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MODERATOR CLARKE: We will now hear a review by Dr. Robert Ticknor, of the North Willamette Experiment Station, Aurora, Oregon of work that has been done on the rooting of pine cuttings. Bob.

REVIEW OF THE ROOTING OF PINES

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Propagation of pines by cuttings has received comparatively little attention from horticulturists until recently (13, 19,22) but has been the subject of intensive investigation by foresters at least as far back as 1934 (1). Most of the results reported in this review have been reported since O'Rourke's (19) article in the 1961 Proceedings. Much of the work has been done in non-English speaking countries so that I have had to depend on *Forestry Abstracts* for most of the results reported in this review. Each of the many factors which influence rooting will be discussed separately.

Tree age. Tree age is probably the most important factor in rooting pine cuttings. Watanabe (26) reported 4, 17 and 30 year *Pinus densiflora* rooted 62, 42 and 30% respectively. Kummerow (10), reporting on rooting needle bundle cuttings of *P. radiata,* found average rooting percentages for 1-3 year trees as 24.7%, for 7-9 year trees as 19.5%, and for 28 year trees as none. An even earlier loss of juvenile rooting ability was reported in *P. thunbergiana* by Ogasawara (16) where cuttings from trees 1, 2, 3, 6 and 10 years old rooted 40, 16, 2, 0 and 0%, respectively.

A possible explanation for this observed decrease in rooting with tree age is contained in reports on content of indoleacetic acid (IAA) and growth inhibitors in pine trees. Yim (31) studied the growth substances in the terminal buds of *P. rigida* 1, 10, and 17 years old. Concentrations of IAA were highest in 1 year and very low in 17 year trees. In 10-year trees, IAA was highest in the buds in the lowest third of the crown. Better rooting of cuttings from the lower third of the crown has often been reported (19). Ogasawara (15) found similar results with 1, 2, 8 and 15 year *P. densiflora.* In addition, he found the content of growth inhibitors tended to in-

crease with age. Ooyama (17) also found growth inhibitors in *P. densiflora* but suggested that shading with blue, green or red cellophane reduced the amount of inhibitor present. Cuttings from 3-year plants rooted 85% under blue cellophane, 55% under green, 35% under red and 20% under clear cellophane.

Some rejuvenation appears possible as Ooyama (17) reported that cuttings from 5-year cutting-grown trees rooted better than the cuttings from the original 11 year trees. Patton and Riker (20 reported that cuttings of *P. strobus* from trees originating as cuttings were consistently superior in rooting ability to those originating from seedlings until the parents were 9 years old. Cameron (1) reported that hedged trees remain physiologically juvenile in that cuttings taken from these root more readily than cuttings from unhedged trees of the same age.

Time to take cuttings. Apparently there are two time periods in which rooting is most successful — November-January (2, 21) and in spring as the new growth matures (13, 22). Roberts and Moeller (22) reported one group of 13 clones of *P. mugo mughus* taken June 8 rooted 50-100% with an average of 78%, while a group of 15 clones taken June 28 rooted 0-100% with an average of 32%.

Cutting length. Short cuttings 4-5 cm have been reported as a factor in successful propagation (30); others feel cutting length is not a factor (29). Very short cuttings, 0.5 cm below the buds, have been used by some Japanese investigators (8, 9, 28).

Needle bundle cuttings, which are composed of the needles surrounding a bud and a small section of stem tissue, have been investigated by several workers (6, 10, 27). Although this technique promises the rapid increase of elite clones, in practice, rooting percentages have been low and much difficulty has been experienced in getting the buds to grow. Ishikawa and Kusaka (7) reported that the removal of the new growth leaders in the spring caused the development of the dormant buds which were used as cuttings the following winter and produced strong shoots. Kummerow and Schmidt (11) suggest the use of cytokinins to develop the buds of needle bundles.

Rooting hormones. McGuire and Sorenson (13) and Roberts and Moeller (22), working with June cuttings of Mugo pine, reported no advantage to the use of rooting hormones. Working with Mugo pine in December, I found Jiffy Grow #2, diluted 1:10, was beneficial but stronger strengths caused excessive callusing and decreased rooting (25). Other workers (12, 23) have reported rooting hormones, generallly IBA, beneficial in degree as well as percentage of rooting. Ooyama and Toyoshima (18) state IBA increased rooting percentage, if some of the untreated checks rooted, but not otherwise. Reines and Bamping (21) reported Rootone better than Hormodin in rooting slash and loblolly pines.

Fungicide treatments. A Spanish report (2) indicated response to 40:60 fungicide-talc mixtures when applied to needle bundles of *P. elliotti.* These fungicides—Maneb, Nabam and Ferbam — induced 60, 40 and 15% root formation, respectively. Grigsby (5) reported on the use of 25% Captan plus 0.8% IBA in rooting of loblolly pine which gave more rooted cuttings with more, stronger, and better distributed roots per cutting than did IBA alone. Doran (3) also reported benefits in using Captan with IBA in the propagation of *P. strobus.*

Rooting media. In the Orient, soil seems to be the favorite propagating medium. A red subsoil was used by several investigators (8, 28, 30). Nagano (14) tried 10 different media for the propagation of cuttings taken from 2-year *P. thunbergiana* seedlings. Rooting percentage was best in black volcanic soil, followed by loam, loam with sand, and vermiculite. The number of adventitious roots was greatest in pumice dust followed by "Kamuma" soil, black volcanic soil and loam. Root length was greatest in sand, followed by vermiculite with sand, black volcanic soil and loam with sand. Ishikawa and Oohasi (9) reported quartz sand the best media, red soil poorest and vermiculite intermediate. Patton and Riker (20) reported sand was better than a mixure of sand and peat.

Media temperature. Grigsby (5) reported his highest soil temperature (78°F.) gave the highest percentage rooting (40%) of 6-year loblolly pine. Ooyama and Toyoshima (18) reported that *P. densiflora* and *P. thunbergiana* rooted best in unheated beds, while *P. massoniana* rooted best in a heated bed. Watanabe, *et al* (26) working with 4, 17 and 30 year *P. densiflora* reported that with soil heating the rate of development of roots from young trees was faster but old trees tended not to root. Increased rooting with bottom heat in a "good" rooting year but decreased rooting in a "poor" year was reported by Patton and Riker (20).

Mist propagation. Although mist propagation has been widely used in the propagation of pines, research reports comparing mist vs. no mist are lacking. One report by Watanabe, *et al* (26) compared the number of days from 20 to 150 that mist was applied to *P. densiflora.* The longest period produced a slight increase in rooting, but they felt that best root growth resulted from 20 to 50 days of misting.

Other practices. Enright (4) found cuttings from 3-year *P. resinosa* and *P. strobus* rooted more quickly and in a higher percentage when taken from heavily fertilized plants than from the unfertilized plants. Libby (12) suggested that cold storage of the cuttings at 38° F. for 20 to 50 days could be beneficial.

Thulin and Faulds (24) report a modified air layering technique helpful in rooting *P. radiata,* and states that, "Vigorous shoots were ringbarked about 6″ below their terminal bud and a ½″ wide section of bark, phloem and cambium was removed. The girdled area was covered with aluminum foil

as a protection against drying. Well-developed callus formed at the base of the girdled shoots in 4 to 6 weeks, after which the shoots were cut from the tree and set as cuttings."

Table I. Reported rooting results with various pine species.

Species	Tree Age	Rooting Hormone	Rooting Percentage	Comment	Ref. No.
P. armandii	14		10		26
P. ayacahuite	14		20		26
P. banksiana	13		2.5		26
P. contorta	8	Jiffy Grow, 1:10	40	March	25
P. contorta	8	Jiffy Grow, 1:10	10	March	25
P. densiflora	17		2.5		26
P. densiflora	4		62		27
P. densiflora	17		42		27
P. densfilora	30		38		27
P. echinata	14		7.5		26
P. elliotti	3	Maneb	60	Needle bundle	2
P. elliotti	3	Nabam	40	Needle bundle	2
P. elliotti	3	Ferbam	15	Needle bundle	2
P. elliotti	14		0		26
P. excelsa	14		62		26
P. koraiensis	13		52.5		26
P. luchuensis	15		12.5		26
P. monophylla	6	Jiffy Grow, 1:10	100	March	25
P. monophylla	6	Jiffy Grow, 1:5	0	March	25
P. mugo	8	Jiffy Grow 1:10	100	December	26
P. mugo mughus	6		50-100 (78 ave.)	13 clones. June	22
P. muricata	14		45		26
P. nigra	12		30		26
P. patula	14		0		26
P. peuce	14		37.5		26
P. pinea	15		0		26
P. ponderosa	12	Hormodin 3	20	March	25
P. pungens	14		40		26
P. radiata	14		32.5		26
P. rigida	20	Hormodin 3	66	Stump sprouts	23
P. rigida	14		12.5		26
P. strobus	4	IBA	30-90	Varies by year	20
P. strobus	13		65		26
P. strobus	4	IBA	95	81 days to root	29
P. strobus	4		100	81 days to root	29
P. strobus	45	IBA	60	157 days to root	29
P. strobus	45		0	157 days to root	29
P. sylvestris	12	Hormodin 3	20	March	25
P. sylvestris	14		0		26
P. taeda	6	0.8% IBA + 10% Captan	10	Bottom heat 72°F.	5
P. taeda	6	0.8% IBA + 10% Captan	29	Bottom heat 78°F.	5
P. taeda	6	0.8% IBA + 25% Captan	23	Bottom heat 72°F.	5
P. taeda	6	0.8% IBA + 25% Captan	40	Bottom heat 78°F.	5
P. taeda	14		0		26
P. thunbergiana	1		40		16
P. thunbergiana	2		16		16
P. thunbergiana	3		2		16
P. thunbergiana	6		0		16
P. thunbergiana	10		0		16
P. thunbergiana	17		15		26
P. virginiana	14		5		26

SUMMARY

Table I lists pines species from which cuttings have been tried and the results obtained.

Following are suggestions for those who wish to try pine cuttings. Take short 4 to 5 cm cuttings in November-December, or in late spring as the new growth becomes firm, from as young a stock plant as possible or from the lower part of older trees. Treat with IBA in talc up to 0.8-1.0%, to which 25% Captan has been added for winter cuttings, with bottom heat up to 78° F. and mist for the first 50 days. Be sure to root prune all rooted cuttings to develop a well-branched root system (24).

If you have a bad year in your pine rooting trials, try again. Patton and Riker (20) took cuttings from *P. strobus* transplanted seedlings each year from 1949 through 1956 and had yearly rooting percentages of 30 to over 90%.

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MODERATOR CLARKE: Our next speaker will be Mr. Brian Gage. He is from the Saratoga Horticultural Foundation, Saratoga, California. This is a non-profit corporation which develops and propagates superior forms of various kinds of plants, particularly trees, trying to build up the general level of the various types of trees with which they work, and getting them into the trade. Mr. Gage:

BRIAN GAGE: Thank you, Dr. Clarke — Many of you have visited the Foundation and are aware of the facilities we have there. We have a small area, just 5½ acres, and therefore we are not in any large scale seed production, but we do have quite a number of species of trees and shrubs that we are growing from seed.