Influence of Rooting Media on Root Structure and Rooting Percentage of Douglas-fir Cuttings

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Introduction

The rooting medium is important in successful propagation of cuttings. The medium can influence the percentage of cuttings that root and the type of root system developed (LONG, 1932). A good medium provides several essential functions: it holds the cuttings in place, it maintains a high moisture content yet is well drained, it allows adequate air cxchange around the base of the cutting, and it must be free of disease and insects (HARTMANN and KESTER, 1968). A lack of one or more of these beneficial characteristics can result in lower percentages of cuttings that root or undesirable root configuration.

The choice of rooting medium used in conifer propagation is usually by chance. Propagators generally continue to use a medium with which they are familiar or with which they have had success when working with other species. Only a few designed tests of rooting materials have actually been done. One test with kanuma soil of five different particle sizes was reported for Pinus *densiflora* and P. thunbergii (OGASAWARA, 1961). Differences between species in rooting percentage and number of main roots per cutting were found. In a comparison of gravel, peat-sand, gravel-Alginure, and compost, cuttings from 12-year-old Douglas-fir *(Pseudotsuga menziesii* (MIRB.) FRANCO) trees rooted best in peat-sand and in compost (KLEINSCHMIT, 1972). Other studies in rooting Douglas-fir cuttings have used river sand (CORNU, 1973), a 5 : 1 sand-peat moss medium (BHELLA and ROBERTS, 1974), and 2 : 1 perlite-peat moss (ROSS, 1975).

Rooting research with Douglas-fir at the Forestry Sciences Laboratory in Corvallis, Oregon, has been done for 8 years in plaster-grade sand. This is fine, washed river sand free of soil and organic materials. Roots grown in such sand were usually long, brittle, and not well branched. The rooted cuttings were sometimes difficult to transplant from rooting beds because the long, brittle roots often broke during lifting or planting. A more branched and flexible root system was desired. The author had observed enough instances in which root habit seemed to be altered with other rooting media to suggest that various ones should be tested. To test that observation, a study of 21 combinations of four common rooting medium substances was started using Douglas-fir cuttings. The effects of different media on root structure and rooting percentage are reported here.

Materials and Methods

The study began in April 1975, in which plaster-grade river sand, fine ground sphagnum peat, horticultural-grade vermiculite, and perlite were tested in combinations of 1 : 0, 2 : 1, 1 : 1, and 1 : 2 with each of the other three substances. One exception was perlite-sphagnum peat (1 : 1), which was accidentally omitted when the media were mixed. The rooting media were placed in galvanized metal flats (51 X 35 X 9 cm). Numerous holes were made in the bottom of the flats to insure aaequate water drainage. Ninety-six Douglas-fir cuttings of random genotypes were arranged in each flat at 3.8-cm spacing. Three flats of each of the 21 rooting media (treatments) were studied.

Rooting was done in one greenhouse room. Polyethylene tents were constructed over three benches, and one of the three flats of each of the 21 media was located at random. Air temperature was maintained at approximately 24° C during the day and 21° C at night. No soil heat cables or fixed overheacl watering systems were used. Watering was done manually once each day with a hand-held fogging nozzle. The different media had different water retention properties, so watering was done carefully to avoid over- or underwatering. Partial shade (about 30%) was provided over the polyethylene tents to prevent excessive heat buildup inside the tents. Vents cut in the tops of the tents permitted hot air to escape and provided air circulation that helped prevent fungus discase.

Cuttings were collected in early April from 2- to 4-year-old Douglas-fir seedlings and stored in polyethylene bags for several days at 1.6° C until they could be placed in the flats. Juvenile Douglas-fir trees were used as sources of cuttings because of the greater rooting potential of cuttings from young trees. The cuttings were cut to 5.0- to 7.5-cm length, completely submerged in a Captan[1]) solution for 5 to 10 seconds, then positioned in the flats with their basal ends about 2.5 cm below the surface of the rooting medium. No exogenous rooting hormones were applied nor were the needles removed from the ends of the cuttings that were to be buried in the rooting media. Rooting success was evaluated in August and in November of 1975. On both dates the cuttings were recorded as having (1) many roots, (2) few roots, or (3) no roots. In August the cuttings with many roots were removed from the flats, while the non-rooted or weakly-rooted cuttings were left in the rooting media until November. The percentage of cuttings which formed roots was calculated for each medium and the external appearance of the root system was recorded. Quantitative analysis of the types of root systems developed was not possible; the rooted cuttings were needed for other studies so destructive methods for evaluating root mass could not be used. Rooting percentage data were subjected to analysis of variance. No transformation of percentage data was done prior to analysis since practically all untransformed data fell within the acceptable range.

Results

Both the percentage of Douglas-fir cuttings rooted and the type of root system formed were greatly influenced by the rooting media. The five best media for percentage of

1) Mention of produced by name does not imply endorsement by the U.S. Department of Agriculture.

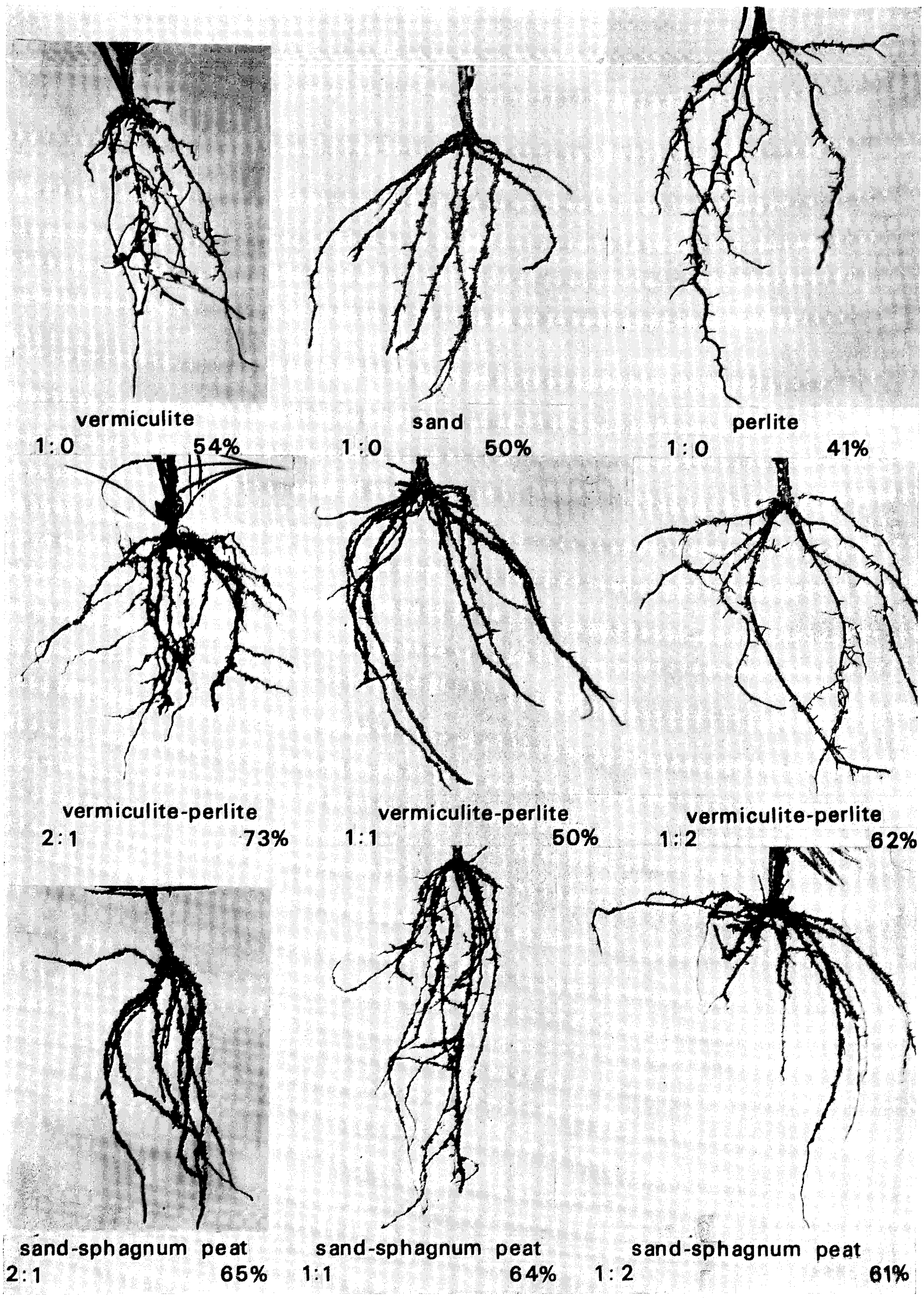

Figure 1. — Typical root structures produced in various rooting mediums are shown. The effects of increasing or decreasing the proportion of sphagnum peat, perlite, sand, and vermiculite can be seen. The rooting substances, ratio of substances, and percentage of rooting achieved are indicated beneath each photograph.

cuttings rooted were as follows: perlite-sand (1 : 1), 78%; vermiculite-sand (1 : 1), 71%; sand-vermiculite (2 : 1), 75%; vermiculite-perlite (2 : 1), 73%; and sphagnum peat-vermiculite (2 : 1), 68% *(Table 1)*.

Considerable between-treatment variation in rooting success was detected (F = 10.7**, d.f. 20, 40). Percentage rooting varied from 0—78% between the different rooting media. Within-treatment variation was also significant (F = 5.0*, d.f. 2, 40). The medium with greatest within treatment variation was the perlite-peat (2 : 1) mixture, in which rooting in the three flats ranged from 0—68%.

The four substances used in rooting media were generally not as effective alone as in mix. The average rooting achieved in mixtures vs. 1 : 0 were 51%/0% for sphagnum peat, 65%/50% for sand, 62%/54% for vermiculite, and 55%/41% for perlite *(Table 1)*. Some mixtures were also undesirable. Perlite-sphagnum peat combinations gave very poor rooting success.

Sizable differences in root thickness, flexibility, and branching were noted between cuttings grown in different rooting media. Higher proportions of sphagnum peat, from 1 : 2 to 2 : 1 ratios, resulted in finer, more branched root systems. At the other extreme, high proportions of perlite usually resulted in short, thick roots. Increased proportions of sand resulted in longer, relatively unbranched, and less flexible roots. Use of vermiculite promoted lateral branching but appeared to have little effect on root thickness or length *(Fig. 1)*.

Rooting media that gave the highest rooting percentage were not always those that grew cuttings with well-branched, flexible root systems. For example, cuttings grown in sand-sphagnum peat (1 : 1 and 1 : 2) formed well-branched, flexible roots *(Fig. 1)*; but rooting percentages were somewhat lower than on cuttings rooted in the five media that had highest percentage of root initiation *(Table 1)*. A sand-perlite (1 : 1) medium gave the highest rooting percentage (78%) of any of the 21 media tested *(Table 1)*, but roots grown in this medium tended to be stiffer or thicker and not nearly as well branched as were the roots grown in many of the other media that contained more sphagnum peat or vermiculite *(Figs. 1 and 2)*.

Daily water requirements varied greatly between different media. Those containing sphagnum peat in 2 : 1 or 1 : 1 ratios were prone to become saturated when watered too heavily or too frequently. Media containing only perlite or perlite-sand (2 : 1 or 1 : 1) dried out rapidly and needed more frequent and heavier watering than did those containing sphagnum peat. It was almost impossible to overwater the pure perlite or the perlite-sand media. Vermiculite was somewhat intermediate in water retention characteristics.

Discussion

The study revealed that root structure was decidedly altered by the medium in which the cutting was grown and that the most desired root structure was obtained at a slight sacrifice in percentage of cuttings that formed roots. Media influenced the percentage of Douglas-fir cuttings that rooted, just as Long (1932) reported for a number of woody ornamental species. The watering procedure followed in this study may have caused the within-treatment variation in rooting percentage to be large. Media that retained too much or too little water generally gave poor results. Four of the five media that had the highest rooting percentages contained vermiculite. Vermiculite media tended to be neither too wet or too dry, since vermiculite retains less water than peat moss but more water than perlite or sand (Hartmann and Kester, 1968).

No Douglas-fir cuttings rooted in flats containing only sphagnum peat, and sphagnum peat-perlite mixtures were also much poorer in percentage of rooted cuttings than the other media. The negative effect in these three media may or may not be related to the acidity (pH 3.5—4.0) of the sphagnum peat. It is important to note than sphagnum peat has many desirable qualities when used in other mixtures. Mixtures of sphagnum peat-sand and sphagnum peat-vermiculite gave fairly high rooting success, and cuttings grown in them formed some of the most branched and flexible roots seen in this study. Also, cuttings grown in sphagnum peat mixtures had a healthier, better needle color than did cuttings grown in infertile sand or perlite. The blue-green color of needles grown in sphagnum peat was probably a response to the release of naturally occurring organic nitrogen in the sphagnum peat. Such observations indicate that sphagnum peat is a useful com-

Table 1. — Rooting percentages for Douglas-fir cuttings grown in 21 rooting medium combinations of sphagnum peat, sand, vermiculite and perlite.

	Rooting Media (I)			
	Sphagnum peat	Sand	Vermiculite	Perlite
(Percent rooted cuttings in the pure media)	0	50	54	41
(Percent rooted cuttings in mixed media) I/II ratios: 2 : 1 1 : 1 1 : 2 / average				
Rooting Media (II)				
Sand	61 64 65	↓		
	63			
Vermiculite	68 60 49	75 71 53	↓	
	50	66		
Perlite	3 [1] 28	53 78 67	73 50 62	↓
	15	66	62	
Mixture average	51	65	62	53

[1] Omitted

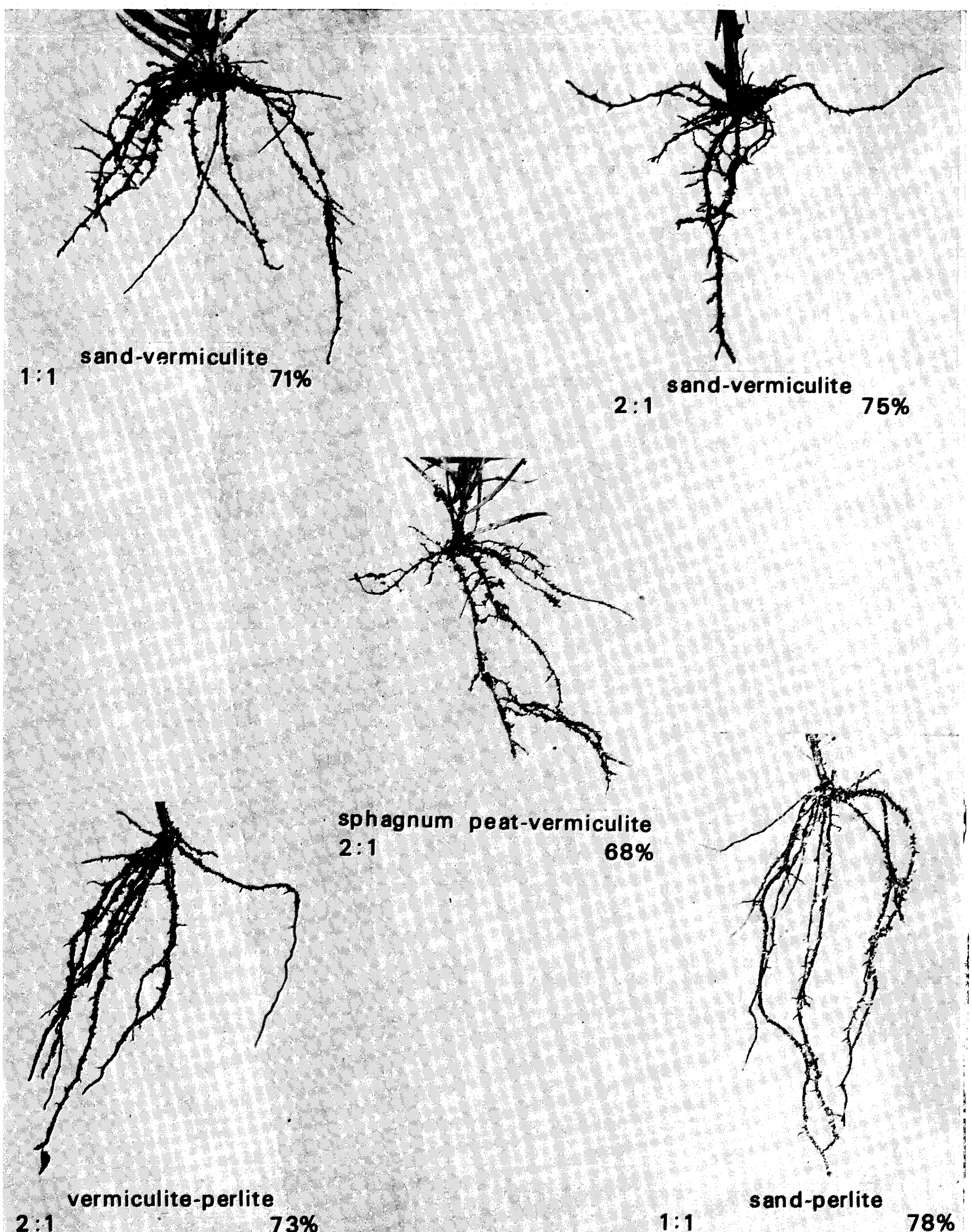

Figure 2. — Root structure is shown for cuttings grown in the five mediums that had greatest percentage of rooted cuttings. The components,, ratio of components, and percentage of rooting achieved are indicated beneath each root system.

ponent in rooting media when it is used in mixture with sand or vermiculite.

The epidermal color of roots grown in pure perlite (1 : 0) was very different from that of cuttings grown in the other 20 media. Perlite-grown roots were yellow or golden brown, rather than the normal dark brown color. Light penetration through the white, porous perlite was probably responsible for the unusual color. Sphagnum peat, sand, and vermiculite, when used alone or in mixtures, was a darker color and not so readily penetrated by light.

The optimum rooting medium for one species and one set of rooting facilities may be a compromise between the medium that gives the highest rooting percentage and the medium that produces cuttings with flexibly branched root structure. It is of little value in most propagation programs to obtain high rooting percentages if many of the same cuttings die after transplanting from the rooting beds because of root breakage or weak root development.

Rooting success varies when facilities and environmental conditions are altered. Results from the study reported above were achieved under "sweat-box" conditions. Results from an unpublished test with 12 of the same media under intermittent mist and 21^0 C bottom heat were somewhat different. The cuttings were taken from 13- 14-year-old Douglas-fir trees, and rooting was started at the same time as the 2- to 4-year-old cuttings in the polyethylene tents. Under these conditions, the best medium was sphagnum peat-sand (2 : 1). Seventy-two percent rooting was obtained vs. 14 to 65% ($\bar{x}$ = 48.0%) for the other 10 media (unpublished data). Root structure was comparable to that found on cuttings grown in the same media in "sweat-boxes". These results indicate that more desirable root systems can be obtained by varying the components in the rooting medium, but that each alteration in rooting facilities or environment has enough effect to justify a simple medium test.

Use of sphagnum peat in mixtures promoted development of flexible, well-branched roots. Perlite produced well-branched roots that tended to be short, thick, or stiff. Vermiculite produced well-branched roots on cuttings and appeared to have little effect on root thickness or stiffness. Roots grown in sand tended to be relatively long, unbranched, and brittle. Sphagnum peat used along was an undesirable rooting medium, as no cuttings rooted in pure sphagnum peat. Rooting was also poor in sphagnum peat-perlite mixtures. Flexible, well-branched roots were usually produced in the media that did not have the highest rooting percentages. Examples were sphagnum peat-sand and sphagnum peat-vermiculite. These components produced excellent roots and shoots with healthy blue-green colored needles.

The best all-around medium is not necessarily the one that gives the highest percentage of rooting, nor the one that forms the most branched and flexible roots, but may be one such as vermiculite-sphagnum peat (1 : 2), that favors both high rooting percentage and flexible, branched root systems for best survival after transplanting.

Summary

The influence of rooting media on percentage of cuttings rooted and the type of root system formed was investigated with cuttings from 2- to 4-year-old Douglas-fir trees. Twenty-one combinations of sphagnum peat, perlite, vermiculite, and sand in 1 : 0, 2 : 1, 1 : 1, and 1 : 2 ratios were evaluated. Rooting was done under polyethylene tents in a heated greenhouse. The rooting media yielding the highest percentage of rooted cuttings were as follows: perlite-sand (1 : 1), 78%; vermiculite-sand (1 : 2), 75%; vermiculite-perlite (2 : 1), 73%; vermiculite-sand (1 : 1), 71%; and sphagnum peat-vermiculite (2 : 1), 68%.

Key words: Vegetative propagation, propagation, asexual, root, rooting media, propagules, Douglas-fir, cuttings.

Zusammenfassung

Es wurde untersucht, inwieweit das Bewurzelungsprozent von Douglasien-Stecklingen vom Bewurzelungssubstrat abhängt. Hierzu wurden im Gewächshaus Stecklinge von 2- bis 4jährigen Douglasien in verschiedene Kombinationen von Sphagnum, Perlite, Vermikulite und Sand gesteckt. In den einzelnen Kombinationen wurden zwischen 68% und 78% bewurzelte Stecklinge erzielt.

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