places a tremendous stress on the plant and it is questionable whether whitewash alone would have helped.

BRUCE BRIGGS: We did a little work on containers this past year trying to keep the soil temperature uniform within a bed of container-grown plants. We used foil paper on the outside of the blocks of container-grown stock. The foil paper did an excellent job of keeping the temperature more uniform.

RALPH SHUGERT: The moderator for the second symposium of this afternoon's program is Dr. Ken Reisch.

KEN REISCH: I would like to bring greetings from Dr. Chadwick who was not able to come this year but wishes everyone well and hopes to be present at next year's meeting.

ROOTING MEDIUMS

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Rooting mediums for cuttings have been discussed for centuries and probably originated when prehistoric man first thrust a spear into the ground. Innumerable materials have been used for this purpose and vary from field soil to sophisticated mixtures of organic and inorganic substances. Included among those which have been mentioned in the literature are sand of various types and particle size, peat moss of different forms, ashes, cinders, flue dust, sawdust, pumice, ground bark, sphagnum moss, soil, rice hulls, coffee, parchment, cocoa fiber, vermiculite, perlite, styrafoam, clacine clay, BR-8 blocks (processed wood fiber), water, and air.

A rooting medium should fulfill the following objectives:

1. Maintain the cutting in a properly oriented position.
2. Minimize moisture loss from the submerged portion of the cutting.
3. Provide a suitable environment for the elongation of roots.

Although there are various schools of thought on the characteristics of a good rooting medium, the following should be considered.

1. Inexpensive
2. Readily available and reproducible
3. Uniform and long lasting
4. Free from disease, insects, nematodes, and toxic substances
5. Easily managed
6. Well drained and with desirable air-water relations
7. Uniform temperature

Matkin (25), noting the importance of the free porosity or air space in the medium, indicated that 1) The medium should have as high a free porosity as practical under the cir-

cumstances; 2) The medium should be as deep as possible since the depth of the medium column affects the air supply; and 3) No layer of coarse material should be placed in the bottom of rooting containers since this shortens the column and raises the water table in the medium.

Much work has related to the effects of various mediums and medium factors on rooting; however, there has been no research to indicate that the medium has any direct effect on root initiation.

This discussion should be prefaced with the statement that numerous investigators and commerical propagators have found variable success with rooting plants in different mediums, thus indicating that there is no one best medium for all plants and all conditions. The variable results are due to plant type, condition of the cutting, season, light, temperature, drainage, means of providing water, type of structure, hormone treatments, etc.

Also, although the medium does not have a direct influence on root initiation, it may have a marked effect on root elongation, type of root system, plant survival, and success in transplanting. For example, Wells, in his book on plant propagation, indicated that many cuttings will root readily in a peat and sand mixture, but roots of some will rapidly begin to rot due to unfavorable air-water relations.

Effect of Mediums on Types of Roots

In 1932, Long (23) published the effects of mediums of sand, peat moss, and a mixture of the two on the rooting of cuttings from 42 different plants. He found that finer roots were produced in peat moss than in sand. However, when the peat moss was kept at a low moisture content, the coarseness of roots approached those formed in sand. He also studied sand mediums with different size particles from fine sand to fine gravel. There was little difference in the roots until during hot summer weather when finer roots were found in the coarser medium. This was attributed to the heavier watering necessary and the greater water content in the fine gravel during this period. Chadwick (4), working with taxus, also found that roots were more fibrous and less brittle in peat moss than in sand. Franklin (11) indicated that roots formed in vermiculite were more fibrous than in sand; however, Bos (3) found the opposite on cuttings of *Philadelphus coronarius* '*Aureus*' rooted in these two mediums.

In a summary of a discussion group, Flemer (10) reported that some firms had found more fleshy and brittle root systems on cuttings rooted in perlite. Also, Gifford (13) reported that peat and perlite provide a good medium for rooting chrysanthemums and that preliminary tests showed that roots in perlite were not as soft and shipped better than those produced in sand and peat.

Results with Various Types of Mediums

A number of articles have described the use of field soil as a rooting medium. Templeton, (36) describing his famous Phytotector system, indicated the value of using soil as a rooting medium because of lower initial cost and reduced costs as a growing-on medium. Roller (33) used field soil, with peat moss added, to propagate *Ilex cornuta 'Burfordi'* and Chase (6) rooted *Juniperus* in the open field. Discussing the Burlap Cloud method, Hancock (17) described the rooting of summer softwood cuttings in soil sifted through a screen.

Sand has long been considered a standard and universal rooting medium; however, very few have reported this material as the ideal medium. Dodd (7) indicated that vermiculite was superior to sand in rooting most magnolias but that sand was just as effective for Star Magnolia. Wells (40) reported that many types of mediums have been used to propagate ilex and that sharp sand only was recommended for the *Ilex crenata* types. It is interesting to note that Hitchcock (19), in 1928, found that *Ilex crenata* cuttings rooted poorly in sand. Esper (9) indicated that sand was found least desirable for rooting evergreens. Many writers, such as Kemp (22) pointed out the importance of sand particle size and the variation in results can be attributed to the relationship between the number and extent of capillary and non-capillary pores in the different sand types. This was illustrated in the work of Matkin (25) who found that free porosity or air space, on a volume basis, was only 1.2% in fine sand, 9.5% in typical propagating sand, and 29.9% in peat moss.

Numerous reports of specific mediums for different species and cultivars have been recorded. Chadwick (5) and Doran (8) gave recommended mediums for cuttings of several deciduous and evergreen plants. Hitchcock (19) classified 96 varieties of cuttings into those which root readily in sand, in peat, or in either. It is important to note that, in this early research, the majority of plants were found to root successfully in either sand or peat or in a mixture of the two. Myrhe and Schwartze (26) also reported 35 species and varieties of broadleaf and narrowleaf evergreens which rooted well in sand as well as in a sand-peat mixture.

Houston and Chadwick (21) reported that softwood cuttings of 20 deciduous and evergreen plants rooted better in vermiculite than in two different grades of silica sand. Gray (14) found that tsuga cuttings rooted best in a medium of ⅓ sand, ⅓ peat moss and ⅓ fine styrafoam. In general, however, much of the research with types of rooting mediums has indicated relatively little difference in effectiveness. O'Rourke and Dedolph (27) found no one medium consistently superior in rooting cuttings of seven plant species. They used sand, arcillite, and perlite plus equal volumes of sphagnum peat and mixtures of styrafoam and peat, and arcillite and peat. Pridham (30) found no significant effect of mediums of cinders,

sand, or vermiculite on rooting evergreen cuttings. Hall and Cannon (15), working with *Rhododendron carolinianum* cuttings noted that the medium was of less importance than timing or hormone treatment. Mediums used were composed of German peat moss combined with sand, perlite, and weblite. Also, Tinga and Hayes (37) found no significant differences in rooting large cuttings of several plants in four medium types and Germany (12) indicated that firethorn will root in practically any medium. He found good results with common brick sand, vermiculite, and perlite as well as mixtures of sawdust and peat.

Effect of Medium pH

Some attention has been given to the effects of pH on the rooting of cuttings; however, in many instances, the effect of pH differences in the medium were confounded by factors of aeration, drainage, etc. In some early research, Hitchcock and Zimmerman (20) found that *Azalea amoena* cuttings rooted better in peat at pH values of 3.70 to 4.68 than in peat near the neutral point. Roof (34) rooted softwood cuttings of several plants in sand adjusted to pH values of 4.3 to 8.5. In general better rooting occurred at pH values of 6 to 8 but this was not conclusive. With some species, he found a high percentage of rooting in the mediums adjusted to pH 5 and 6. Parker and Kamp (29) found significantly better rooting on cuttings of coleus, carnation, and chrysanthemum in mediums with pH values of 7 and 8 than at any other pH. VanDrunen and Kamp (38) found similar results on Hatfield yew cuttings with little to no rooting at pH levels of 5 and 6 and best rooting at pH 7. This subject is also somewhat controversial since numerous cuttings, including yew, have been successfuly rooted in sand, peat, and other mediums with low pH values. Also, in relation to this same factor, Mahlstede (24) indicated that a low pH, under 4, inhibited callus formation on cuttings.

Variant Medium Types

Some propagators have used rooting mediums established in layers. Halward (16), in propagating *Cercidiphyllum japonicum* cuttings in cold frames, used a mixture of loam, peat moss, and sand with a layer of 1½ inches of sand on top. Shammarello (35) described a medium for rooting rhododendrons in a sashhouse as being composed of a layer of gravel underneath a layer of two grades of sand mixed with peat moss on which an electric heating cable was placed. The same mixture was then placed on top of the cable. Baldseifen (1), using a modified Nearing Frame, placed layers of shredded peat moss, peat moss mixed with course sand, and a ¼ inch covering of sand on top for rooting deciduous azalea cuttings. Ravestine (31) described a unique medium for rooting magnolia and viburnum hardwood cuttings. Two and one-half inches of peat moss was put in the bottom of the bench and covered by

a thin layer of peat moss. The cuttings were laid on top of this followed by a layer of sphagnum moss and a cover of peat moss. The layers were moistened as they were added and no additional watering was necessary.

Rooting Growing-on Mediums in Containers

Several workers have reported the use of mediums for both rooting and growing-on and the most detailed medium was proposed by Vermeulen (39) who suggested the term Propicon to cover the broad area of propagation in containers. The medium was composed of 53% German peat moss, 17½% #1 Horticultural Perlite,, 17½% finely shredded styrafoam, 9% fine sharp deep pit sand, and 3% soil. Tinga (37) successfully rooted large cuttings of several species directly in containers in four types of mediums and Reisch (32) reported the use of a medium composed of ⅓ soil, ⅓ peat moss, and ⅓ sand to root hardwood cuttings in 1 gallon plantainers. In other work, Hess (18) used a light weight medium ⅓ vermiculite, ⅓ styrofoam, and ⅓ peat moss to root cuttings directly in plant bands under mist, which provided rooted plants ready for shipment.

Current Aspects

With the advent of mist propagation techniques, some changes have occurred in the concept of desirable medium types. Numerous mediums have been used successfully with equally numerous variations in misting systems. As discussed by Matkin (25), free porosity or air space in mediums used in mist propagation should not be less than 20% by volume.

Although there have been few reports of the commercial rooting of cuttings in air, this has been effectively accomplished by chance, when a cutting roots on top of the surface under a mist line, or by intent, as in a recent research study at The Ohio Agricultural Research and Development Center. In this work, rose cuttings were successfully rooted in air with the bases extending into a mist chamber. This technique enabled the workers to treat the roots with varying concentrations of calcium and chelate compounds to determine effects on root anatomy and absorption.

One of the newest innovations in rooting mediums, a block composed of softwood kraft wood pulp with a hole for inserting the cutting, appears to have considerable promise. Beck and Adams (2) described these 1.5 inch cubes, known as BR-8 Blocks and manufactured by the American Can Company, as follows. The wood pulp is stabilized against decay by polymerizing acrylonitrile in the fibers, and nutrient ions are sprayed onto the block. Each block weighs 4.5 grams and absorbs more than ten times its weight in readily available water. Roots readily penetrate the structures and subsequently develop well in surrounding soil. Geraniums have been satisfactorily rooted and grown to flowering in 3-inch BR-8 Blocks. Studies, using

these blocks with floriculture crops at the Ohio Agricultural Research and Development Center, have indicated that they can be used effectively under mist and must be steam pasteurized to prevent rot organisms from developing on the cuttings. In these trials, cuttings of poinsettia, carnation, rose and geranium were rooted and grown on successfully.

Conclusions

1. Numerous types of mediums can be effectively used for rooting cuttings.
2. Aeration and drainage are two critical properties of any medium.
3. The success or failure of a medium is dependent on both its physical properties and the management program.
4. Many of the discrepancies in the literature can probably be attributed to a failure to recognize and report differences between medium types, especially with various grades of sand, peat moss, etc., as well as differences in natural and man-made environmental conditions.
5. There is no mystical significance associated with a given medium for a specific plant.
6. The trend of current and future approaches to propagating mediums, stresses the added feature of a growing-on medium to save labor, cost, improve handling efficiency, and result in less disturbance to the root system.

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MODERATOR REISCH: The next two speakers on this afternoon's program are fellow travelers. I had the pleasure of being with them on a trip to California last spring. The first speaker is Earl Robinson who will talk on the subject of "Peat-perlite as a Rooting Medium."

PEAT — PERLITE AS A ROOTING MEDIUM

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At Medford Nursery we have tried to mechanize as much of our operation as possible. The first area we worked with was the propagating bench. The tedious and time-consuming job of filling and emptying benches did not appeal to us. Certainly a more efficient use of greenhouse space was possible. We looked to our western friends and found that they felt somewhat the same way.

We began by using a poured concrete bench suspended by a 12 x 16 x 4 cinder block protruding under the concrete slab on the wall side and 1¼" pipe legs on the other side. Copper tubing spaced at 6" centers graduated from 1" to ¾" to ½", was used for our heat source. This formed a radiant heat slab. The 180° water is tempered down to 90° to give a good even heat. The two benches are zoned separately. The two zones enable us to have two different temperatures in each bench, or to shut one bench down completely. The air temperature is on another zone. This allows us to efficiently keep flats warm and air cool. We also make use of the polyethylene tubing combined with exhaust fans that thermostatically control cooling—(Acme system). Our mist system is controlled by a counter-weight on a screen—(Mist-o-matic control).

The rooting medium to go into the flats was our next problem; drainage, aeration, and weight being critical. Our first peat-perlite mix of ½ sphagnum peat and ½ medium grind perlite, by volume in a standard flat remained too wet when the flats were placed directly on the concrete bench. We decided it was necessary to place the flats on lath to elevate them above the bench slightly. We also went to a deeper flat; namely, 4" in depth. This also remained too moist, as indicated by browning of the end of the stem, and rooting only on the upper portion of the stem.

In our second mix we used ⅓ sphagnum peat moss, ⅔ perlite, and watered this down with Aqua-Gro, and Morsodren. The results were greatly improved—heavy rooting with a root system that was much finer. Morsodren, available from E. C. Geiger, is an excellent fungicide for cuttings.