Methods A, B, and C each require bending, stooping or possible kneeling. These movements are not only fatiguing but might also be considered as non-productive efforts since they are only ancillary to the process of cane severing. Method D was tested to determine if, by reduction of these ancillary efforts, the overall task of cane cutting could be made easier without sacrificing productivity. The raisin grape spreading machine (normally used in conjunction with the mechanical harvester) was modified to serve as a power unit, as shown in the photo. Solenoid-operated hydraulic valves were used to control the rotation of hydraulic motors, each of which was coupled to a cable take-up drum.

Sleds

A flat bottomed sled with a pedestal-mounted seat was attached by means of a cable to each drum. A crew member rode facing the vine from a seated position on each sled, and each man was provided an electrical switch which premitted him to independently energize the drive motor to which the cable take-up drum was coupled. The power unit moved along between the rows at a constant speed of 22 ft per minute (.25 mph). Sled motion was initiated when the worker activated his electrical switch. When the sled was drawn to the proper position adjacent to the vine trunk, the switch was opened, the sled stopped and it remained stationary while the canes were found and cut.

In the meantime, the open center directional hydraulic control valve allowed the cable to unwind from the drum as the power unit continued its advance along the row. A cable length of 11 ft permitted a maximum stationary time for the sled of 30 seconds, the additional time being needed under occasional adverse cane cutting conditions due to dense foliage or improper cane position. Normally, the worker spent about 16 seconds in a stationary position, and drum speed was designed so that sled movement from vine to vine could be achieved in three seconds. On the average, total cycle time was 19 seconds per vine.

Method B can be adopted without any capital investment. Method C requires the use of a pneumatic pruning machine. These are commercially available and can easily accommodate the necessary crew size for cane cutting. However, the labor savings which can be realized with method C are not sufficient to justify the capital investment in a pneumatic pruner when cane cutting is the only use made of the machine. Growers who already own these machines or who may be contemplating purchase for vine pruning in the winter can use them to serve a dual purpose, thereby reducing their labor costs.

Individual cane cutter

A higher productivity of the individual cane cutter was demonstrated with method D than with any other method tested. The cane wire was within easy reach and at about shoulder height for the worker in his seated position, and all bending and kneeling motions were eliminated. However, this method required an additional crew member to serve as operator for the towing unit. Thus, the overall productivity of this three man crew was .25 acres per man hour, which was lower than for the two man crew using method C. In order to make method D comparable with method C, the productivity of each cane cutter on the sleds would have to be .45 acres per man hour, an increase of 21 percent. The design of the equipment could be improved to further the productivity of the workers. However, even if such a high level of productivity was attained, the crew size required would still be the same as for method C. Therefore, overall crew productivity and size required with the sled concept would, at best, be no different than for method C. Consequently, the additional capital investment required to adopt the sled concept cannot be justified.

Canes-not-cut were less than 5%, and acceptable from the standpoint of harvesting for each of the four methods studied. The average number of wire cuts per row was also quite low, especially considering that the shears were activated more than 900 times per row. However, any cutting of the trellis wire is undesirable since the severed wire sags to the ground and the fruit can not be detached by the harvester. In some cases, this may result in the complete loss of the fruit on two full adjacent spans. In addition, the cost of trellis maintenance is increased. The use of a high tensile strength cane wire may provide a practical solution to this problem, since this wire offers high resistance to cutting.

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NURSERY SPA

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Increasing the spacing of container-grown trees increased trunk caliper and taper, but growth in height was less than those spaced can-to-can. At the closest spacings, the lower foliage was sparse, giving the trees a leggy appearance. Adequate spacing (about twice the can-to-can area) gave benefits of increased trunk caliper and taper, and fuller foliage with a minimum sacrifice in height.

SPACING AND ARRANGEMENT of containers in nursery production commonly uses the least area consistent with ease of providing adequate care. Plants in gallon cans usually are placed can-to-can in beds of several hundred containers. Larger containers usually are closely spaced in 2- or 4-can rows with narrow aisles between.

Tree height and caliper growth of nursery-grown trees largely determines their monetary value and how well they will be able to stand upright in the landscape. Earlier observations of the lack of response to pruning treatments of close-spaced, container-grown trees raised the question of the influence of spacing on trunk development of young trees.

This study was carried out at Oki Nursery in Sacramento and at the Saratoga Horticultural Foundation. Seedlings of *Betula verrucosa* Ehrh., European white birch; *Dodonaea viscosa* 'Purpurea' Jacq., purple leaved dodonaea; *Eucalyptus sideroxylon* A. Cunn., eucalyptus or mulga ironbark; and *Liquidambar styraciflua* L., Liquidambar or sweetgum, planted in gallon cans were placed during late June and early July, 1967 in blocks having spacings of 7, 10, and 14 inches on center. These spacings gave surface areas per plant of about 50, 100, and 200 square inches (300, 600, 1200 cm^2), or area relationships of about 1 (can-to-can spacing), 2, and 4. The growing media were modifications of "U.C. Type" mixes containing sand, organic matter, etc. Six plants were replicated three times at each spacing with each replicate surrounded by guard plants at the appropriate spacing.

CING CONTAINER-GROWN TREES

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In December 1967, the plants were moved into 4-gal (egg) cans at Sacramento and into 5-gal cans at Saratoga (both will be referred to as 5-gal cans). The spacings were increased to 10, 17, and 24 inches on center. These spacings gave areas of about 100, 300, and 600 square inches (600, 1800, 3600 cm^2).

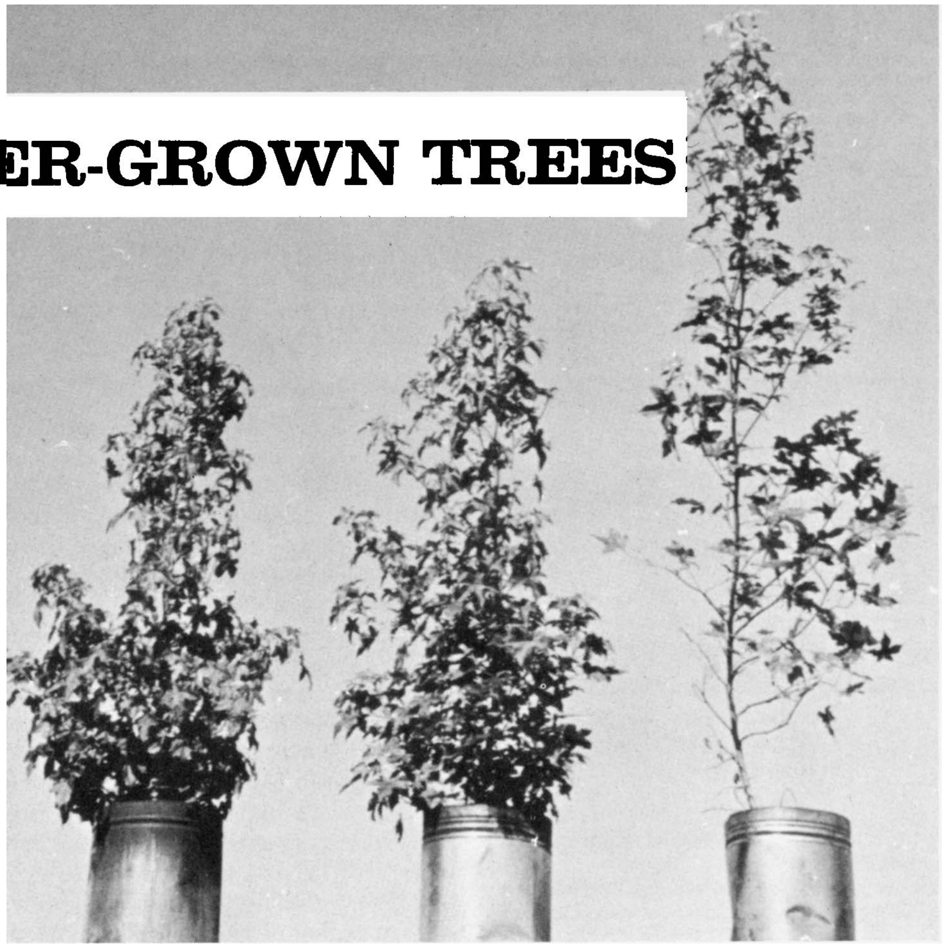
During the two growing seasons, the lateral branches along the trunks were pinched several times, beginning when their tips were 2 to 3 inches beyond the edge of the cans. Except for the lateral pinching and the elimination of staking, the plants received regular nursery care.

The birch and eucalyptus trees were ready for sale or moving to larger containers at both locations in late June 1968 and were removed from the experiments. The dodonaea and liquidambar at Sacramento were removed in early July, while those at Saratoga remained in the experiment until the end of 1968.

Height and trunk area growth was 15 to 20% greater at Sacramento than at Saratoga for the four species at the widest spacings. These differences probably were due to the higher rates of fertilization and warmer, sunny spring weather at Sacramento. The species responded similarly to the spacing treatments at the two locations. Liquidambar was the only exception as noted later.

As spacing increased, trunk caliper and taper (decrease in caliper with height) increased and plant appearance improved, but increases in height were less, (see graph 1 and photo). At the closest spacing, the lower foliage was heavily shaded and much of it dropped. The closest-spaced trees were not as attractive as those given more space (photo).

Increasing the area per plant had less effect on the height of the trees the first season in the gallon cans than it did the second year when the trees were in 5-gal cans. However, trunk area was increased on the average 30% both years when the can-to-can area per plant was increased to the intermediate spacing. Since taper is a height-caliper relation, it was more greatly influenced during the 5-gal stage than during the 1-gal stage.



Influence of spacing on liquidambar at Sacramento, left to right: 600, 300, and 100 square inches per plant, 1968.

The effect on height and trunk-area growth and taper was greater between the intermediate versus can-to-can spacing than the effect between the maximum and the intermediate spacing, graph 1.

Of the four species, liquidambar was most affected in height growth and taper by increasing the area per plant. Eucalyptus and dodonaea were most affected in trunk-area growth. In the 5-gal can, taper of dodonaea also was markedly increased as the area per plant increased.

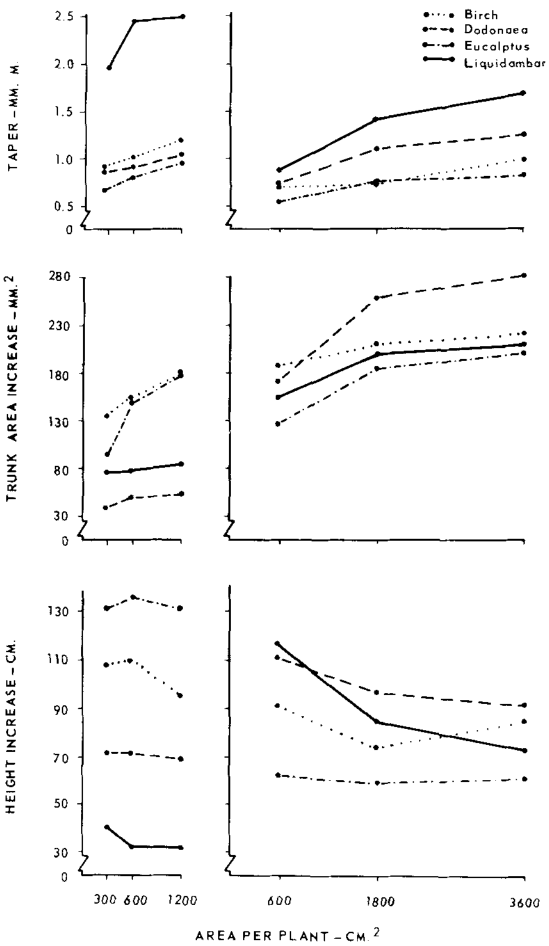
Internode length of the 1-gal-size plants was little affected by spacing. With 5-gal-can plants, internode length of birch, dodonaea, and eucalyptus was increased at the closest spacing, though not significantly. The closest-spaced liquidambar plants, however, formed significantly more nodes and had longer internodes (graph 2).

At Saratoga, the internodes of the closest-spaced liquidambars began to be longer than those of plants with greater spacing after 6 nodes had been formed in 11 cm (4 inches) of new growth (total tree height of 27 inches), graph 2. The intermediate spacing began to have an evident effect on internode length after 8 nodes had formed in 16 cm (6 inches) of new growth (total height of 27 inches). At Sacramento, differences in internodal length of the closest-spaced liquidambars were not evident until 14 nodes had formed in a total of 56 cm (22 inches) of new growth (total tree height of 41 inches). Little or no difference in internode length occurred between plants at the intermediate and the greatest spacings at Sacramento.

The Sacramento-grown liquidambar produced a greater number of leaves and made more height and trunk caliper growth by July 9, when the trees were withdrawn from the experiment, than did those at Saratoga during the entire 1968 growing season. By July 9 at Sacramento, however, the growth rate had declined to 40% of its maximum, with a reduction in differences between the internodal length of trees at different spacings, graph 2.

At Saratoga, length of newly formed internodes remained fairly uniform throughout the summer, although shorter than at Sacramento. The initially higher rate of growth at Sacramento was probably the result of higher rates of fertilization, higher light flux and warmer spring weather.

GRAPH 1. INFLUENCE OF SPACING ON TRUNK-AREA AND HEIGHT INCREASES, AND THE TAPER OF 4 SPECIES OF TREES IN 1-GAL (1967) AND 5-GAL (1968) CONTAINERS AT SACRAMENTO AND SARATOGA



The decline in growth rate may have been due to an interaction between water stress brought on by the large leaf area per plant, an increasingly restrictive root system, and the hot, dry summer weather. On the other hand, Saratoga is subject to morning overcast and cooler temperatures during the spring and summer. This and lower nutritional levels at Saratoga could account for the differences observed between the two locations.

Although these experiments demonstrated the influence of spacing on tree growth, they did not reveal which of the probable causes might be responsible. Maximum rates of height growth of many plants are attained at light intensities considerably below that of full summer sunlight. If reduced light intensity were a factor, then the stimulus must come from the lower portion of the plant, since the region of stem elongation of the plants, particularly of liquidambar, was equally exposed to light regardless of the spacing. Experiments here to determine growth effects of light on low foliage have been inconclusive.

Transpiration also may affect stem elongation, depending on plant spacing. Transpiration of plants at the greater spacings may be increased due to greater exposure to radiation, greater air movement, and more leaves than in closely spaced plants. Water deficits may be more frequent and severe on plants at greater spacings. Shoot growth of such plants would be reduced.

Trunk motion

Reduced movement of the region of shoot development and elongation may be responsible for the greater height growth of closely-spaced trees. Staked trees, which are less free to move, grow taller than unstaked trees. Node production and internode length of liquidambar have been markedly decreased by brief periods of motion. Trunk motion as influenced by tree spacing could account for the differences observed at each location. This may seem only of academic interest, but it may offer some interesting possibilities in nursery production. One problem is that seedlings often are left in the seed flat and first liner pot so long that their trunks become tall and spindly. A short period of motion either by moving the flat or using air might result in sturdier plants more tolerant to transplanting. Such studies are now under way.

Further experiments are needed to determine the mechanism responsible for greater stem elongation of closely-spaced trees.

Increased trunk caliper

Adequate spacing the first season gave benefits in the form of increased trunk caliper with a minimum sacrifice in height. Spacing greater than the intermediate area (100 square inches for gallon cans, 300 square inches for 5-gal cans) was of little benefit. A slightly closer spacing than the intermediate might give adequate plant development with more economical use of space. In these experiments, the containers were in a square arrangement. For practical nursery operations, however, the plants might be better arranged in double rows (preferably in a north-south direction) with greater spacing between than within rows. The spacings used by some nurseries approximate the intermediate spacings of these experiments.

Equally as important as spacing, would be moving the plants to larger containers at greater spacing before the plants reach a size that would begin to adversely affect their development. Internode length at Saratoga was influenced between each of the three spacings but only between the intermediate and closest spacings at Sacramento. Therefore, it seems that trees in the interior valleys could be spaced closer than those grown in the coastal valleys.

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Assistance, plants and use of facilities were provided by Oki Nursery, Sacramento; and the Saratoga Horticultural Foundation, Saratoga, California.

GRAPH 2. INFLUENCE OF SPACING ON INTERNODE LENGTH AND NUMBER ON LIQUIDAMBAR AT SACRAMENTO AND SARATOGA, 1968