plants from the *in vitro* environment to the soil environment. With the high production rates in tissue culture we are not concerned about material costs. In a cost study we found that media costs consumed about 9% of total expenditures. We feel that you get a higher percentage of transplants with higher agar.

BRUCE BRIGGS: You mentioned the use of GA. Have you noticed any slowing up in rooting of your plants, as we have found with woody material?

MARK ZILIS: We have found that it increased axillary bud break in asters but have not noticed any significant root inhibition.

ROOT AND SHOOT GROWTH RATE RELATIONSHIPS OF TWO JAPANESE HOLLY CULTIVARS DURING PROPAGATION

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Abstract. Cuttings of *Ilex crenata* Thumb. 'Helleri' and 'Rotundifolia' were rooted and grown in polyvinyl chloride pipe sections from which longitudinal sections could be removed for root observations. Plants were fertilized at either 150 or 300 ppm N with a 20N-8.7P-16.5K soluble fertilizer. Rate of root and shoot growth was determined through 2 to 3 flushes of growth following rooting by taking weekly measurements of shoots and roots. Root growth of both cultivars usually preceded a shoot growth flush by 1 to 2 weeks. This growth pattern was observed at both fertility levels.

The propagation of woody nursery plants in small containers is widely practiced in the nursery industry. Following rooting the plants are fertilized and grown in these containers until they are large enough to transplant to the field or larger containers. A well balanced root and shoot system is necessary if these plants are to survive transplanting shock. Gilliam and Wright (3) demonstrated that fertilizer treatments of rooted cuttings which encourage top growth may limit root growth. This indicates that some control over root and shoot growth is possible. Before control can begin, however, some knowledge of root and shoot growth patterns during and following rooting are required.

This study was made to determine the pattern of root and shoot growth during and following rooting of *Ilex crenata* 'Helleri' and 'Rotundifolia' grown at two fertilizer levels following rooting.

MATERIALS AND METHODS

Experiment 1. Single-stem 'Helleri' cuttings, 7 cm long, were taken Feb. 8, 1977, and placed in metal flats containing a medium composed (by vol) of 2 peat: 2 perlite: 1 Weblite (Webster Brick Company, Roanoke, VA 24012). Cuttings were rooted under intermittent mist (10 sec/10 min) and subsequently grown in a greenhouse at 28°C (82°F) (day)/21° (70°F) (night) under natural photoperiod until Sept. 30, when longday conditions were maintained with incandescent light at about 162 lux from 11 pm until 2 am. After 4 weeks in the propagation bench, when roots became visible, 50 uniform rooted cuttings were transplanted into polyvinyl chloride (PVC) pipe sections, 3.8 cm diam × 30.5 cm long, containing the above medium.

For viewing and measuring root systems, a longitudinal section was cut from one side of each pipe (Figure 1) according to Murdoch (5). The section was secured in place with masking tape and a rolled sheet of transparent acetate plastic was inserted to cover the inside of each pipe. A piece of nylon shade cloth was wired to the bottom of each pipe to retain the growing medium. Pipe sections with transplanted cuttings were then placed at a 56° angle against a shelf with the window side down.

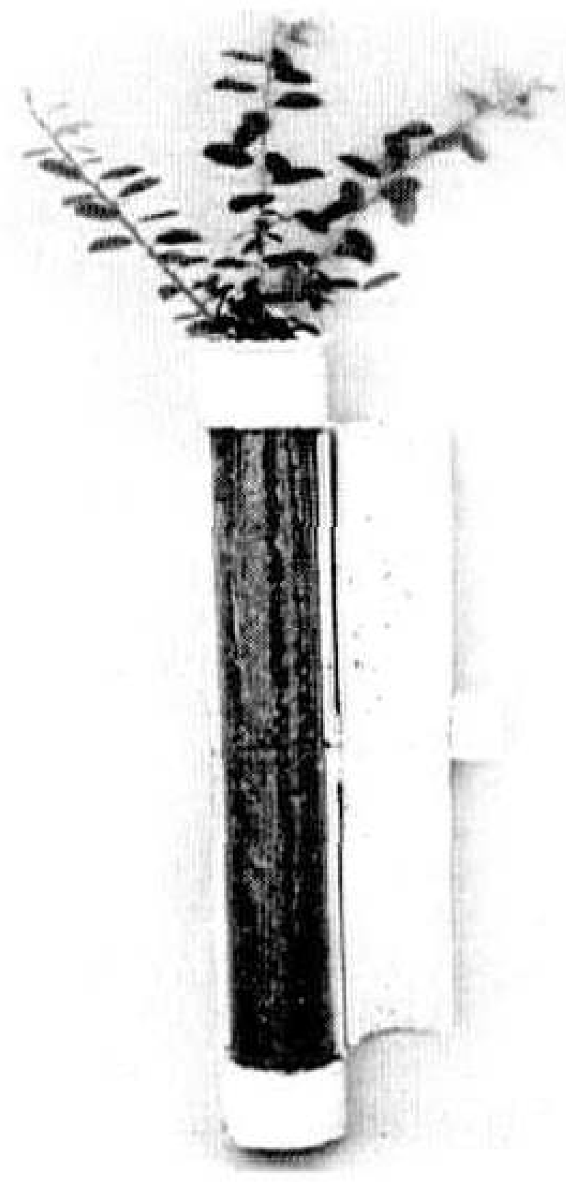

Figure 1. System used for measuring root and shoot growth during rooting and growth of 'Helleri' and 'Rotundifolia' holly.

Twenty ml of 20N-8.7P-16.5K soluble fertilizer was applied weekly at levels of 150 or 300 ppm N. Micronutrients were applied once with a Hoagland and Arnon (4) micronutrient solution in which 5 ppm of iron was supplied in the form of NaFeEDTA. A randomized block design with 5 plants per treatment in each of the 5 replicates was used.

On April 24, 3 shoots and 3 roots per plant were selected for weekly measurements until Dec. 13. Growth occurring between measurements was determined, divided by the number of days in the period, and plotted as growth rate ($-$cm day^{-1}).

Soluble salt levels were determined for 5 tubes (1 from each replicate) on Oct. 5 and showed low readings indicating low fertility in tubes. Fertilization was changed on Oct. 14 by placing the tubes in a tub containing the fertilizer solution.

Experiment 1 was repeated from Sept. 18, 1977 to Feb. 2, 1978, except that cuttings were rooted directly in the pipe sections.

Experiment 2. Single stem 'Rotundifolia' holly cuttings, 7 cm long, were propagated, grown, and measured as in Experiment 1 with the following exceptions: (1) cuttings were rooted directly in the pipe sections under intermittent mist to prevent transplant shock; (2) fertilizer treatments were begun July 26, 1977; (3) a randomized block design with 5 plants per treatment in each of the 4 replicates was used; (4) measurements were taken weekly from July 28, 197 to Dec. 27, 1977.

RESULTS AND DISCUSSION

Root growth of both cultivars of Japanese holly in all experiments was episodic with each root flush usually preceding a shoot flush by 1 to 2 weeks (Figure 2 and 3). Growth patterns for 'Rotundifolia' holly (Experiment 2) were identical to 'Helleri' holly and therefore are not shown. Episodic responses were observed at both fertility levels in each of the 2 experiments and the rate of root growth for each experiment and cultivar was shown to be greater at 300 ppm N than at 150 ppm, although not significantly at the 5% level (data not shown).

Exceptions to the chronological order of root growth to shoot growth occurred in Experiment 1 and 2. Following the 2nd root and shoot growth flush in Experiment 1, there was a period of 2 to 3 months in which no shoot growth occurred (Figure 2). Root growth, however, continued throughout this period of inactive shoot growth. After bottom fertilization was begun on Oct. 14, shoot growth began again within 3 weeks with a concurrent decrease in root growth.

Data from the repeat of Experiment 1 (Figure 3) shows the normal patterns of shoot growth for 'Helleri' holly grown under adequate nutritional programs following rooting. This experiment presents a clear picture of the chronological relationship of root to shoot growth.

A period of active root growth preceded each shoot flush of 'Helleri' and 'Rotundifolia' holly. The above results may be explained in the following manner. Nitrogen absorbed by plant roots tends to react first with carbohydrates in the roots (1,6). As the root system develops to the extent that it can absorb higher levels of fertilizer, nutrients in excess of what is needed

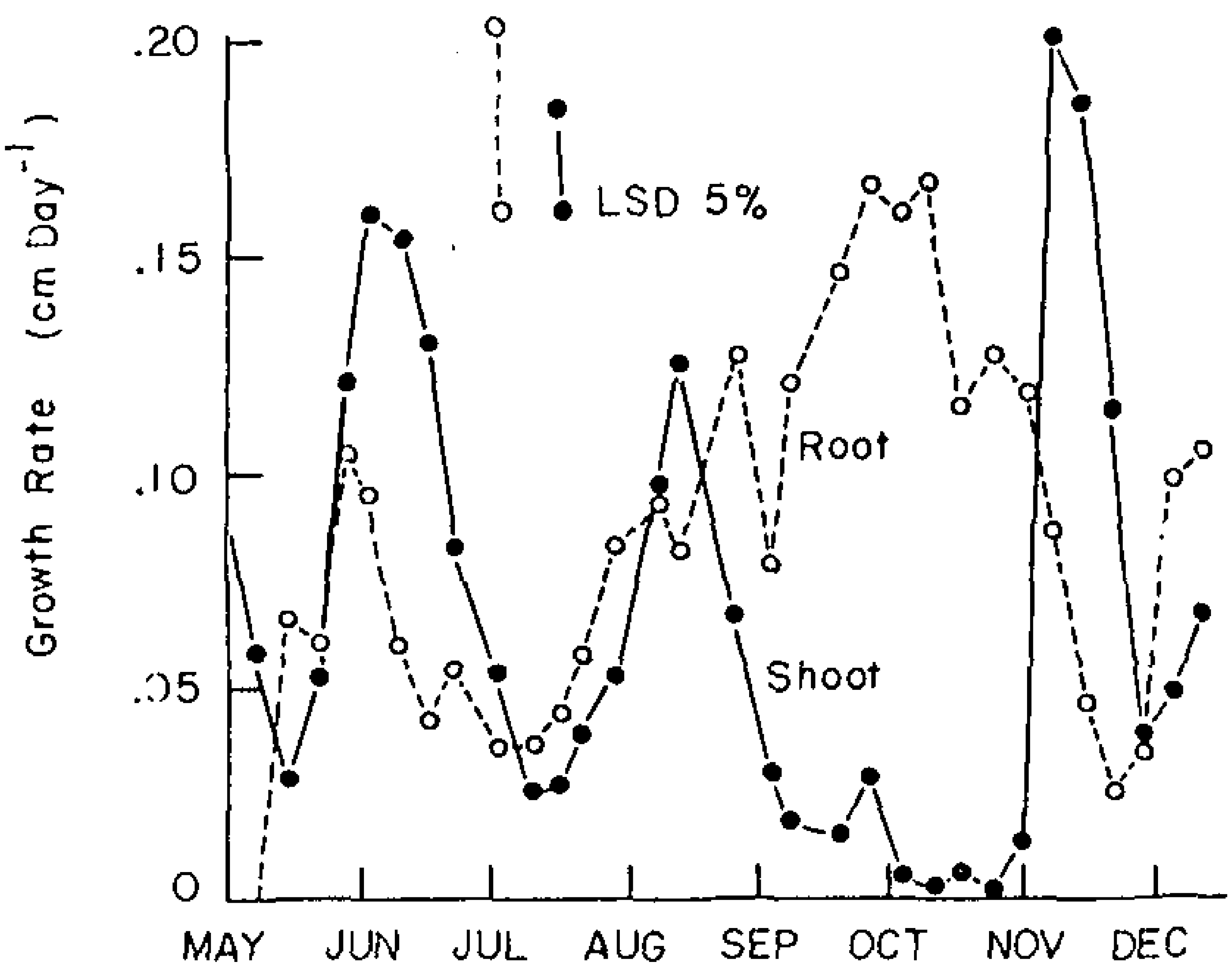

Figure 2. Root and shoot growth rates of 'Helleri' holly grown at 300 ppm N applied as 20N-8.7P-16.5K soluble fertilizer.

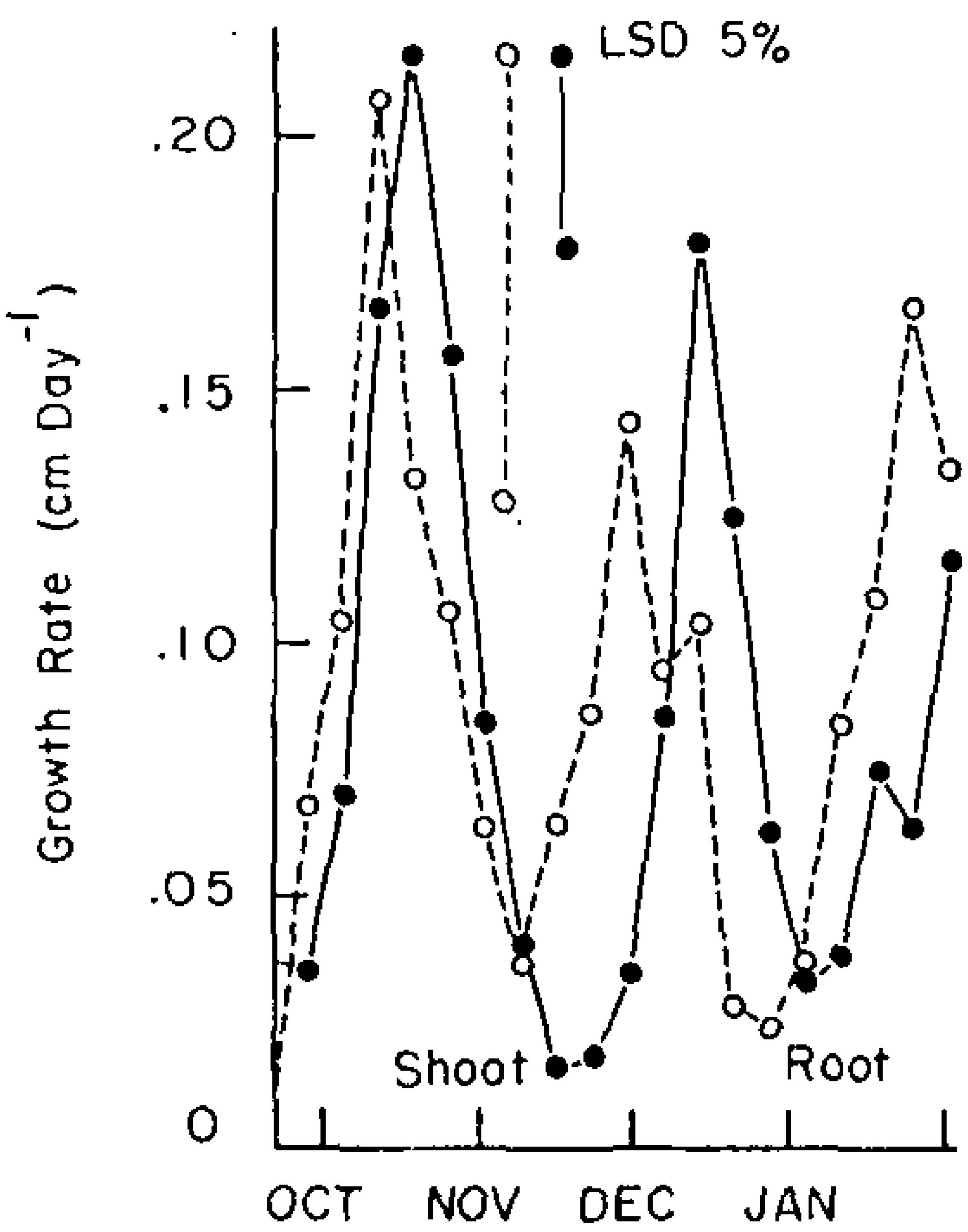

Figure 3. Root and shoot growth rates of 'Helleri' holly grown at 150 ppm N applied as 20N-8.7P-16.5K soluble fertilizer.

for root growth are translocated to the plant tops where they are used in conjunction with carbohydrates for protein synthesis and shoot growth. Consequently, less carbohydrates remain for translocation to the roots, and root growth is then limited relative to the shoot growth. Since root growth, and hence nutrient absorption is at a low level, new shoot growth eventually depletes the nutrients level within the plant, and growth of the plant top ceases. Carbohydrates become available again for translocation to the roots, root growth and nutrient absorption begins again, and the cycle repeats itself. In agreement with this theory, Gilliam and Wright's data (2) show with 'Helleri' holly that the tissue nitrogen concentration of the plant top is at its highest level when shoot growth begins and at its lowest level when shoot growth ceases.

Periods of active root growth preceding successive top flushes would explain further results obtained by Gilliam and Wright (3) who found fertilizer to be more efficiently used by 'Helleri' holly when applied during a period following the cessation of shoot elongation and preceding the next flush of shoot growth.

A nutritional correlation between periods of root and shoot growth as described above would also explain the 2 to 3 month periods in Experiment 1 in which no shoot growth occurred (Figure 2). The 20 ml of fertilizer solution applied to each plant at the soil surface was insufficient to penetrate to the lower portions of the containers where root growth was most active. The low fertilizer level was adequate for root growth which continued until fertilizer levels were increased by bottom fertilization. When higher fertilizer levels reached the roots in the lower portions of the tubes, root growth decreased and shoot growth increased. This implies that if more root growth is desired on small liners, then relatively low fertilizer rates are required.

A question that this study introduces is the proper time to transplant rooted liners to the field. If plants were transplanted following a shoot flush then a period of root growth would quickly follow establishing the plant in the field or container in respect to water and nutrient uptake. If plants were transplanted following a root flush and just before a shoot flush then considerable stress would be placed on the plant by the increased top development with no concurrent root growth.

With this knowledge, and if similar trends are recorded for other container-grown woody plants, nurserymen should be able to positively manipulate both root and shoot growth by timing fertilizer applications and varying the rate of fertilizer applied.

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Friday Morning, December 14, 1979
NEW PLANT FORUM
Jack Alexander and Michael A. Dirr, Moderators

MODERATOR DIRR: Our first speaker on this portion will be Dr. Sidney Waxman who has three plants he would like to discuss.

SIDNEY WAXMAN: *Pinus strobus* 'Yu Coon' is a dense fast growing shrub or small tree grown from seed obtained from a witches' broom. Unlike normal white pines, it retains the lower branches. Its dense branching develops naturally without pruning. The dimensions of this plant, after having been grown for 15 years, are 10½ feet tall and 7 feet broad.

Larix × *eurolepsis* (unnamed cultivar) is a weeping, spreading tree. Its most interesting characteristic is that the major branches tend to grow horizontally and undulate, while the secondary branches weep. Its winter character is also of interest.

Sciadopitys verticillata (unnamed cultivar) has several characteristics that make it desirable. The foliage is deep green. The needles do not bronze in the winter but retain their green color and become glossy. Also this particular tree was selected from among many others because of its ability to root easily. Cuttings taken during the past 10 years have rooted consistently with high percentages.

MODERATOR DIRR: Elwin Orton has one plant to present.

ELWIN ORTON: *Pyracantha coccinea* 'Rutgers' is the result of a cross 14 years earlier. We have had it under test that long and I believe that it will be a replacement for the cultivar 'Lowboy'. In contrast to 'Lowboy', which is extremely susceptible to scab, 'Rutgers' has been absolutely free of scab and fireblight for 14 years.

MODERATOR DIRR: Edmund Mezitt has two *rhododendron* plants he would like to present.

ED MEZITT: The first rhododendron is *R.* 'Weston's Pink