blood-red spotting in the upper corolla and curly margins. A vigorous, upright, and spreading plant it grows to 6 ft. Rhododendron hardiness rating of H1.

Rhododendron **'Haaga' (*R. brachycarpum* ssp. *tigerstedtii* × *R.* 'Doctor H.C. Dresselhuys').** The profuse flowers on 'Haaga' are pink. The plant habit is a well-branched and rounded. A vigorous plant growing to 5 to 7 ft. Rhododedron hardiness rating is H1.

Azalea 'Lemon Lights'. A new introduction from the University of Minnesota. Part of the Northern Lights series of hardy deciduous azaleas. 'Lemon Lights' comes from the same cross as 'Golden Lights' and 'Northern Hi-Lights' and was selected for its good yellow color and floriferous habit. Flowers appear in May and cover the shurb. Plants grow to 6 to 7 ft tall and wide, demonstrate good mildew resistance, and are hardy to -40F. Propagation is by cuttings or tissue culture, and like other members of the Ericaceae family we micropropagate it on Woody Plant Medium with 2iP or zeatin.

Desirable Characteristics of Propagation Media

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INTRODUCTION

The field of soilless media is undergoing a rapid technological change and I would like to examine our current use of media components and look ahead to the new possibilities for propagation media. We will focus on the physical, chemical, and biological characteristics of each medium component so you may have a clear understanding of why a particular blend of raw materials may work for your crops.

The propagation medium has three functions: (1) To hold the seedling or cutting in place during the rooting period, (2) To provide moisture for the cutting, and (3) To permit diffusion of air to the base of the cutting (Hartmann and Kester, 1990). In looking at a propagation medium for either seedlings or cuttings, we are usually seeking the proper blend of air porosity and water-holding capacity. If a grower is using a mist system to keep the relative humidity of the air around cuttings high, the medium must have a higher air-filled porosity. Indeed, many of the propagation manuals that specify an air-filled porosity of 15% to 20% were written for mist propagation systems (Handreck and Black, 1994. With the advent of fog systems and the subsequent effect of less water reaching the leaves, a higher moisture content may be desirable for maximum rooting. Seedlings require different degrees of air porosity and water retention depending on the size of the seed and the type of mist system or growth chamber used for germination. In addition to the physical characteristics, a grower needs to know the chemical nature of the media. More recently, emphasis has been on the biological characteristics of growing medium components. Keeping your own system in mind as we proceed, let's examine these characteristics of the most commonly used propagation medium components.

INORGANIC COMPONENTS

Sand was one of the first materials to be used in propagation due to its ready availability and low cost (Table 1). Sand is usually used in conjunction with other organic components such as peat moss to increase the available water in the root zone. Although sand is defined by the U.S.D.A. system of soil classification as having a particle size of 0.05 to 2.0 mm, those in the medium to very coarse size ranges are preferable (0.25 to 2.0 mm) (Hartmann and Kester, 1990). The air-filled porosity percentage will depend on the size and shape of the sand particles. With a bulk density in the range of 1.3 g ml^{-1} sand does an excellent job of holding the cuttings in place during rooting. A neutral pH and low mineral nutrients are typical. Occasionally, a sand may be contaminated with calcium carbonate and can raise the pH of the medium (Landis et. al., 1990). We have also found that river sand which is commonly available in the Northwest can be contaminated with agricultural chemicals. In some instances, we have found low pathogen levels as well.

Perlite is perhaps the most commonly used aggregate component in rooting media today. It is an alumino-silicate mineral that is mined and then popped at high temperatures. Perlite has a closed cell structure that repels water and, therefore, is used to increase air porosity in a mix (Landis et al., 1990). It has a very low bulk density of 0.20 g ml^{-1} and is available in several particle sizes. The most common propagation grade of perlite has particles in the 3.0- to 3.2-mm size range, a water-holding capacity of 19% and an air-filled porosity of around 53%. There is also a very fine-textured grade commonly used for seedling mixes. One of the largest drawbacks to perlite is the tendency to crush if handled roughly or frequently. Once crushed, its ability to provide aeration is greatly reduced and the fines may actually clog a mix. Due to the low water retention of perlite, it is commonly mixed with peat moss, bark, or compost. A study carried out by Tilt and Bilderback (1987) showed a peat moss and perlite (1 : 1, v/v)blend had a total porosity of 85%, a water-holding capacity of 56% and air space of 29%. Due to the high temperatures during processing, perlite is sterile and it contains almost no plant nutrients. The cation exchange capacity (CEC) of perlite is very low and the pH is around 7.0.

Table 1. Comparison of inorganic components.

Component	pH	Bulk density	WHC	AFP
Sand	7.0	1.3	26%	10%
Perlite	7.0	0.2	19%	53%
Pumice	7.0	1.1	25%	30%
Vermiculite	7.0-7.5	0.11-0.15	39-52%	30-40%
Rockwool	6.0-6.2	N/A	60%	20%

WHC- water holding capacity
AFP- air-filled porosity
Bulk density is in g ml^{-1} on a dry weight basis.

Pumice, a volcanic rock mined in central Oregon and throughout the western U.S., is used regionally as a perlite replacement. It has a bulk density of 1.1 g ml^{-1} with air porosity between 30% to 34% and water-holding capacity of 25% to 26%. Pumice dries out faster than perlite due to the greater number of macropores. Watering practices must be adjusted if the grower is accustomed to using perlite in the propagation mix and is changing to pumice. Pumice has the advantage of costing half as much as perlite in the regions where it is readily available. It comes in many grades and screenings suitable for nursery mixes. We find that for most nursery mixes a 3/8 in. screening without fines is the best all purpose grade. For rooting of cuttings, many nurseries prefer to keep the fines or "flour" in the pumice. The pH of pumice is in the neutral range, the CEC is very low and the rock is chemically inert. We have not found any evidence of pathogens or chemical contaminants in the years we have tested pumice at our plant. Being a volcanic rock, it is very stable and does not crush. However, it is heavier than perlite and when wet may be too heavy for many workers to handle. Growers have found that a peat moss and pumice (1 : 1, v/v) blend is an effective propagation mix for cuttings and a common planting mix consists of equal parts of bark, peat moss and pumice (1 : 1 : 1, by volume).

Vermiculite is another inorganic component frequently used for propagation blends, but has some significantly different properties. Vermiculite is an aluminum-magnesium-iron-silicate mineral, currently mined in Africa, Brazil, China, and some regions of the United States, and consists of thin plate-like sheets. It is expanded under temperatures up to 1000C that forces the mineral into a sponge-like structure with numerous pores. It is lightweight with a bulk density in the range of 0.11 to 0.15 g ml^{-1} (Landis et. al., 1990). The sponge structure creates a high water-holding capacity in the range of 39% to 52% depending on the grade or coarseness of the mineral. Air porosity varies between 30% and 40%. The plates contain many cation binding sites producing a high CEC. Vermiculite is sterile due to the high processing temperatures. It supplies magnesium and some potassium to a mix as it breaks down (Handreck and Black, 1994) and the pH is around neutral. The particles are physically unstable when wet and crush easily. In addition, it is more *expensive than any other raw material and the supply has been erratic in recent* years. However, if a grower wants a mix that is inherently sterile, a blend of perlite and vermiculite is the first choice.

Rockwool, widely used in Europe, has not met with wide acceptance in the Northwest although it is used by growers on the East Coast. Rockwool can be hydrophobic or hydrophilic and is usually blended to give a proper ratio of both types. Grodania manufactures a rockwool with 60% water-holding capacity and 20% air-filled porosity. The pH is slightly below neutral in the 6.0 to 6.2 range and the rockwool is sterile (Barletta, 1992).

ORGANIC COMPONENTS

The most common organic component (Table 2) used in propagation mixes is Canadian sphagnum peat moss. It is available in several grades with the majority of growers using a single-screened moss, typically referred to in the trade as "grower's grade". However, there is wide variation in the particle size from one producer to the next and even from one bale to the next. The distinctive and desirable features of sphagnum peat moss include a large amount of internal pore space capable of holding water and nutrients and a high buffering capacity to withstand rapid changes in pH and a low bulk density. The pH of sphagnum moss ranges from 3.0 to 4.0 which helps to balance the higher pH of inorganic components. Water-holding capacity is 50% to 60% by volume and air porosity is 25% to 30% (Conover and Poole, 1977). Peat moss is typically low in plant nutrients. Our tests have shown significant levels of beneficial microorganisms of *Trichoderma* and fluorescent pseudomonads. Both have been suggested as antagonistic to certain root rots. Peat moss is familiar to most U.S. growers and the majority have adapted their nutrient and watering systems to a peat-based medium. When mixed with inorganic components, peat moss can aid in water and nutrient retention for cuttings or seedlings and possibly provide suppressive activity to root-rot development. Several drawbacks exist, however, including the hydrophobic nature of peat moss. This is usually overcome by adding a wetting agent. Additionally, peat bogs are environmentally sensitive and considerable pressure is being mounted to reduce or modify harvesting of the peat. Consequently, the price and availability may fluctuate in coming years.

In the 1970s and 80s, a group of researchers across the country looked at possible alternatives to peat. Some of the results of those studies were composted bark—pine, fir, and redwood. They found that under proper composting conditions, the finished bark was high in beneficial microorganisms that were naturally suppressive of root rots (Bilderback, 1992; Thomas, 1993). Since that time, many growers have incorporated bark into their growing or propagation media. Properly composted, bark has a pH in the range of 4.0 to 6.5 depending on the source. Water holding capacity can vary from 15% to 40%, depending on the degree of composting and the amount of fine particles. Air porosity will also vary for the same reason and may range from 30% to 50%. It is possible to buy composted bark from a wide number of suppliers in the U.S. Be certain to ask about their composting procedures and ask for a nutrient analysis and compost maturity test before trying it on your cuttings and plants. Possible phytotoxicity may occur with barks due to the monoterpenes present in some bark (Landis et al., 1990).

Table 2. Comparison of organic components.

Component	pH	Bulk density	WHC	AFP	CEC
Peat moss	3.0-4.0	0.03-0.14	50-60%	25-30%	100-120
Composted bark	4.0-6.5	0.25-0.30	15-40%	30-50%	140-210
Composts	6.0-8.0	0.20-0.40	varies	varies	varies
Coir fiber	5.3-6.4	0.16-0.25	60-70%	25-30%	95-100
Worm castings	6.5-8.0	0.55-0.60	50-60%	10-12%	N/A

WHC- water-holding capacity.
AFP- air-filled porosity.
Bulk density is in g ml^{-1} on a dry weight basis.
CEC is expressed as meq/100g.

Compost is one of the newer components on the market for use in growing media and quality can vary considerably. It may range from yard trimmings to municipal sewage sludge. National standards are not in place fully so this is a "buyer beware" situation. Know what the source of the compost was, the degree of compost maturity, and the available nutrients. Some composts are high in soluble salts while others can be low in all nutrients. In addition, ask for pathogen and environmental toxin tests. While composts may be used for growing media, it is not advisable at this time to use them for propagation media without extensive testing in your nursery and consultation with your county extension agent.

Coir fiber is another recent introduction into the U.S. nursery industry. It has been used extensively in Australia and Europe in greenhouse and nursery operations. Coir fiber is the byproduct from the mesocarp of a coconut. After the long fibers are extracted for use in mattresses, brooms and other products, the finer particles are left behind and this is the part being used as a horticultural substrate. Coir has excellent physical properties. It does not repel water like peat moss and holds more water than many sphagnum peats due to its finer pore structure (Dyke, 1994). The pH of coir is somewhat higher than peat moss ranging from 5.3 to 6.4. However, the CEC is similar to peat. Total pore space is as high as 96% with large pores accounting for 16% which allows for good drainage (Handreck and Black, 1994) and bulk density falls between 0.16 to 0.25 g ml^{-1}. There is less overall shrinkage compared to bark or peat. If a grower decides to use coir in place of another organic component, remember to adjust watering practices or use less coir than one would use of peat moss. Additionally, coir requires more nitrogen initially due to the drawdown of nitrogen for microbial activity. No information is currently available on levels of beneficial microorganisms in coir. Due to the importation of the product from southeast Asia, it is at least as expensive as peat moss and, in some cases, more expensive.

The final organic component to look at today is earthworm castings. Worm castings arise from a process called vermicomposting and are becoming increasingly available as worms are used to process waste products. Castings have a relatively high pH from 6.5 to 8.0 and higher levels of potassium, calcium, and magnesium than peat moss or bark. They are biologically active with bacteria, actinomycetes, and fungi (Grapelli et. al., 1985). Grapelli et. al. (1985) looked at castings in propagation media. They pointed out that biological components, such as gibberellins, cytokinins, and auxins known to promote rooting, were present in worm castings. They found that castings greatly favored rooting percentages and the amount of root biomass (Grapelli et. al., 1985). Our company has always used wormcastings as a component in our retail mixes and our own studies have shown increased root and shoot growth in mixes with castings included. Ongoing studies at the U.S.D.A.-Agricultural Research Center in Corvallis, Oregon with castings suggest suppressive action against root rots (Linderman, 1995, personal communication). We have found the dense nature of castings limits their use to no more than 20% of a propagation medium.

The proper blend of media components will be specific to your propagation needs. Seedlings, cuttings and liner stock will all differ in their requirements for water-holding capacity and air porosity. The physical characteristics of the medium are critical to the future success of a plant's health, but, consider as well, the chemical and biological aspects. I predict that future media will be as carefully constructed for their biological properties as current media are for porosity. For those of you mixing your own media, I hope this will give you new insights into possible alternatives. For those growers purchasing propagation media already premixed, this should show you some of the future raw materials to look for from your supplier.

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How to Use Biological Control to Manage Propagation Pests

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INTRODUCTION

Biological control is the suppression of pest populations by their natural enemies. This, of course, occurs naturally in our environment. It is quite a "bug eat bug" world out there. How do we utilize this occurrence to our benefit in our pest management programs? In order to successfully implement a biological control program in propagation systems, the pest management professional will need to hit the books. Applied biological control or 'biocontrol' is an information-intensive science and art. The science requires an intimate familiarity of both the pests and their natural enemies. The art of biocontrol is taking this information and transforming it into a practical and economical program suitable for a specific nursery location. In order to do this, biological control should be viewed in the broader context of integrated pest management (IPM).

IPM is a pest management strategy using multiple tactics to suppress a pest population below damaging levels. An IPM program includes several important aspects: pest identification, regular monitoring, action thresholds, and integrated