Scientia Horticulturae, 11 (1979) 9—17
Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

WATER RELATIONS OF NURSERY POTTING-MEDIA

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(Accepted for publication 12 February 1979)

ABSTRACT

Beardsell, D.V., Nichols, D.G. and Jones, D.L., 1979. Water relations of nursery potting-media. *Scientia Hortic.*, 11: 9—17.

The available water-holding capacities (AWHC) of different potting-materials varied widely; coarse sand has a very low AWHC, and peat moss, sawdust, poppy straw and brown coal each have a high AWHC. The AWHC determines the length of time taken for plants to wilt, except in the case of peat moss and pinebark. Much of the available water in peat moss is rapidly lost through evaporation and easy exploitation by the plant. Pinebark, because it resists water loss through evaporation, and because its available water is not readily accessible to the plant, is able to maintain plants unwilted for a longer time than peat moss despite its lower AWHC. The AWHC and wilting-time of mixtures of 2 potting materials can be predicted from their individual properties.

INTRODUCTION

Plants grown in containers have only limited access to water. After aeration, the next most important physical property of a potting-medium is a high water-holding capacity. Different potting-materials are known to vary widely in their water-holding capacities (Boggie, 1970). A previous paper (Beardsell et al., 1979) showed that experimentally determined available water-holding capacities (AWHC) of mixtures of 2 potting-materials could be predicted from their individual AWHC. This work also showed that peat moss had the highest AWHC of the range of potting-materials that were tested. Nursery experience, however, indicates that although peat moss contains a large amount of water, it cannot prevent plants from wilting for very long. This has been attributed to water loss by evaporation due to the "wick effect" of peat moss (Laurie and Ries, 1950).

A wilting-experiment was set up to study the water relations of 8 potting-materials alone and in certain combinations. This experiment was designed to determine the water loss from the media due to both evaporation and transpiration. We also wanted to determine whether the water relations of 1:1 mixtures of the materials could be predicted from the water relations of the individual components.

MATERIALS AND METHODS

Potting-materials. — The 4 organic potting-amendments, peat poss, pinebark (from *Pinus radiata*), hardwood sawdust (from *Eucalyptus camaldulensis*) and composted poppy-straw waste, and the 4 mineral materials, coarse sand, sandy loam, scoria (particle size ⩽ 6 mm) and brown coal (a mixture of powdered and granulated brown coal with particle sizes ranging from dust to 8 mm), were each put into twenty 13-cm pots. Each of the 4 organic potting-amendments was also mixed in equal proportions with each of the 4 mineral materials, giving a total of 24 different potting-media, each replicated 20 times. The pH of all of the potting-media, except scoria which has a natural pH of 7.5, was adjusted to 6.0—6.5. The volume of potting-media in each pot was 650 cm^3.

Plant culture. — Marigold seedlings (cultivar 'Jubilee') were planted into 10 of the pots of each media. The plants were liquid-fertilized for 10 days before the start of the experiment. The trial was carried out in a glasshouse supplied with supplementary heating and cooling.

Water loss. — All pots in the experiment were thoroughly saturated, and after 2 hours of draining the initial weights of the pots and their contents were measured. No further watering of the pots was carried out. The pots (and their contents) were weighed daily until the fifth day and every second day from then onward. The dry weights of the media were determined by oven drying at 102°C. All data are expressed as volumetric moisture percentage (Ayres et al., 1972).

Wilting time. — The time taken to the first sign of wilting was recorded. This stage was defined as "Stage 1" wilting. The time taken for all leaves to wilt was also noted and defined as "Stage 2" wilting. Finally, the time taken for the plants to wilt irreversibly was noted and defined as "Stage 3" wilting. Although irreversible wilting (Stage 3) is, by definition, the wilting-point, we placed more importance on the point when all leaves were wilted (Stage 2) because plants beyond this stage are of no use to nurserymen.

RESULTS

Available water. — Table I shows that the time taken for plants to wilt is not necessarily proportional to the amount of available water held in the materials. It is true that coarse sand maintains plants unwilted for only 4.3 days because of its low AWHC of 24.8 volume percent (Table I), and sandy loam, scoria, brown coal, sawdust and poppy straw maintain plants unwilted for a longer time in proportion to their higher AWHC. However, peat moss maintains plants unwilted for only 7.3 days, yet it has a very high AWHC. Pinebark, although it contains 11.7 volume percent less available water than peat moss (Table I) can maintain plants unwilted for 10.4 days.

TABLE I

The relationship between the available water-holding capacity, unavailable water and plant wilting for various potting-media

Material	Days to Stage 1 wilting	Days to Stage 2 wilting	Days to Stage 3 wilting	Available water (volumetric moisture %)	Unavailable water, remaining at Stage 2 wilting (volumetric moisture %)
Coarse sand	4.0	4.3	5.0	24.8	4.5
Scoria	5.3	7.1	8.8	34.7	6.6
Peat moss	5.7	7.3	9.0	50.2	6.1
Sandy loam	6.5	7.8	9.4	30.8	4.5
Brown coal	6.7	9.4	11.0	47.8	27.5
Pinebark	10.1	10.4	>14	38.5	13.7
Sawdust	10.0	11.6	>14	51.9	12.3
Poppy straw	8.1	12.0	>14	50.8	12.3
L.S.D. $P = 0.01$		1.42	On Stage 2 wilting-data		
L.S.D. $P = 0.05$		1.08			

Figure 1 shows that for all 3 stages of wilting, peat moss has a higher AWHC than would be expected from the relationship of AWHC versus wilting-time of the other media. The regression curve relating the AWHC of all the potting-materials except peat moss to all stages of wilting is not significantly different to the curve relating AWHC to Stage 2 wilting only ($Y = -7.5 + 0.62\,X - 0.0050X^2$, $r = 0.85^{**}$).

The good regression lines relating the AWHC of each material with all 3 stages of wilting (Table II) show that no matter what stage of wilting is used, the time taken to wilt is directly related to the AWHC of each individual material.

TABLE II

Relationships between available water-holding capacity (X) and time taken for the 3 stages of wilting (Y) for each material

Material	Equation	Regression coefficient	Significance
Coarse sand	$Y = -\ 0.82 + (0.22 \pm 0.10)\,X$	0.51	5%
Scoria	$Y = -13.00 + (0.58 \pm 0.09)\,X$	0.76	1%
Peat moss	$Y = -11.56 + (0.38 \pm 0.06)\,X$	0.79	1%
Cranbourne sandy loam	$Y = -\ 5.69 + (0.45 \pm 0.09)\,X$	0.71	1%
Brown coal	$Y = -\ 6.96 + (0.34 \pm 0.05)\,X$	0.85	1%
Pinebark	$Y = +\ 8.54 + (0.50 \pm 0.13)\,X$	0.77	1%
Sawdust	$Y = -\ 6.90 + (0.77 \pm 0.18)\,X$	0.13	
Poppy straw	$Y = -\ 0.87 + (0.23 \pm 0.06)\,X$	0.75	1%

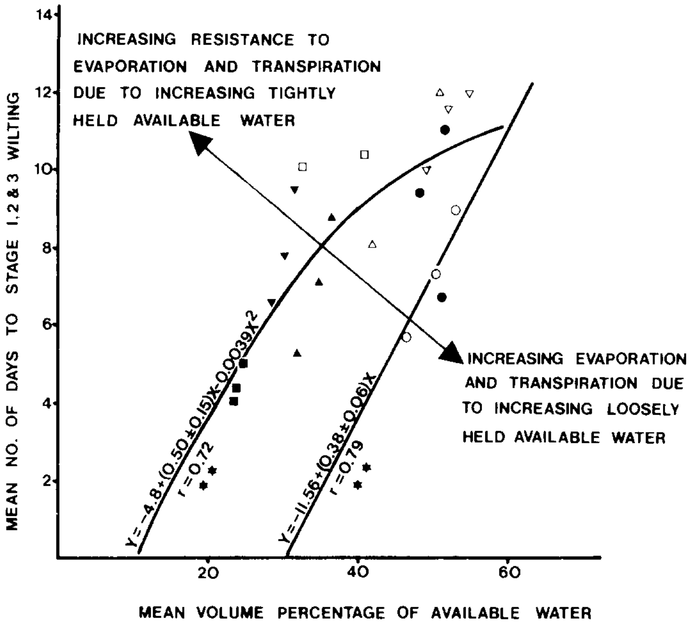

Fig. 1. The relationships between the amount of available water and the time taken for plants to reach each of 3 stages of wilting. The curvilinear function is the relationship for all media except peat moss. The linear function is the relationship for peat moss alone. The materials represented are coarse sand (■), sandy loam (▼), scoria (▲), brown coal (●), pinebark (□), poppy straw (△), sawdust (▽) and peat moss (○).

Evaporation. — The water loss from the pots which did not contain plants is considered to be almost entirely due to evaporation. Some water loss may be attributed to microbial activity but this is probably negligible.

Figure 2A shows that peat moss loses half its water by evaporation in a little over 6 days. The rate of water loss through evaporation is also very high for brown coal. Poppy straw, scoria and coarse sand lose less water through evaporation, while sawdust and especially pinebark resist water loss through evaporation.

Transpiration. — When plants are grown in pots, there is additional loss of water by transpiration. A reduction in evaporation of water may have resulted from shelter by the plant canopies, but this was probably small. Figure 2B shows the total loss of water from the potting-media through evaporation and plant transpiration. The most important feature is the rapid loss of water from peat moss caused by plant transpiration. The resistance to water loss from pinebark due to transpiration is also evident.

Calculation of the separate effect of transpiration in Fig. 3A shows that plants transpire more water from peat moss than from any of the other organic amendments, until water in it becomes limiting. Both poppy straw and pinebark and, to a lesser extent, sawdust do not allow high transpiration rates.

Figure 3A and B shows that plants do not transpire as rapidly in coarse sand, scoria and brown coal as they do in peat moss. Sandy loam also limits plant transpiration (Fig. 3B), possibly because of its poor aeration and drainage properties.

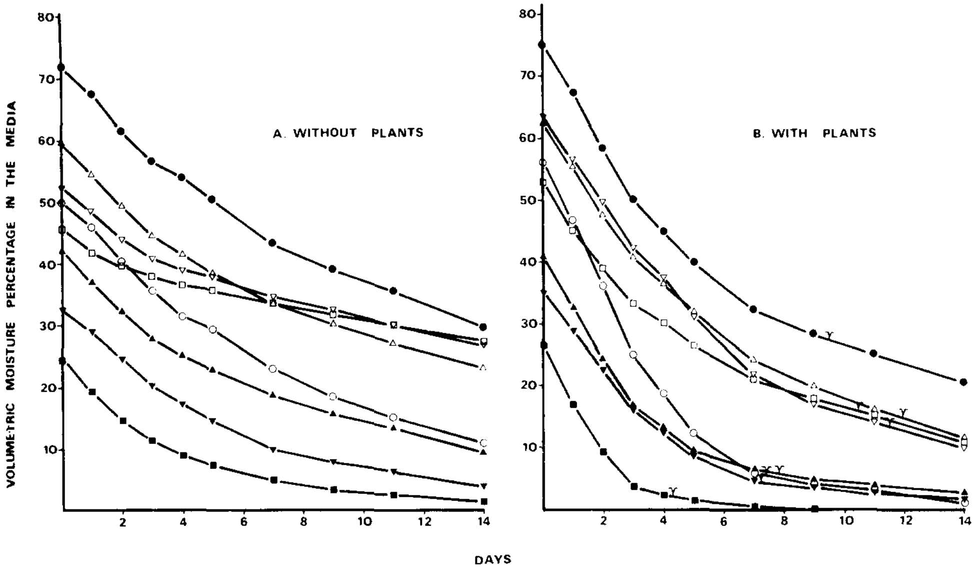

Fig. 2. (A) Water loss from the media without plants. (B) Water loss from the media containing plants. The materials represented in both figures are coarse sand (■), sandy loam (▼), scoria (▲), brown coal (●), pinebark (□), poppy straw (△), sawdust (▽) and peat moss (○). Wilting-point (Stage 2) is marked for each material by an arrow.

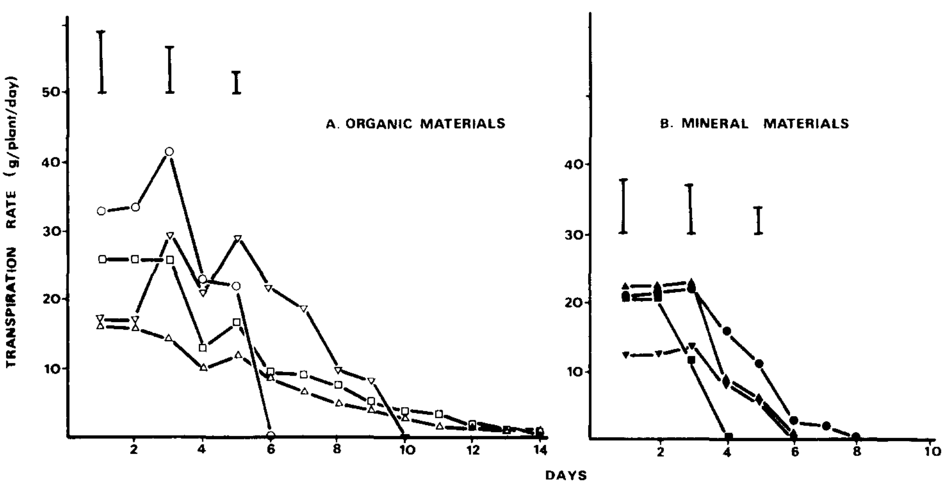

Fig. 3. (A) Daily rate of transpiration from marigolds growing in each of the 4 organic amendments. Bars represent LSD 5% on the data for Day 1, Day 3 and Day 5, respectively. The materials represented are peat moss (○), pinebark (□), sawdust (▽), and poppy straw (△). (B) Daily rate of transpiration from marigolds growing in each of the 4 mineral materials. The materials represented are scoria (▲), brown coal (●), coarse sand (■) and sandy loam (▼).

Unavailable water. — Brown coal has by far the greatest amount of unavailable water (see Table I). Pinebark, poppy straw and sawdust have a moderate amount of unavailable water while scoria, peat moss, sandy loam and coarse sand contain very little unavailable water.

Potting-mixtures. — Table III shows that both the time taken for wilting to occur and the AWHC of 1:1 mixtures of 2 materials (one an organic amendment and the other a mineral material) can be predicted fairly accurately from the known properties of the ingredients.

TABLE III

Wilting-time (WT) and available water-holding capacity (AWHC) expressed as volumetric moisture percentage

Mixture	Predicted WT	Actual WT	Predicted AWHC	Actual AWHC
Sawdust/sandy loam	9.7	11.2	41.4	46.1
Sawdust/scoria	9.4	9.0	43.3	44.9
Sawdust/sand	8.0	7.5	38.4	40.6
Sawdust/brown coal	10.5	8.8	49.9	46.4
Pinebark/sandy loam	9.1	11.0	34.7	36.8
Pinebark/scoria	8.8	8.9	36.6	39.5
Pinebark/sand	7.4	8.1	31.7	30.6
Pinebark/brown coal	9.9	9.3	43.2	41.6
Poppy straw/sandy loam	9.9	8.6	40.8	43.4
Poppy straw/scoria	9.6	8.7	42.8	43.7
Poppy straw/sand	8.2	7.0	37.8	40.9
Poppy straw/brown coal	10.7	9.6	49.3	54.7
Peat/sandy loam	7.6	6.6	40.5	47.4
Peat/scoria	7.2	8.2	42.5	48.0
Peat/sand	5.8	5.8	37.5	40.6
Peat/brown coal	8.4	9.2	49.0	50.4

Regression equations:

predicted wilting-time versus actual WT $Y = 3.13 + (0.66 \pm 0.17)\,X$; $r = 0.70^{**}$.

Predicted AWHC versus actual AWHC $Y = 6.34 + (0.80 \pm 0.12)\,X$; $r = 0.88^{**}$.

DISCUSSION

The distance above the regression curve which relates wilting-time to the amount of available water (Fig. 1) can be interpreted as representing a combination of increasing tightly held available water and/or increasing resistance to water loss through evaporation for any material (e.g. pinebark). Distance below the regression curve represents an increasing proportion of loosely held available water and/or increasing water loss from evaporation for any material (e.g. peat moss). An important result of this, is that the standard technique of measuring the AWHC of soils used in a previous paper (Beardsell et al., 1979), does not give meaningful estimates of the real water relations of potting-materials. The only meaningful measure of the AWHC of a potting-medium comes from the performance of plants.

Poppy straw has the best water relations of all the materials that were tested because of its high amount of available water (Table I), because of its regulated water supply to plants (Fig. 3A) and because of its moderate resistance to evaporation (Fig. 2A). Sawdust also has excellent water relations because of its high level of available water (Table I), because it resists evaporation (Fig. 2A) and because it also exerts a small regulating effect on plant transpiration (Fig. 3A). Pinebark, because it strongly resists water loss through evaporation (Fig. 2A) and because it does not allow plants readily to exploit its available water (Fig. 3A), can maintain plants unwilted for almost as long as poppy straw and sawdust even though it has much less available water (Table I). Brown coal waste has fair water relations (Table I), mainly due to its high AWHC. Although water evaporates fairly readily from brown coal waste (Fig. 2A), plant transpiration is not as high as in peat moss (Fig. 3A and B). The high level of water initially held in brown coal (Fig. 2A) is offset by the high level of unavailable water held. Peat moss has fairly poor water relations because its very high AWHC is offset by a very high rate of water loss through evaporation (Fig. 2A) and transpiration (Fig. 3B). Since peat moss allows greater transpiration, plants growing under optimum conditions would grow faster in this material. If nursery practice allows plants to wilt in peat moss, the extra growth would not, however, be attained. Scoria, sandy loam and coarse sand all have poor water relations because of their poor AWHC.

While the potting-materials have widely different water relations (Fig. 4), both the time taken for wilting to occur and the AWHC of 1:1 mixtures of 2 materials can be fairly accurately predicted from the known properties of the ingredients. The materials used in this experiment simply added their water-holding properties to those of the mixture. There are no significant interactions between any of the potting-materials in the mixtures tested. This is the same result as was shown earlier for the aeration properties (Beardsell et al., 1979). Work by other authors (Richards et al., 1964; Boggie, 1970; Hunter and Whiteman, 1975; Brown and Pokorny, 1977) has shown that the physical properties of 2 different potting-materials are also additive when mixed in ratios other than 1:1. The nurseryman can be fairly confident that he can make up a potting-mixture of specific physical properties, such as good aeration or good water relations, by manipulating ingredients which have different properties.

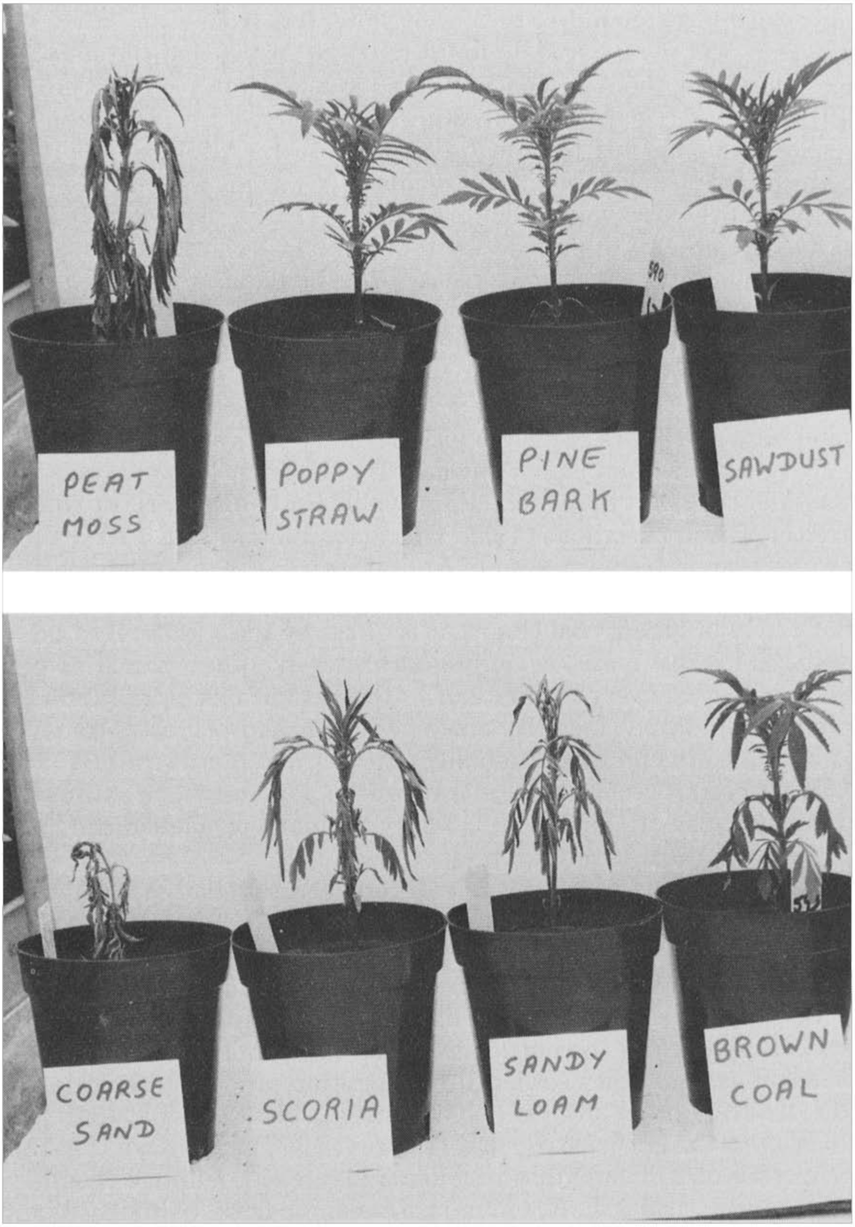

Fig. 4. Marigolds in the 8 different potting-materials after 8 days without watering in a glasshouse.

ACKNOWLEDGEMENTS

We would like to thank Mr. R. Jardine for advice and statistical analysis. We would also like to thank Miss A. Hallpike and Messrs. J. Robertson and W. Robertson for technical assistance.

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