An investigation of moisture retention in rhododendron soils

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FINAL

Abstract

Towards designing a soil that is suited to Rhododendron growth in the University's Arboretum, we have measured the dehydration of four soil mixtures over time. Readings were taken quasi-periodically with a plant probe. Our target soil would be 25% water-saturated, representing a loss of 10%, after one week. The mixtures consist of various doses of sand, peat, and vermiculite. None of the candidates met the target within the preset tolerance (±1%). We infer, by interpolating between our data, that peat moss is the critical ingredient for the retention of water, and that vermiculite accelerates the rate of water loss. We further speculate that the rate of moisture loss could be mediated by varying the mass ratio of vermiculite or sand.

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1. Introduction

Rhododendrons belong to the Ericales, an order of plants that are adapted to acidic soils. The root systems are frequently adventitious, and thus require soils that are well-oxygenated. Soil ventilation is crucial for the proper growth and flowering, and as such, is a major determinant of the overall splendor of the plant. Factors that contribute to ventilation include porosity, drainage, and climate. Porosity is well characterized in the literature, and can be controlled by the selection of soil type.

The Arboretum is populated by several species of Rhododendrons, and we were charged with the design of a soil recipe that would retain water at a concentration of 25 ± 1% over one week. Our purpose is the provision of a soil mixture for the rapid growth of low-upkeep Rhododendrons in this Arboretum.

We explored this problem by creating four test soils, which contained various combinations of sand (hereafter referred to by ‘S’), peat moss (‘PM’), and vermiculite (‘V’). These mixtures were watered to an initial concentration of 35% and left to dry in a controlled environment. Each soil had a different porosity, and hence, should exhibit different rates of water loss. These rates are reflected in the time-course of moisture, which we assayed by standard probing techniques.

In this report, we shall restrict our discussion to the experiment outlined above. That is, we shall only consider *porosity* as the independent variable (along with time, naturally). We are not measuring the *in vivo* loss of water from the soil, as it would depend on the rate of transpiration through the plants’ leaves. Rather, we are concerned with the native soil only (no plant was involved). Based on our data, we are able to provide recommendations for the design and optimization of an ideal soil for Rhododendron culture.

2. Materials

The reagents used in this study were sand, vermiculite, peat moss, and tap (non de-ionized) water. The exact composition of the soil mixtures is provided in TABLE 1. The recipes therein reflect the initial contents of the mixtures. Water is the only ingredient that is time-varying.

Table 1 **Net volumes of ingredients in soils.** Volumes are given such that the final mixture volume is I L, based on the combination of materials shown in TABLE 3. The volume of water was estimated to give an initial moisture content of 35%.

Material	Total Volume Used (L)
Sand	4
Peat Moss	4
Vermiculite	4
Water	6.46 (1.62 per 3 L of mixture)

3. Apparatus

The experiment was implemented with the following items, and their multiples, as listed in TABLE 2. The neutron probe was constructed from a hollow sleeve of PVC, in which the sensor was insulated. The detector consisted of a bolus of Am-241 that was coated by a layer of Be. The returning slow neutron signal (resulting from the loss of energy that occurs upon collision with water) was transformed into current via a scintillator and photomultiplier array. The heights of the soil pots were not measured.

Table 2 **Apparatus used in this study.**

	Equipment	Purpose
4	8'' Plastic flower pots	To contain the contents of the soils
1	Mixing tub	To mix the contents of the soils
1	I L beaker	To measure volumes of solid and fluid materials
1	Neutron plant probe	To assay water content
1	Thermostat/barometer system	To keep temperature and pressure constant
1	Vacuum fume hood	To prevent the escape of vermiculite
1	Humidifier/dessicator system	To keep ambient humidity constant

4. Procedure

All preparations and measurements were done in a climate-controlled greenhouse. The sand and peat moss were taken from sterile stocks. Vermiculite was procured in its non-exfoliated form. All manipulations involving vermiculite were done under an inverse-flow fume hood as precaution against inhalation, as it is slightly noxious, and a carcinogen. These materials were apportioned into the flowerpots (previously autoclaved) according to TABLE 3. This was done using the beaker, measuring by 1 L or 1.5 L multiples to make a final volume of 3 L (e.g. soil A would be composed of 1 L of each material; soils B, C, and D would be composed of 1.5 L each of their two respective materials). These mixtures were then mixed and weighed. In this way, all mixtures were homogenous, not layered.

Water was added from a tap source. The mineral content of the water was not characterized. We estimated a volume that would give 35 % moisture content upon addition to the soil, as *measured* by the probe. In this way, we were able to calibrate the probe for all future measurements. Calibration drift was characterized over the course of the experiment by assaying the moisture from a source of pure water (known molarity of water), and found to be negligible.

The mixtures were placed in an isothermal and isobaric chamber. Temperature was maintained via a thermostat, and pressure was maintained at 770 mmHg throughout the entire experiment. Humidity was monitored and adjusted by a humidifier/dessicator system. Once per day (although the time varied) the moisture content of each mixture was probed. Data were taken over one week. These measurements were done by immersing the probe 25 cm into the soil pot, a distance commensurate with the depth of

Rhododendron roots. Only one reading was taken for each pot on each day. On the sixth day, the readings were not taken, and thus are omitted from our data.

The data were plotted on a linear scale using standard software. Measurement times were binned into days, instead of using absolute hours. This is valid since all measurements were taken nearly at the same time.

Table 3 **Compositions of four soil mixtures.** It was not specified whether the amounts of each substance were given as mass percentages, or volumes.

Soil	S (% of solid volume)	PM (% of solid volume)	V (% of solid volume)	Initial Water (% of total volume)
A	0.33	0.33	0.33	35
B	0.00	0.50	0.50	35
C	0.50	0.00	0.50	35
D	0.50	0.50	0.00	35

5. Results

Our raw data is shown as an array in TABLE 4. We found that moisture content decreased in all soils over time, though at different rates. Soils B and D presented ending moisture levels that flanked, but fell outside of, the desired 25 ± 1% target window.

Table 4 **Probe data collected over one week for four soil mixtures.**

	Moisture (%)			
Day	**Soil A**	**Soil B**	**Soil C**	**Soil D**
1	35	35	35	35
2	30	32	22	28
3	26	32	5	26
4	22	30	0	24
5	20	30	0	23
6	-	-	-	-
7	18	29	0	21

6. Discussion

The time-courses for the loss of water from the four soil mixtures are shown in FIGURE 1. These data suggest that an ideal soil would contain peat moss, possibly because it is the only organic, and thus highly water-retentive material. The cellular biomass within peat moss explains the slower drying rates of mixtures containing it (soils B and D). Peat moss' porosity may also redound to its ability to hold water, as its granule structure would allow the percolation of water throughout the mixture, and inhibit its evaporation. However, the hydrating properties of the peat moss must be offset by a more arid substance, such as vermiculite or sand. In particular in two-material mixtures, either *more* vermiculate, or *less* sand, should be used than peat moss. We have interpolated this from soils B and D, which contain peat moss commonly, but produce final water contents that are outside of our target. This is not to say that an ideal mixture would only contain two materials, since a total mix might be necessary to maintain a biologically viable soil. Our data also suggests that vermiculite has a deleterious effect of water retention, as the exorbitant rate of water loss from soil C indicates.

Instrument (probe) and A/D conversion errors were estimated to be negligible compared to the size of the measurements. Human imprecision, during the initial watering, as well as during the mixing of soils, was estimated to be 2%.

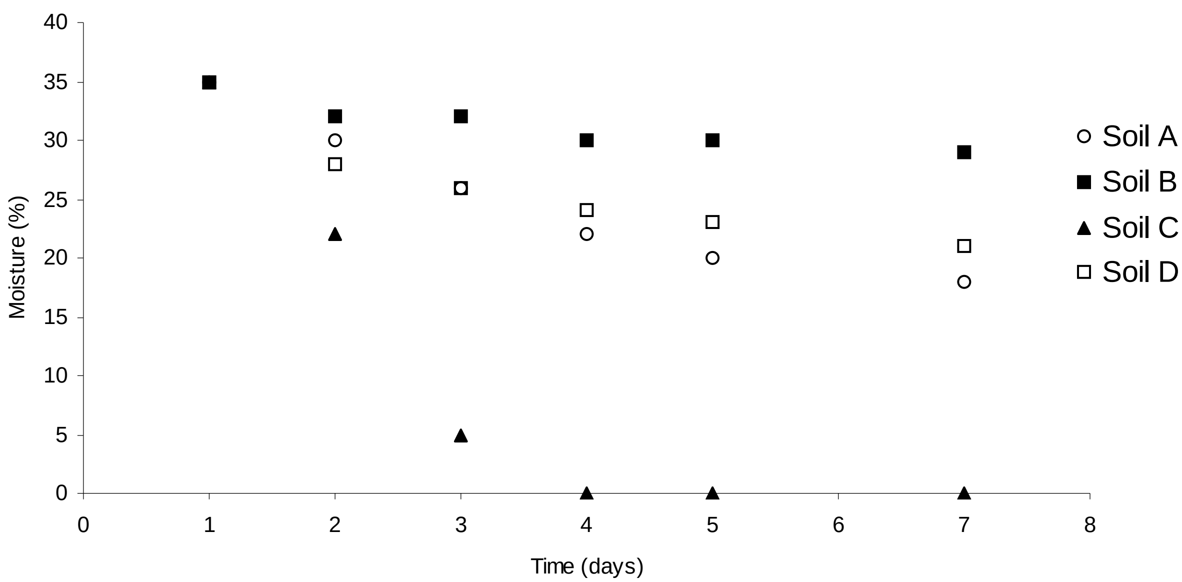

Figure 1 Loss of moisture from four different soil mixtures over one week. The data points on the first day overlap. The data from Soil B and soil C overlap on Day 3. Data from Day 6 was not recorded.

7. Conclusion

The probe data indicates that none of our four test soils met our target of 25 ± 1%. Peat moss was identified as the critical ingredient, as water retention was improved as its concentration was increased. Further, soil C, which had no peat moss, showed the fastest rate of dehydration. We conclude that it would be possible to design a more optimal soil by fixing equal portion of peat moss and sand, and then titrating the appropriate amount of vermiculite, or removing excess sand.

8. Recommendations

We put forward three recommendations for further studies in this area. Multiple data points should be acquired for each soil pot, on each day. This would facilitate a statistical analysis of the data, which is currently not possible, given its singularity. Further, the effect of layering the soil materials (peat moss, sand, and vermiculite), as apposed to homogenizing them, should be investigated. Finally, a general model-based method should be employed to predict the water retention of soils, irrespective of their contents. This could be done by measuring the rate of dehydration of each material individually, then solving a linear system involving these rates and their associated concentrations.