 3 and 4) show the low level superior to medium and high levels when transplanted on October 1, and superior to the high level on December and

TABLE VI

PINES: FIELD PERFORMANCE

Container Size	Seasonal Flush (cm.)	Total Height (cm.)	Caliper (cm.)	Branches
small-	12.7 b[1]	25.6 b		
medium-	13.0 b	26.0 b	N.S.	N.S.
large-	9.7 a	22.2 a		

Planting Date	Seasonal Flush (cm.)	Total Height (cm.)	Caliper (cm.)	Branches
Oct. 1-	18.2 b	34.0 c	1.04 c	14.6 b
Nov. 1-	9.6 a	20.9 ab	0.76 a	10.2 a
Dec. 1-	8.6 a	19.0 a	0.75 a	9.8 a
Mar. 1-	10.9 a	24.6 b	0.89 b	11.5 a

[1]Means followed by the same letter are not significantly different at the 0.05 level.

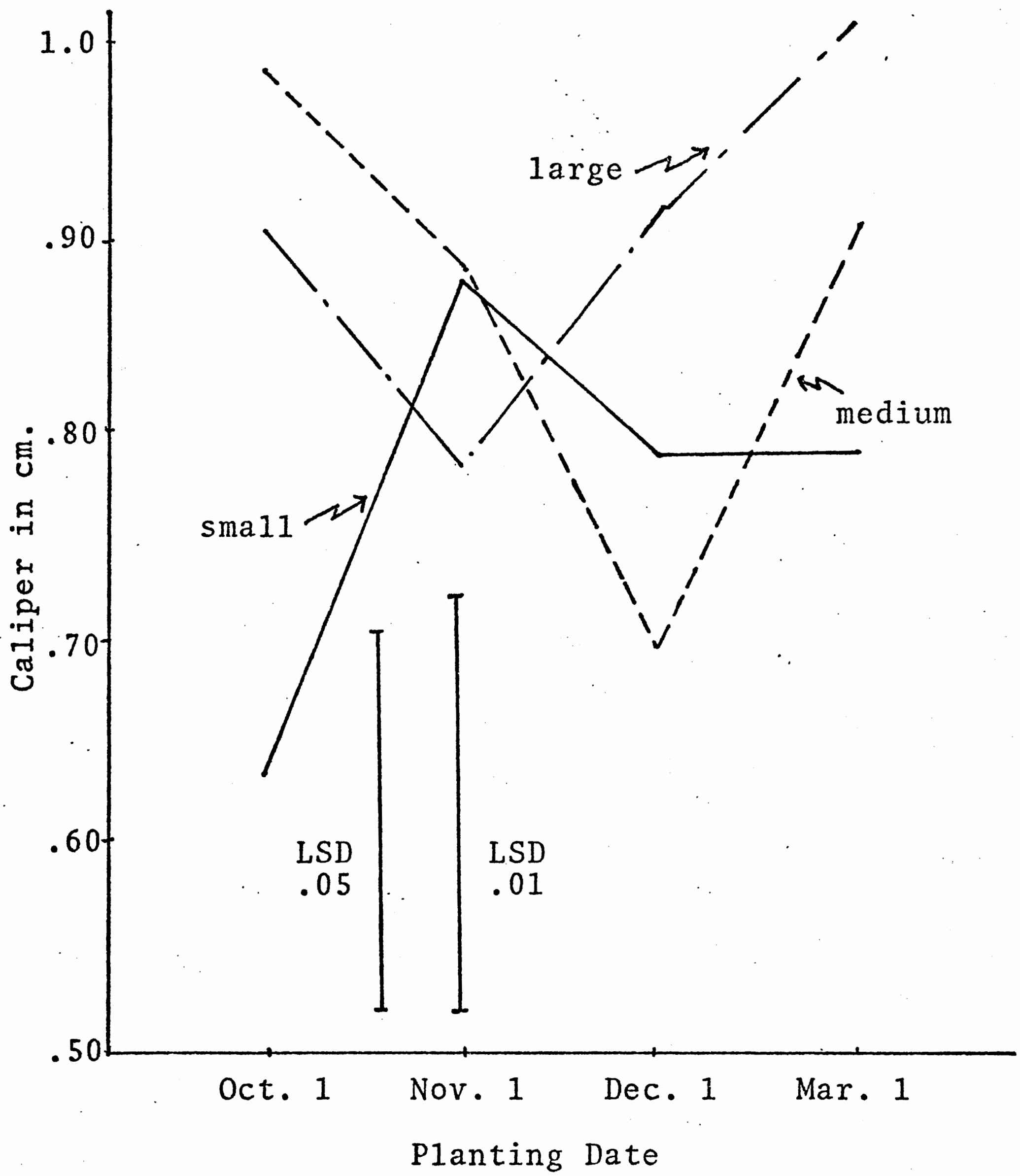

Figure 2. Effects of Container Size and Planting Date on Stem Caliper of Northern Red Oak

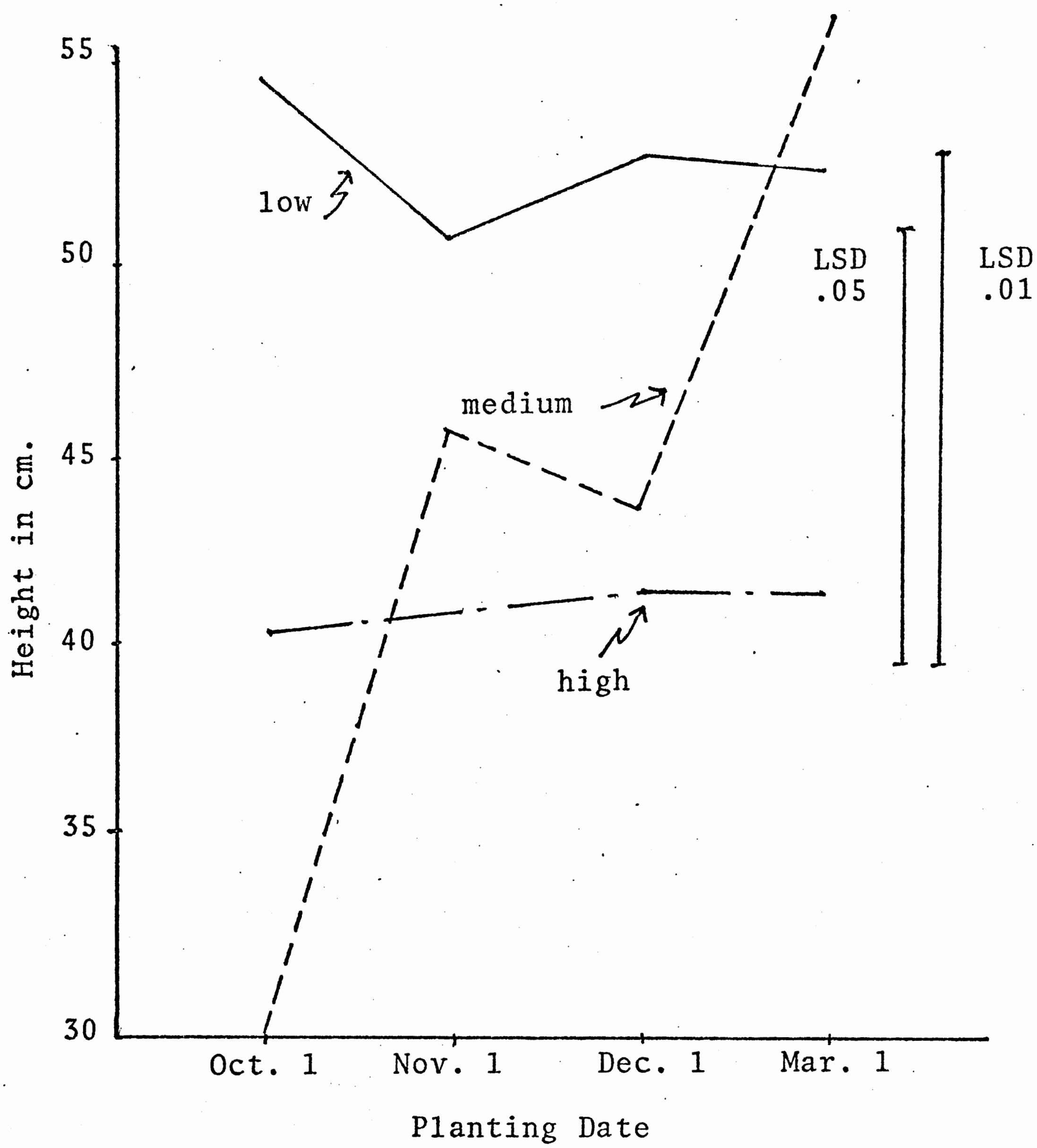

Figure 3. Effects of Fertility Levels and Planting Date on Height of Northern Red Oak

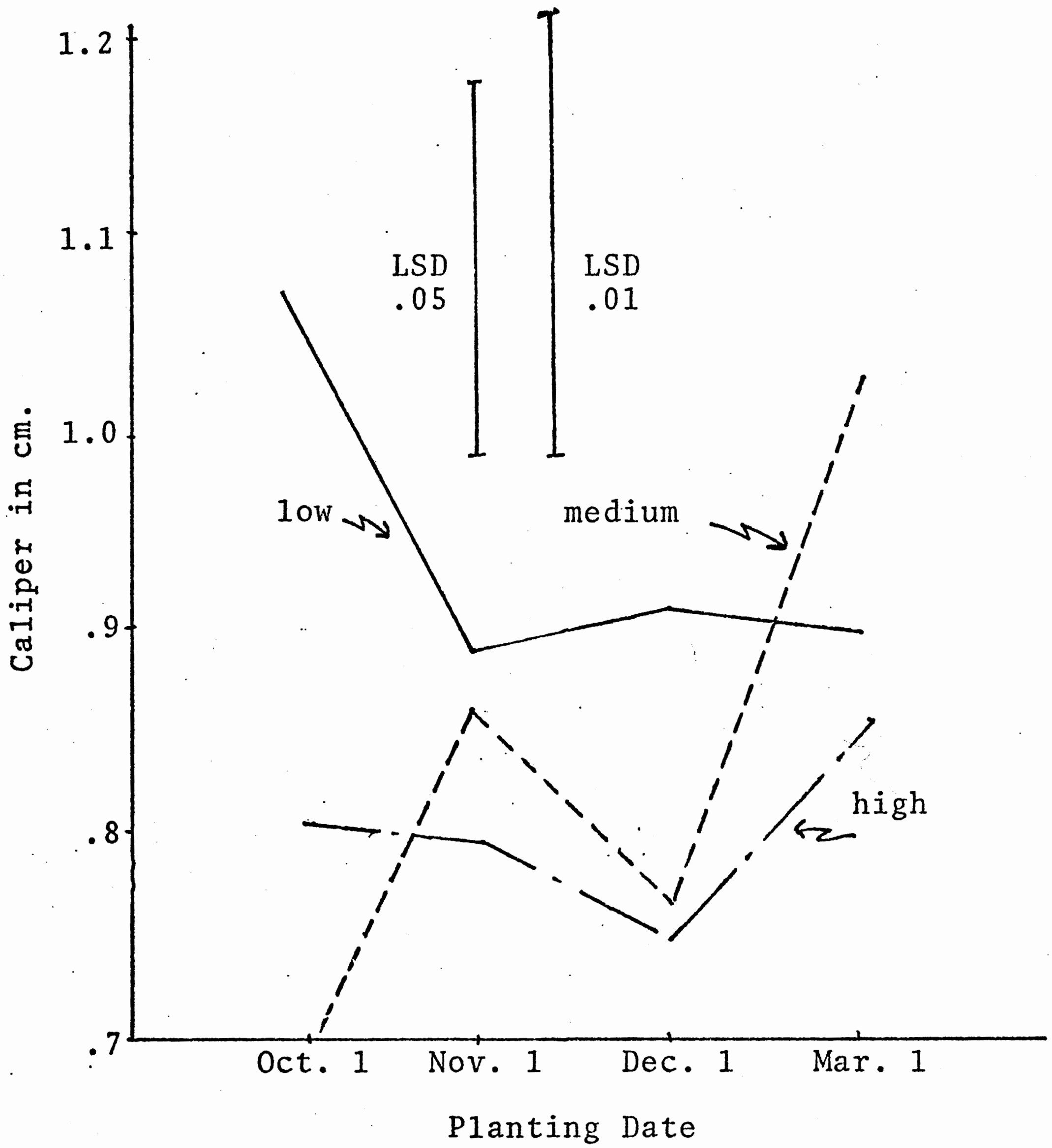

Figure 4. Effects of Fertility Levels and Planting Date on Stem Caliper of Northern Red Oak

March 1. The middle rate outperformed the high rate on March 1. The general trend favors a low level of fertility (Table VII).

Chinese Pistache

Chinese pistache grown in large containers and transplanted on October 1 were severely injured during winter while plants grown in smaller containers showed little or no injury (Figure 5). However, after November 1, seedlings grown in smaller containers increased in die-back and seedlings grown in larger containers exhibited less die-back. On March 1, after over-wintering, seedlings grown in medium and large sizes sustained no die-back, while those grown in small containers suffered 20% die-back. Seedlings grown in smaller containers were apparently pot bound and stunted by the increased time in the container. Excessively succulent tissues due to rapid initial growth and inability to respond to dormancy factors at all fertility levels were probably responsible for the severe die-back of seedlings grown in medium and large containers during the winter.

As a result of die-back, planting date and container size interactions were not significant for height on the first three planting dates, even though significant differences existed when planted-out (Figure 6). On March 1, seedlings grown in large containers were significantly larger than those in small and medium sizes. However, short seedlings grown in small containers planted on October 1

TABLE VII

OAKS: FIELD PERFORMANCE

Container Size	Height (in cm.)	Caliper (in cm.)
small-	39.9 a[1]	0.78 a
medium-	51.5 b	0.88 ab
large-	47.3 ab	0.93 b

Fertility Level	Height (in cm.)	Caliper (in cm.)
low-	53.1 b	0.953 b
medium-	44.2 a	0.827 a
high-	41.4 a	0.803 a

[1]Means followed by the same letter are not significantly different at the 0.05 level.

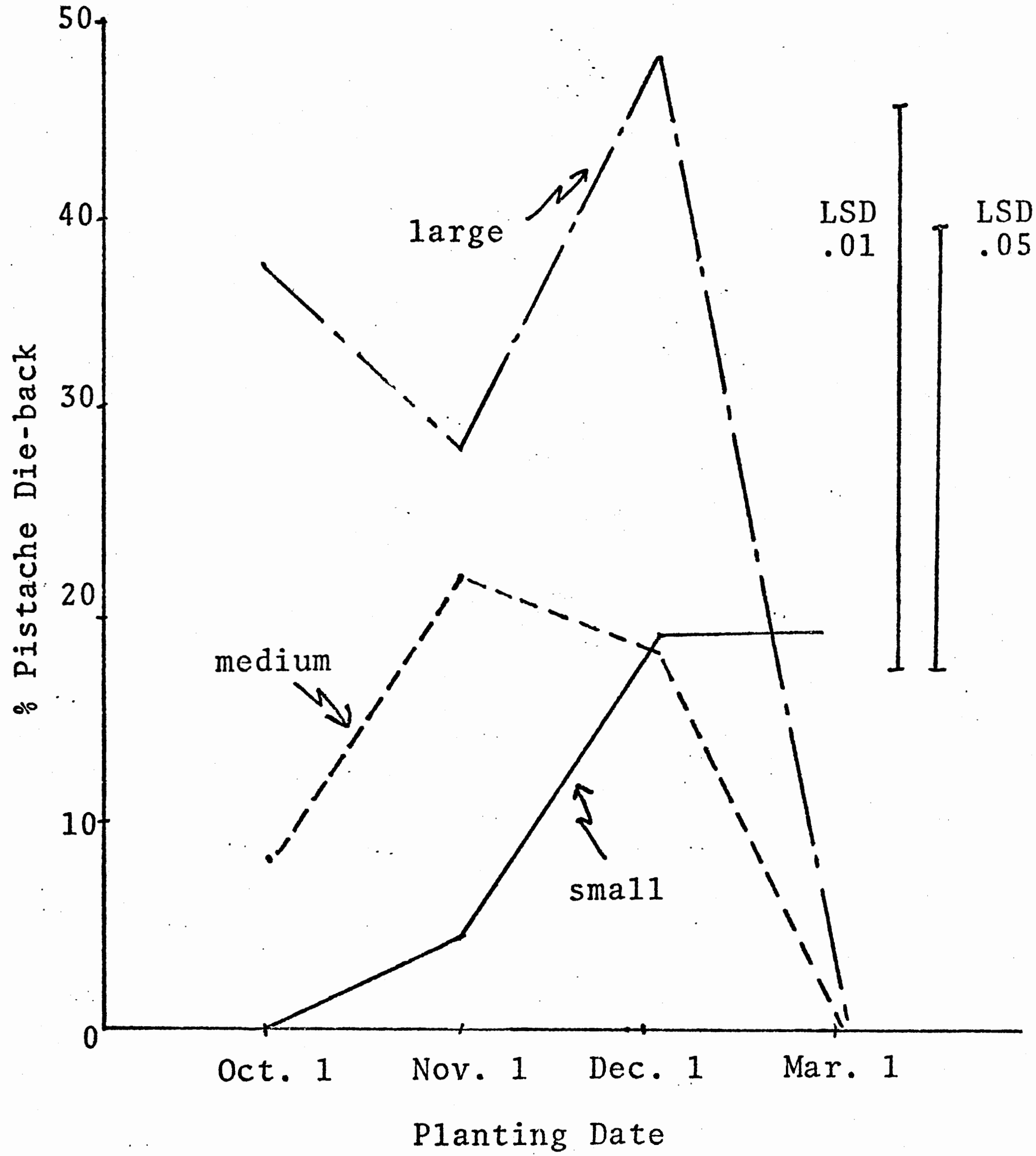

Figure 5. Effects of Container Size and Planting Date on Die-back of Chinese Pistache

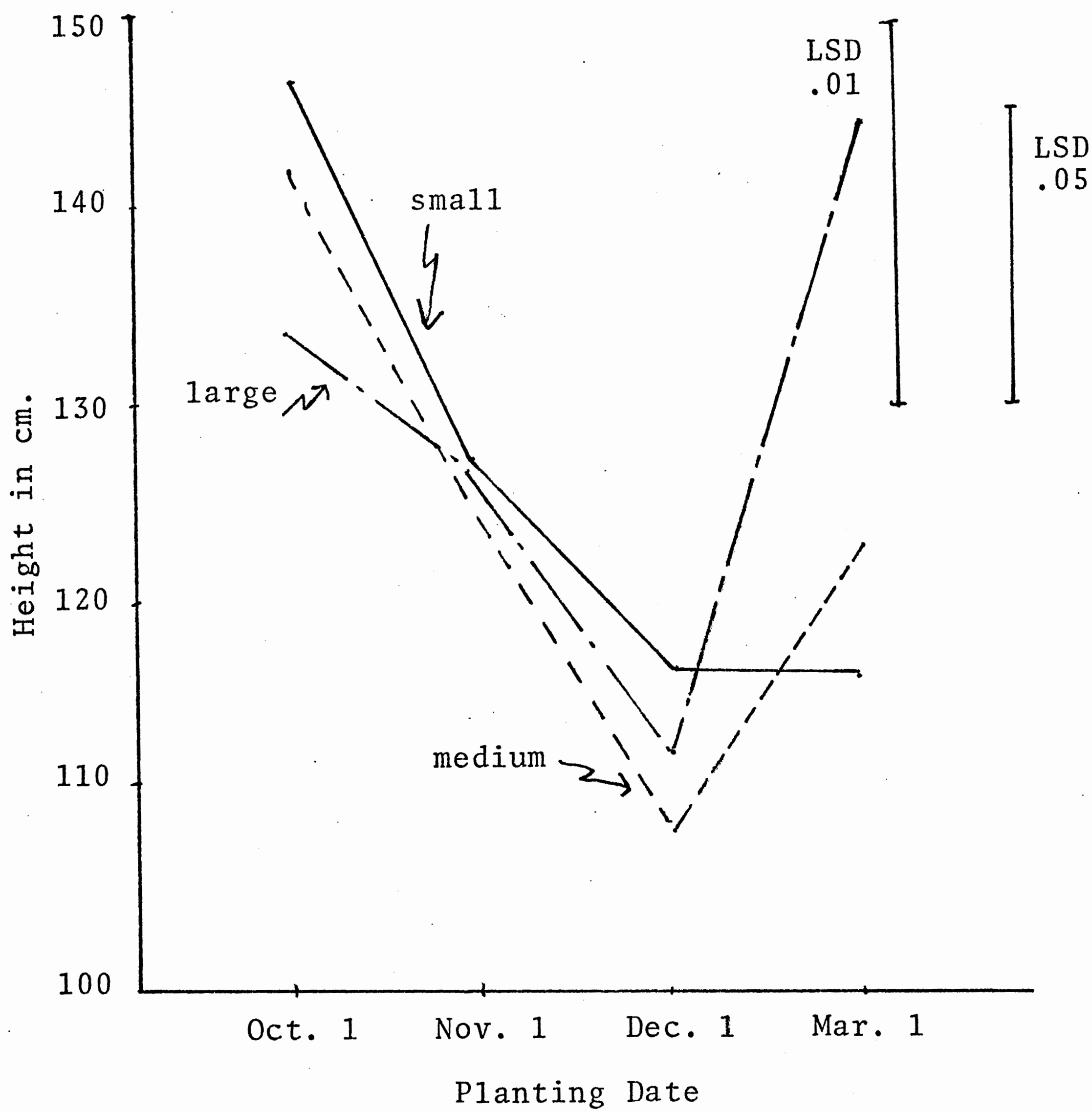

Figure 6. Effects of Container Size and Planting Date on Height of Chinese Pistache

(0% die-back) outperformed tall seedlings grown in the large containers planted on March 1 (0% die-back) after one growing season in the field. This was probably due to root establishment of the October 1 planted seedling in the field during the winter and/or the larger March 1 planted seedling becoming pot bound and stunted. Seedlings grown in large containers must be planted out early enough to allow for sufficient establishment to be able to respond to dormancy factors. The general trend suggests earlier fall planting-out dates (Table VIII).

TABLE VIII

CHINESE PISTACHE: FIELD PERFORMANCE

Container Size	% die-back	Height (in cm.)	Caliper (in cm.)
small-	10.95 a[1]		1.39 a
medium-	12.18 a	N.S.	1.43 a
large-	28.77 b		1.53 b

Planting Date	% die-back	Height (in cm.)	Caliper (in cm.)
Oct. 1-	15.2 a	115.8 b	1.54 b
Nov. 1-	18.5 ab	110.1 ab	1.45 ab
Dec. 1-	28.8 b	91.5 a	1.33 a
Mar. 1-	6.7 a	112.0 b	1.48 ab

[1] Means followed by the same letter are not significantly different at the 0.05 level.

CHAPTER V

CONCLUSIONS

The production of pines in smaller containers and low fertility levels appears to be the superior system. Earlier planting-out dates in the fall perform better than late fall dates. Over-wintering in the medium size container is feasible but not necessary.

Oaks grew best in larger containers at lower fertility levels. Early fall planting produced the best results, but over-wintering in large containers is feasible.

Chinese pistache, although largest in larger containers following the seedling production phase, exhibited severe die-back due to succulent growth. Chinese pistache was the most sensitive of the three species to late fall planting dates. Rapid root development of this species necessitates early transplanting to avoid root binding. Over-wintering, although lessening danger of die-back, reduces performance after transplanting the following spring.

This system of seedling production in bottomless containers, and using slow-release fertilizers continues to perform admirably, further refinements in nutrition and transplanting timing hold great promise for even better performance in the future.

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