Influence of Plexiglass Inserts on Prevention of Root Spiraling of Container Grown Tree Species

by

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Container grown nursery stock provides several advantages to the consumer and nurseryman. Container grown plants will suffer less transplanting shock and do not require digging and balling that are involved when producing balled and burlapped plants. The planting season of container grown plants can be extended into the summer, and the ability of the nurseryman to display greater quantities of more attractive plants is enhanced. Finally, plants grown in containers do not compete for water and nutrients as they would if grown under field conditions (3, 7, 12).

However, there are disadvantages to container growing. First, trees are more susceptible to low temperature damage when overwintered in containers. Second, watering practices become more critical because there is an increased number of plants per acre that require individual attention. Third, container grown plants may require numerous transplantings, which increase labor costs. Lastly, some containerized plants have a tendency to develop a defective, twisted, root system (7), known as pot bound or root spiraling, when grown in containers for an extended time period. It is the root spiraling which may lead to girdling roots in the landscape, unless corrective measures are taken by the person planting the tree (12, 16).

To understand root spiraling, it is important to first understand how the root reacts in soil. The root increases in length when the cells in the meristematic region divide, elongate, and push the root tip forward through the media (15, 17). According to Taylor (17), the root passes through the soil partly by growing through existing voids and partly by moving soil particles from its path. When there are no pores larger than the rootcap, a root will either displace the soil or will be diverted horizontally. This can be shown when roots encounter a hard pan or the bottom of the container. In containers, the root will be diverted horizontally until it comes in contact with the container side wall, at which time spiraling occurs.

Roots are considered to be positively geotropic. The primary root exibits greater geotropic response than do secondary roots. Both tend to grow vertically or orthogeotropically. Tertiary roots and other roots of a higher order are less geotropic and will grow more horizontally or plagiotropically (15).

The area of gravity detection in roots is situated in the root cap (2, 15). The nature of gravity detection by the root cap has only been hypothesized. A popular hypothesis concludes that root cap cells contain amyloplast. It is the response of the amyloplast to gravity, by its movement toward the lower side of the cell, which may cause geotropism (15).

Root spiraling will occur in a container-grown ornamental tree after a prolonged period of time. Root spiraling may occur in one or both of 2 stages. The first stage in which root spiraling can occur is by the propagating practices at the liner stage (11). This stage of root spiraling is characterized by a bending of the primary root close to the soil surface. The bending is the result of the primary root being longer than the container depth. The second stage in which root spiraling may occur is during the development period of the container tree. This stage of root spiraling is characterized by the root growth following the contour of the container (7).

Various attempts to control root spiraling have been reported. The control of root bending can be accomplished through root pruning. The pruning of roots during transplanting from seed beds to the container will effectively reduce the amount of bending by reducing the initial roo force (11).

Chemical control is another method of controlling root growth in containers. Furuta, et. al. (8), tested the effect of copper sulphate and copper naphthenate on Eucalyptus and Jarcaranda. The chemicals were sprayed on the inside of 3.8 l containers, after which the plants were allowed to grow for 10 weeks. The plants were then transplanted into 19 l containers to determine the root development outside of the original root ball. The chemicals were effective in preventing root growth on the surface of the original root ball; however, plant height and root volume was lower in treated plants. Once the plants were placed in the 19 l containers, there was no reported effects of the chemicals on root development. Copper levels were not determined in this study. However, copper sulphate and copper napthenate have been reported to be toxic to plants (1).

In a preliminary study, silver nitrate, cupric sulphate, cobalt chloride, and sodium borate were found to be effective in pruning roots of Gymnocladus dioicus, Catalpa bignonoides and Cercis canadensis (14). According to Pellet (13), it may be difficult if not impossible to obtain clearance to use the heavy metal compounds.

Container design alteration is the last method of controlling root growth in containers. Three designs have been studied. One design uses a process of air pruning (4, 9, 10), another utilizes water pruning (13), and the last uses barriers to impede root growth (5).

Air pruning utilizes bottomless containers with either a wire mesh bottom (10), or placed on wire mesh benches (4). In either case, containers are raised off the ground to provide for free air movement under the container. Air pruning begins as the primary root grows down through the wire. The air pruning stimulates development of lateral roots. The lateral roots grow out to the sides of the container, then towards the corner and finally down through the wire where it is also air pruned.

Air pruning has proven to be beneficial in production of seedlings. (4, 10). According to Dickinson and Whitcomb (5), transplanted air pruned 9 week old seedlings of Carya illenoensis and Quercus acutissima established very quickly under field conditions with only one watering.

Gibson and Whitcomb (9), grew Pinus thunbergi, Pistacia chinensis, and Quercus rubra in 3 sizes of square bottomless containers. They concluded that container size did not influence plant establishment or survival, however, it was noted that smaller containers were more desirable for pines.

Producing plants for seedling production using the air pruning procedures may be beneficial. However, producing large plants utilizing this method is probably impractical, because the labor force and the materials needed, would drive the production cost out of a realistic range (14).

The process of water pruning or "Minnesota system" utilizes a method developed by Pellet (13). This method was developed with the intention of eliminating not only root spiraling within the container, but also winter injury to the root system and also tipping due to wind.

A square bottomless container was used to solve the root spiraling. However, instead of the roots growing out into the air to be pruned, they grow into a resevoir of standing water below the container. To achieve this desired condition, a waterproof container with drainage holes drilled 7.6 cm above the bottom were used. This container was buried to the top as a permanent fixture. The bottom 7.6 cm was filled with gravel and water, and the square bottomless container placed on gravel. Tree liners were then placed into the growing containers and as roots grew into the water saturated gravel, they were prevented from further growth by insufficient oxygen levels.

Pellett theorizes that having the permanent container below ground, problems of winter injury to the roots could be prevented by maintaining soil temperatures similiar to those in field production. The permanent containers would help prevent tipping over in windy weather because of increased anchorage. Quercus borealis, Quercus bicolor, Ostrya virginiana and Betula sp. were effectively root pruned. However, Salix alba 'Niobe' roots were able to survive, possibly due to the nature of the tree itself. The main disadvantage with the "Minnesota system" would be the high initial installation cost and the lack of suitable container components.

The third design method, utilizes barriers or ribs to impede root growth. Initially, this was done using Betula nigra directly seeded into a 0.9 l cylindrical container. Containers had either 0, 2, or 4 plastic ribs of 1.75 cm each. The ribs were glued onto the inside wall of containers (1). Plants were allowed to develop for 6 months, and this was transplanted into a 3.8 l plastic container. Care was taken not to disturb the original root ball. In containers where ribs were present, roots were deflected downward by the ribs. After 7 days, the 3.8 l containers were removed, and the root development was analysised. Fewer roots grew into the 3.8 l container when 0 or 2 ribs were present. Branching of the roots was greatest in containers having 4 ribs.

A followup study was done the next year to determine the effects of ribs in larger containers (5). Bare root seedlings of Quercus palustrus, Taxodium distichum, and Pinus thunbergi were planted in 7.6 l containers. Rib insert numbers of 0, 2, or 4 ribs, measuring either 1.75 X 2.6, 1.75 X 5, or 1.75 X 10 cm, were glued vertically onto the inside wall of the container. Each rib was placed to the container base. Spiraling roots of Pinus thunbergi were modified, while the root force of the other 2 species bent the ribs over and continued to spiral. Unfortunately, the selection of the ribs, anchorage of ribs, and lack of data presented to backup any statements made it difficult to make any conclusions.

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Influence of Plexiglass Inserts on Prevention of Root Spiraling of Container Grown Tree Species[1]

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Abstract. *Acer saccharinum*, *Eleagnus angustifolia*, *Pinus nigra*, and *Quercus macrocarpa* were grown for 2 seasons in 7.5 l containers modified with vertical plexiglass inserts. The addition of 6 or 8 vertical inserts reduced root spiraling for all species for both growing seasons, while containers with no inserts developed numerous spiraling roots. Most root spiraling occurred in the bottom 5 cm of each container. The addition of the vertical inserts had no effect on root and shoot dry weight for all species tested.

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Container grown nursery stock provides the nurseryman with several advantages when compared to bare root and balled and burlapped plant production. There are, however, disadvantages with growing plants in containers. For instance, a tree must remain in a container for several years in order to produce a large enough specimen for sale, and during this period the trees may require numerous transplantings (4). Without transplanting spiraling roots may result (1, 3, 6).

Various attempts to alleviate root spiraling have been reported. Davis and Whitcomb (2) observed that with trees placed in square bottomless containers supported on raised wire mesh benches, air would prune the roots, thus developing a non-spiraling root system. However, this method may prove to be too expensive to implement. In a preliminary study, Pellett (5), effectively pruned roots of Gymnocladus dioicus seedlings by placing a layer of silver nitrate in the soil.

The purpose of this study was twofold: First, to evaluate the effects of rigid plexiglass inserts on root and shoot development, and secondly, to determine the optimum number of plexiglass inserts which would alleviate root spiraling.

Acer saccharinum, Eleagnus angustifolia, Pinus nigra, and Quercus macrocarpa were transplanted on June 12, 1979 into 7.5 l semirigid plastic containers, using a growing medium consisting of sandy loam soil, coarse sand and pine bark (1:1:4 v/v/v). Acer and Eleagnus were dormant 1 year old bare root liners. Quercus and Pinus were actively growing 1 year old plants produced in Rootrainers[T] (Spencer-Lemaire Industries Limited, Edmonton, Canada). Plants were fertilized with a solution containing 200 ppm N, 112 ppm P, and 166 ppm K through a constant feed injector system. During the second growing season, an automatic watering system was used to apply all water and nutrients.

Containers were modified by placing 0, 4, 6, 8 plexiglass inserts vertically on the inside container wall (Fig. 1a). The distance on the container wall between plexiglass inserts was 7.5 cm for 8 inserts, 10 cm for 6 inserts, and 15 cm for 4 inserts. The plexiglass inserts were made from two 0.3 X 4.0 X 17.5 cm sheets, which were bonded together (Fig. 1b), forming a 4 X 4 cm "T", 17.5 cm in length. The crossbar of the "T" was placed next to the container wall. Experimental design was a complete randomized block with 8 replications.

During the summer of 1979, the containers were grown under polypropylene saran, providing 50% shade. After the first growing season, 4 replications of all species were harvested. Dry weight of shoots and roots, percent root spiraling, and visual rating of degree of root spiraling were determined.

During the fall of 1979, the remaining plants were placed in a fiberglass greenhouse for overwintering. Straw mulch was placed on and around the containers and plants were watered as needed.

During the spring of 1980, plants were moved outside and placed on an unshaded gravel area. After the second growing season, the remaining plants were harvested and dry weight of shoots and roots were made by oven drying at 65 C for 48 hours. Roots were divided into percent primary roots, fibrous roots, and roots other than primary roots which were larger than 0.5 cm in diameter. Primary roots included only the tap root, while fibrous roots included all roots smaller than 0.5 cm in diameter. Root spiraling was determined as (a) percent root spiraling, and (b) visual rating of degree of root spiraling.

Percent root spiraling was calculated as the percentage of the surface of the rootball occupied by roots. Each rootball was divided into 3 strata (Fig. 2a), so that the area of greatest root spiraling could be determined. The area of spiraling roots were determined by measuring the length and diameter of horizontal, exposed roots. These roots were predominately fibrous.

Visual rating for the degree of root spiraling was obtained after washing the media from the rootball and therefore included spiraling within the rootball. The roots that were evaluated as spiraling maintained a horizontal rigid form (Fig. 2b), and were predominantly roots greater in diameter than 0.5 cm. Visual ratings of the bare root system was on a scale of 0 to 10, with 0 = no root spiraling, and 10 = all roots exhibited spiraling. The bare root ball was divided into 3 strata, and the degree of root spiraling was determined for each stratum.

Container inserts decreased percent root spiraling regardless of species (Table 1). Greatest root spiraling was observed on the rootball surface of trees in containers with 0 inserts, while the least root spiraling was noted in containers with 6 and 8 inserts. Percent root spiraling was most prevalent in stratum 3 for both growing seasons. However, when root spiraling did occur in stratum 1 and 2, it was predominantly in containers with 0 and 4 inserts. The percent root spiraling of _Pinus_ and _Quercus_ was generally less than that of _Acer_ and _Eleagnus_. When percent root spiraling did occur in _Pinus_ and _Quercus_, it was concentrated in the bottom portion of the container. Minimal difference in percent root spiraling was noticed between 1 and 2 growing seasons. This indicates that much of the surface root spiraling occurs during the first growing season.

Container inserts had a positive effect on mitigating the degree of root spiraling for both growing seasons (Table 1). Degree of root spiraling decreased with increasing number of container inserts. Very little root spiraling occurred in containers with 6 and 8 inserts. Highest degree of root spiraling occurred in stratum 3. Root spiraling that occurred in stratum 1 and 2 was found mostly in containers with 0 inserts. After one growing season, Acer demonstrated greater degree of root spiraling, while after two growing seasons Eleagnus displayed the greatest degree of root spiraling. Considerable difference in the degree of root spiraling was noted between 1 and 2 growing seasons. This denotes that root spiraling beneath the surface of the rootball will increase over time.

The results from both methods of measuring root spiraling demonstrate that spiraling decreased when container insert number increased (Fig. 3). In containers with no inserts, when a root grew to the side wall, it was obviously deflected and thus grew along the container wall. In containers with inserts, these spiraling roots were intercepted by the inserts and the roots were diverted either downward along the insert or inwards to the center of the rootball. Similiar observations were reported by Dickinson and Whitcomb (3).

Dickinson and Whitcomb (3) stated that root spiraling was greatest in the bottom portion of the container, thus inserts need only be placed in stratum 3. This observation was for Pinus thunbergi, Taxodium distichum, and Quercus palustris grown in 7.5 l containers for 1 year. The present study substantiated that the greatest amount of root spiraling occurred in stratum 3, but root spiraling was observed in other strata. These observations suggest placement of container inserts in the bottom two-thirds of container depth would be beneficial, especially for fast growing species.

Dry weight of roots and shoots for both growing seasons showed no difference between insert treatments (Table 2). Also, after 2 growing seasons, only the percentage dry weight of primary roots were affected by inserts, whereas the root sizes associated with root spiraling were not affected. An increase in the relative amount of primary root was caused by 4 and 8 container inserts. Further growth data in terms of total shoot growth in cm, showed no difference between insert number. The data for plant growth indicates that the addition of container inserts did not adversely affect the plants growth.

Generally, Quercus grew at a slower rate than Acer, Eleagnus, and Pinus (Table 2). This is due to the fact that Quercus is a slow growing species and the other 3 species are medium to fast growing plants.

When considering root growth and root spiraling together, the container inserts did not affect the total root size. However, in containers with inserts, the fibrous roots and the roots greater in diameter than 0.5 cm were relatively short, heavily branched, and tended to grow in towards the middle of the container; whereas when these roots were evaluated in containers without inserts, the roots were much longer, less branched, and remained on or near the surface of the rootball.

The use of container inserts commercially could prove to be beneficial to the nurseryman if used properly. The containers would need to have the inserts spaced 7.5 cm apart, thus the number of inserts per container would depend on the container size. The insert length would need to be equal to the container depth for easy removal of inserts before shipping or sales. The substance used to make the inserts would need to be comparable to plexiglass in characteristics; non-corrosive, non-toxic, and strong enought to resist the force of a root.

As another alternative, a container could be molded, thus preventing the necessary labor cost of placing and removing inserts in the container. The specifications would include: insert spacing at 7.5 cm, insert length two-thirds the depth of the container, and the insert would need to extend into the media 4 cm.

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Table 1. Effects of species, container insert number, and container depth on percent root spiraling and degree of root spiraling for two growing seasons.

	Percent Root Spiraling		Degree of Root Spiraling[z]	
Treatment	1979	1980	1979	1980
Species				
Acer saccharinum	17.71	15.21	0.29	0.85
Eleagnus angustifolia	8.96	7.29	0.15	1.35
Pinus nigra	6.46	4.17	0.00	0.63
Quercus macrocarpa	1.67	4.99	0.13	0.58
Insert number				
0	21.67	22.71	0.40	2.60
4	9.37	7.08	0.15	0.54
6	3.75	1.46	0.02	0.23
8	0.00	0.42	0.00	0.06
Container depth				
Stratum 1	1.09	1.88	0.00	0.25
Stratum 2	7.19	5.94	0.03	0.67
Stratum 3	17.81	15.94	0.39	1.66
LSD 5%				
Species	1.98	2.09	0.18	0.33
Insert number	1.98	2.09	0.18	0.33
Container depth	1.71	1.81	0.15	0.29

[z]Degree of Root Spiraling rating: 0 = no root spiraling, 10 = all roots exibited spiraling.

Table 2. Effects of species and container insert number on the size of roots and shoots for two growing seasons.

	Dry Weight[z]				Root Distribution[y]		
	Shoot		Root		A	B	C
Treatment	1979	1980	1979	1980	1980	1980	1980
Species							
Acer saccharinum	31.04	47.94	27.86	43.51	24.03	17.37	58.77
Eleagnus angustifolia	28.16	58.59	22.84	45.13	21.64	21.72	56.64
Pinus nigra	24.73	87.12	19.52	40.77	24.49	31.67	43.85
Quercus macrocarpa	11.03	19.82	16.87	29.27	24.04	17.37	58.61
Insert number							
0	22.74	58.59	22.39	42.94	21.55	22.62	56.01
4	24.04	51.59	22.46	36.99	25.39	19.89	54.72
6	23.32	52.82	21.46	41.18	21.89	24.49	53.65
8	24.86	50.47	20.79	37.57	25.40	21.13	53.48
LSD 5%							
Species	2.92	10.70	3.14	7.98	n.s.	3.91	5.46
Insert number	n.s.	n.s.	n.s.	n.s.	3.39	n.s.	n.s.

Interactions were not significant.

[z]Dry weight of shoots and roots in grams per 7.5 l containers. Mean of 4 plants.

[y]Root Distribution: A = percent primary roots, B = percent of roots greater than 0.5 cm in diameter, but not including primary roots, and C = fibrous roots.

Figure 1. Container insert construction. A) the placement of container inserts vertically on the inside container wall. B) construction of the plexiglass inserts. Each "T" shaped insert measures 4.0 X 4.0 X 17.5 cm.

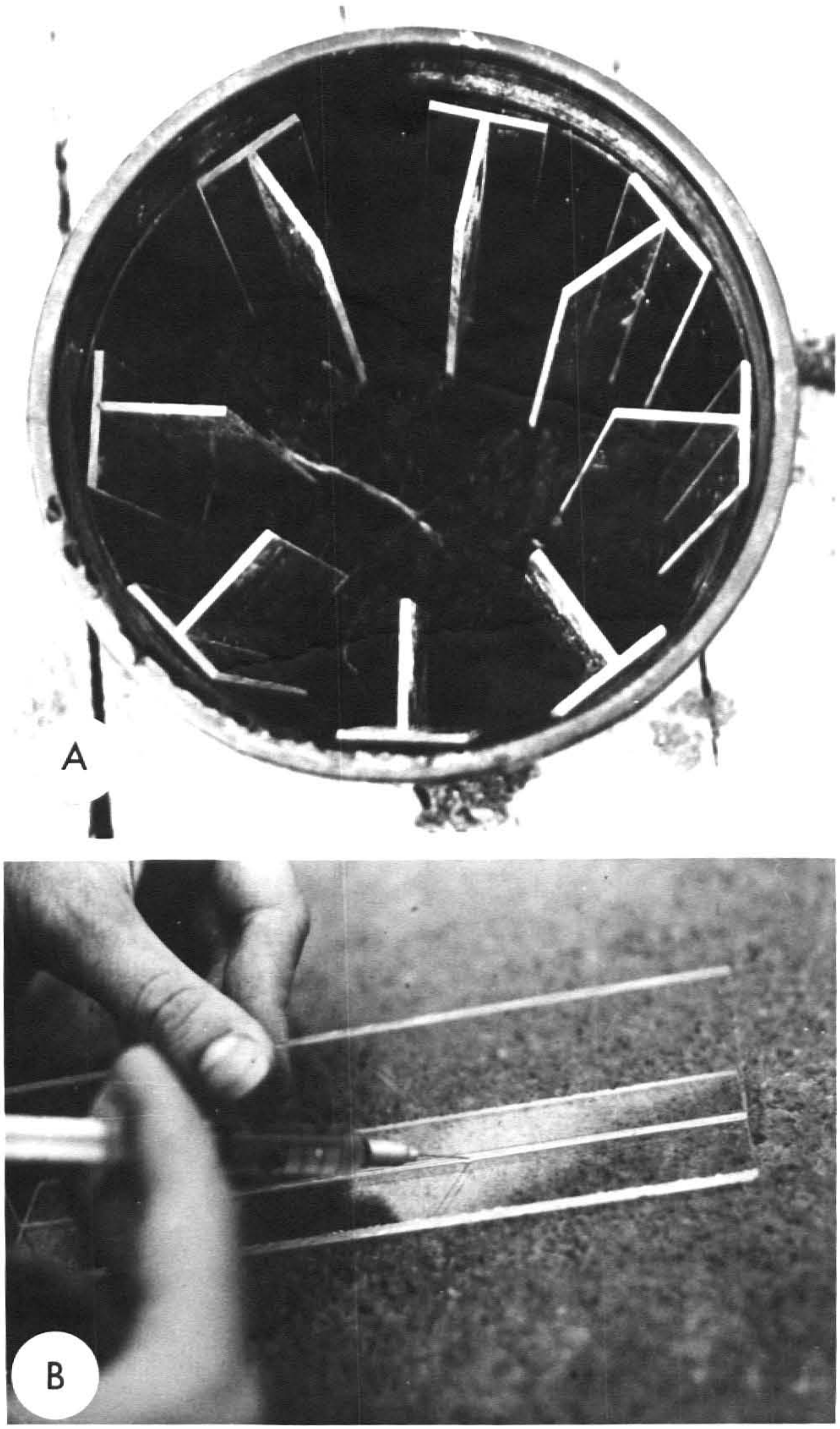

A
B

Figure 2. Strata segmentation for root spiraling. A) each stratum measured 5 cm in height. Stratum 1 begins with the top layer, stratum 2 is the center layer, and stratum 3 is the bottom layer. B) Quercus macrocarpa with no inserts. Example of a root being evaluated for degree of root spiraling. It has maintained a rigid horizontal pattern.

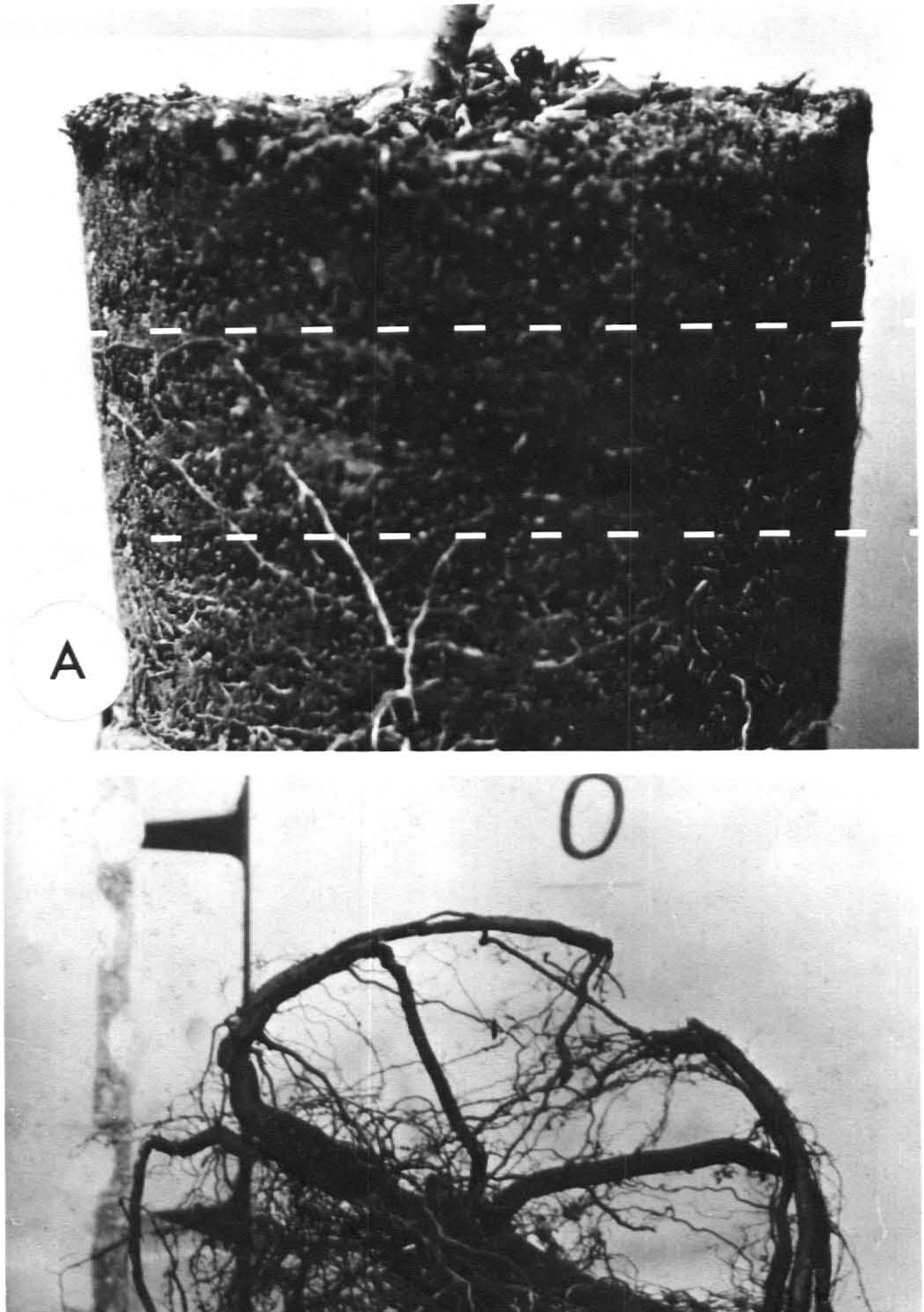
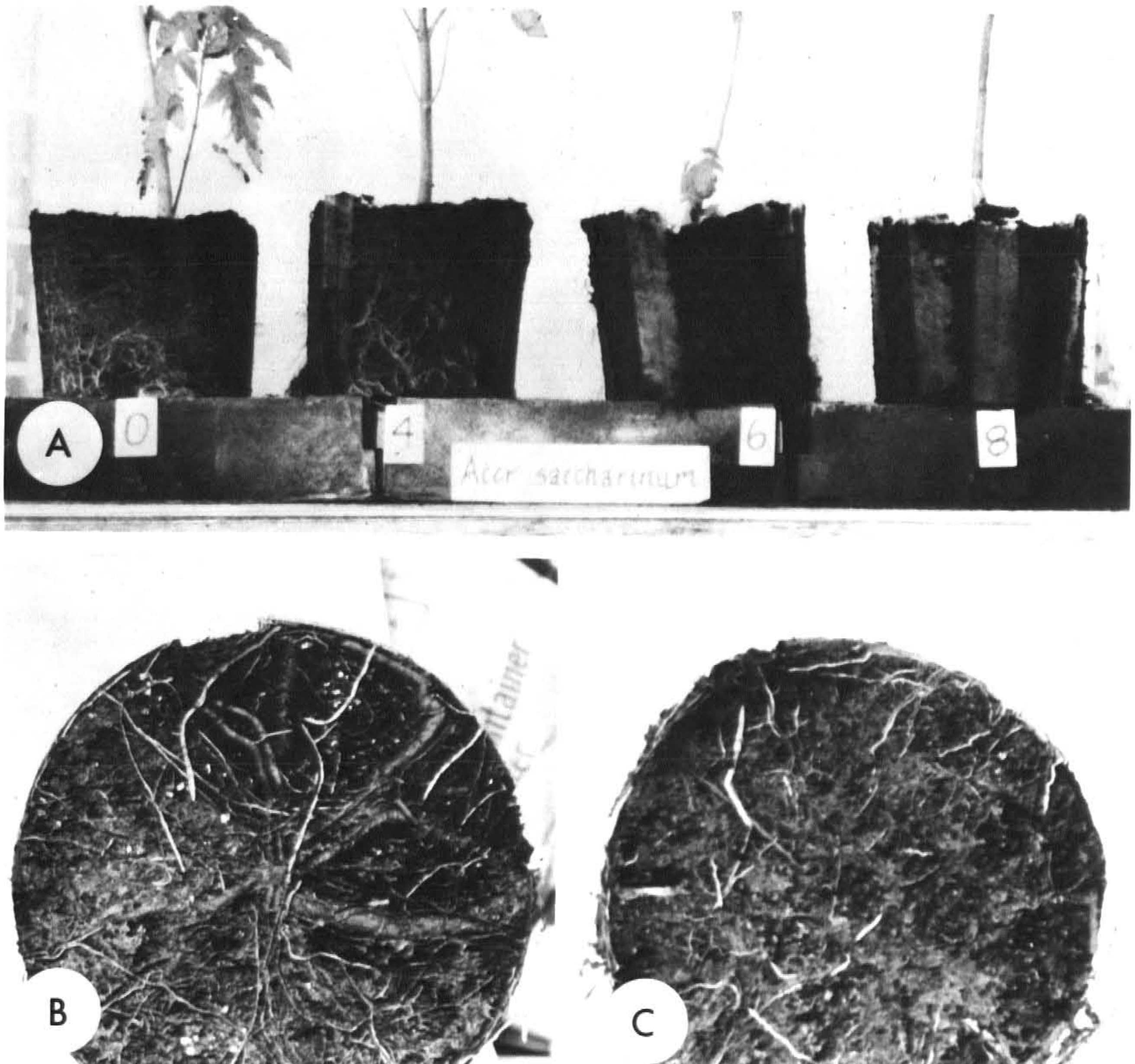

A
0
B
QUERCUS MACROCARPA

Figure 3. Root spiraling in *Acer saccharinum* and *Quercus macrocarpa*. A) percent root spiraling of *A. saccharinum* with 8 inserts showed no spiraling (right), while rootball with no inserts showed extensive spiraling (left). B) and C) root spiraling of *Q. macrocarpa* for no inserts (left), and with 8 inserts (right). Note the large spiraling roots when no inserts are present, and the lack of spiraling roots when 8 inserts were used.


A
0
4
Acer saccharinum
6
8
B
C

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