Efficient producers do reduce these problems to a minimum, however.

SOIL STRUCTURE RELATIONSHIPS . . . SOIL . . . WATER . . . PLANTS . . . IN CONTAINER GROWN ORNAMENTALS

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There are wide and varying types of media that have proven successful in the growing of container ornamentals. If we checked with the many successful nurseries we would find a tremendous range of growing media being utilized. However, three important aspects would have been satisfied. Those are 1) aeration, 2) water holding capacity, and 3) nutrient holding capacity (2,3,6). The key to success is learning to combine proper cultural practices with the particular mix one has chosen. However, there are many factors to consider when selecting a growing medium.

Climatic Conditions. What is the rainfall, temperature (diurnal fluctuation), length of growing season, humidity, wind and day length like in the area where the plants will be grown? California nurseries, for example, are afforded an opportunity to use more native soil in their mixes, due to their low rainfall, than nurseries in the southeastern states (6). Of course, these are variables we have little or no control over, unless we build greenhouses. Therefore, we must consider these factors just as we do when deciding what plants to grow.

Plants to Grow. It is, of course, most practical to grow all of our varieties of plants in the same soil mix. Matkin, *et al.* (3) reported that John Innes Horticultural Institution in England demonstrated that a single soil mixture could, with minor modification, be used for growing a wide range of plants. However, waxleaf ligustrum, azaleas, and bromeliads just cannot be treated alike; but the fewer different formulations of soil mix, the more simplified the growing problems.

SOIL

Things a good soil mix must possess or — the functions of a soil:

1) *Good Soil Aeration.* This will assure that a mix has good drainage, which is so very important in growing plants in containers. Buscher (1) reports a procedure to determine the amount of air-filled pore space. He further states that 15 to 25% air-filled pore space is desirable for container-grown ornamen-

tals. Our mix provides between 18 to 22%, depending on when it is checked. It must be remembered that a soil mix is always undergoing physical changes. Organic matter decomposes during the growing season and roots are growing in the medium, both of which affect aeration and other physical properties.

Smith (6) reports that three problems arise when aeration and drainage are restricted: 1) there is a reduction in available soil oxygen; 2) possibilities for soil disease organisms to become established, i.e. *Pythium*, *Phytophthora*, *Rhizoctonia*, are greatly enhanced by excessively wet conditions; 3) more toxic soil gases are present during times of poor soil aeration.

2) *Nutrient Holding Capacity.* Cation-exchange capacity (CEC) is the ability of a solid particle, which possesses a negative surface charge, to hold positively charged ions, i.e. potassium, ammonia, calcium, etc. Furuta (2) reports that montmorilonite clay and humus have relatively high CEC's of 10 and 20 respectively, whereas, sand has essentially 0. Vermiculite and peat moss have a CEC of 15 and 20, respectively, while redwood sawdust has a CEC rating of 3. The negatively charged soil holds these positively charged ions until displaced by another positively charged ion such as hydrogen (H^+). The released element is then absorbed by the plant, thus the frequency of fertilization of these positively charged ions is dependent on the CEC of the mix. A mix with a high CEC requires less frequent fertilizer applications compared to a mix with a low CEC. One should realize the drawbacks if he selects a mix that requires continuous fertilizer applications. Although this may result in a good quality plant in the shortest period of time, more money will be spent on fertilizers and plant quality will deteriorate rapidly once it reaches the retailer. A plant that has a reserve capacity of fertilizer goes to the retailer and the ultimate consumer in better shape nutritionally. We have received compliments from landscape firms which utilize our plant material because fertilizer continues to be available to the plant after planting.

3) *Water Holding Capacity.* The ability of a soil to hold this precious commodity, water, determines the frequency of irrigation applications. In selecting a soil mix, this ability and climatic factors, such a rainfall, humidity, and wind must be considered and a compromise reached. Matkin, *et al.* (3) state that a plant which is constantly supplied with the proper amount of water grows continuously, whereas a plant exposed to occasional water deficiencies grows intermittently and is smaller. Of course, if the plant is placed under too much water, stress death results. Thousands of plants are lost annually because of the following: they blow over and are not uprighted, watering tubes get knocked out, the water source or system

fails, or possibly and unfortunately the person in charge of watering just didn't water the plants in time. In equilibrium within the water in the container are the negatively charged ions, such as nitrates (NO_3^-), which are available and essential for plant growth. Therefore, each successive irrigation should contain only enough water to have free water begin to run out of the drain holes, or excessive leaching of these negative charges ions results. These three factors: 1) aeration, 2) cation exchange capacity, and 3) water holding capacity, are the essential properties that must be brought together. If they are combined in the right proportions and good cultural practices are followed, the result will be a beautiful plant capable of being in someone's landscape. Only then do we, the nurserymen, receive the aesthetic reward for our efforts — a beautiful plant in a landscape.

4) *Anchorage and Physical Support.* The soil provides a medium in which the roots grow, thus rendering physical support to the top of the plant.

5) *Readily Available and Affordable.* The ingredients should be readily available and at a reasonable cost, as Patterson (4) stated. Peat moss possesses some excellent properties as a medium. It has a high cation exchange capacity but due to its rising cost, presently $5.80 for a 12 cubic foot bale, many growers have turned to pine bark as a substitute.

6) *Duplicatable and in Good Supply.* One should be able to reproduce the same mix time and time again. The ingredients used must therefore be in good supply and of a uniform consistency or grade.

7) *Lightweight.* The mix should be light enough in weight so that plant size rather than weight is the limiting factor in shipping. For example, our filled 1 gallon can weighs 6 lbs. This allows us to ship approximately 6,000 one gallon plants or 36,000 lbs on a standard 40-foot semitrailer. Of course, the lighter the mix the easier it is for wind to blow the containers over; therefore, a weight between 6 and 8 lbs is ideal.

8) *Free of Weed Seed and Harmful Pathogens.* The medium should be free of weed seed and harmful soil pathogens, i.e. *Pythium*, *Phytophthora*, *Rhizoctonia*, etc. If the ingredients are not free of weed seed and pathogens, the grower must treat them in one of the following ways to eliminate these harmful factors. *Chemical fumigation* — the use of chemicals such as methyl bromide. *Steam pasteurization* — both aerated and regular; in this procedure the soil mix is heated to a high enough temperature to kill most of these harmful pathogens and weed seed. *Composting* — this is a procedure which is becoming accepted. In this procedure enough fertilizer, normally ammonium nitrate, is added to the mix to insure raising the tem-

perature of the mix to a high enough temperature for a period of six weeks to destroy harmful organisms. Leaching of the excess ammonium nitrate is required before the containers can be planted. We prefer to use a combination: gasing certain ingredients, i.e., rice hulls, with methyl bromide, and then composting the entire mix.

9) *Low in Salinity and Toxic Elements.* Soil amendments should not contribute to the overall salinity of the mix. Excess salinity, due to fertilizing, must be easily leached in order to have a good container mix. The ingredients should not contain excessive mineral elements in high enough concentrations to be injurious to plant materials.

10) *Stable Under Chemical or Steam Treatments.* Ingredients must be stable to such treatment.

11) *Handleable and Mixable.* Ingredients should be able to withstand handling by front-end loaders, soil mixers, can fillers, etc. They should also be easy to mix together and, after mixing, should not separate readily. Good mixing techniques and equipment should be used to insure a consistent growing medium and thus reduce the variables we have been discussing.

12) *Low Fertility.* Ingredients should contain little or no fertility so the grower can add the essential fertilizer elements in proper proportions. This will require the application of some elements during mixing, planting, and growing either by hand-feeding or the use of liquid fertilization. Soil tests and/or tissue tests should be made periodically during the growing season to determine which nutrient elements need replenishing and how much is needed.

13) *Stability in Storage.* Ingredients should be stable in storage and not subject to chemical changes or shrinkage or, stated another way, relatively slow to decompose. Straw and sawdust, for example, decompose much faster than pine bark (2).

There are other factors to consider outside of the container such as site preparation and water.

Site Preparation – The areas where the containers are placed should be well prepared, hard-surfaced areas to provide for adequate drainage.

WATER

It is extremely important to consider several factors about the water source just as in the selection of medium.

1) *Water Quantity.* A nursery must have an endless supply of this precious commodity. It is better not to reuse runoff water because the fertility of such water is unknown and it could spread diseases.

2) *Water Quality.* The water must also be low in salinity, free of harmful pathogens, free of weed seed, and contain no toxic elements or elements in excess. Plant injury will result if certain elements are in excess.

3) *Type of Irrigation System.* The type of irrigation system also affects decisions on the soil mix.

Overhead Sprinklers. The use of overhead rotary sprinklers or some type of overhead system is most commonly employed. However, proper spacing of the sprinklers is required to do an adequate job since sprinklers throw different amounts of water at different distances. It is advisable to have gas cocks or valves on each sprinkler for cleaning out debris during operation and to be able to cut selected sprinklers off thus making the water system more flexible.

Tube Systems. This system employes a tube running to each container. Tube systems, when installed properly, deliver an exact amount of water to each container, do not waste water, and allow the foliage to remain dry. These systems do have their drawbacks, however. They are not feasible for one gallon and smaller containers, rabbits and rodents eat the tubes, and feeder tubes are easily knocked out of the containers.

There are three things that happen to water inside a container: 1) gravitational water runs out the drain holes 2) evaporational water returns to the atmosphere and 3) transpirational water is used by the plant.

PLANTS

Plant Requirements for Water & Nutrients. Plants have varying needs for water and nutrients and more research is needed in these two areas. Yuccas do not require the same amount of water as waxleaf ligustrum. Plants should be grouped based on their water, fertility and spray requirements. This means planting charts must be prepared well in advance of planting just as one prepares propagation schedules in advance.

Raulston (5) has reported that the total leaf area appears to be more important in determining water loss than species, shape, size or foliage characteristics. Raulston further states that, in low transpiration plants, i.e. *Podocarpus*, with large medium surface exposure, twice as much water was lost by evaporation from the medium as through transpiration. In other species, i.e. *Ligustrum*, the medium surface areas were shielded from the sun and wind by the larger vegetative growth. One must conclude that plants should be grouped based on their overall size, larger plants thus requiring more watering than smaller plants. For this reason 1, 2, and 4 gallon containers should not be treated alike, but plants should be watered based on their needs. It might be necessary for growers to have 5 or more watering classifications, as we do, if they are planning to grow a wide range of plant materials.

Large plants, such as Wheeler's dwarf pittosporum, develop canopies which act like umbrellas and make it almost impossible to get water into the container with overhead irrigation. The color of the containers, amount of exposure to sunlight and spacing of the containers also affect the amount of water required. It is possible to alter temperatures by occasional overhead watering during the heat of the day, thus taking advantage of its evaporative cooling effect.

In conclusion, there are many factors and variables that must be considered in soil/air/water relationships. The key is learning to manage these variables to the grower's advantage.

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SOIL ADDITIVES FOR IMPROVEMENT OF WATER RELATIONSHIPS

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Abstract. Soil drainage influences soil color; state of oxidation of iron, manganese, nitrogen, sulfur, and other elements; soil acidity; type and activity of microorganisms, production of certain toxic substances; and soil temperature. Poor drainage of many soils has encouraged consideration of several additives for the improvement of water relationships. Gypsum ($CaSO_4 \cdot 2H_2O$) has been found to be an excellent material for use in maintaining soils in good structural condition and for reclaiming structure in soils where poor structural conditions exist.

Soil Additives: Need. Soil additives come in many different sizes, shapes and forms. For the container grower, vermiculite, perlite, humus, sand, gravel, pine bark, etc. are very much a part of his mix. For many, one or a combination of the above may constitute the entire medium. But what about field grown