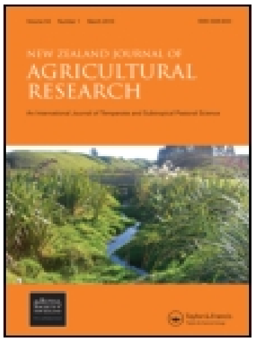

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Evaluation of potting media for commercial nursery production of container-grown plants

IV. Physical properties of a range of amended peat-based media

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A range of peat-based container media was prepared by additions (0, 25, 50, 75, 100%) of a New Zealand commercial nursery amendment (sand, perlite, pumice, sawdust, bark chips or soil) to the Mataura peat. Physical properties related to air–water relationships were studied for their suitability as peat substitutes for container-plant production. Peat and perlite showed water-release characteristics which approached those most suited for use in container plant production. Increasing additions of sand, pumice, sawdust, or bark to peat resulted in less water relative to air being held in the media at tensions less than 100 cm water. Sand, pumice, sawdust, and bark released a large proportion of their water at less than 50 cm tension. Over 80% of the total pore space in sand and pumice, and about 70% in sawdust and bark, was occupied by the macropore water (0–100 cm tension). Additions of soil to peat decreased the proportion of macropore water and also the proportion of air to water in the media. Total pore space did not measure container aeration as well as did air capacity measurements. Container capacity changes much faster than total pore space after changes in the pore size distribution of peat-based media from the additions of either pumice, sawdust, or bark to the peat.

INTRODUCTION

Many ornamental plants are grown in containers. Container media, containing large amounts of organic and inorganic amendments, are used to extend limited soil supplies or for improving the properties of soils used. Materials commonly used in New Zealand include peat, sand, pumice, perlite, sawdust, bark, and soil.

The use of containers alters the normal soil–plant relationships because containers are small and shallow. This means that large quantities of water needed to sustain plant growth must be available within a small volume of the medium. The shallowness of the medium also causes excess moisture content (poor aeration) problems because of a zone of saturation at the bottom of the container, which extends upward, its height depending on the moisture characteristics of the medium (Spomer 1974a). Hence the concept of soil "field capacity" is replaced by "container capacity" (White & Mastalerz 1966) which is controlled by both the nature of the medium and the size and shape of the container.

Physical properties of a number of commerical potting media have been studied (e.g., Bunt 1961a, b; Richards *et al.* 1964; Waters *et al.* 1970; Goh & Haynes 1977). Some aspects of air and water relations in container media have been reviewed (Arnold Bik 1973; Spomer 1975). However, in practice optimal water storage and aeration properties are found by a "trial and error" method.

Recently, attempts have been made to rationalise changes in physical properties as amendments are added to the soil. For example, Spomer (1974b) has introduced the concept of the "threshold proportion" or the minimum amount of monodispersed amendment that must be added to a soil before aeration improves. This forms the basis of a theoretical method of predicting the total porosity and aeration of any container soil mixture. Other workers (e.g., Verdonck *et al.* 1974) have examined water and air economy of horticultural substrates with the aid of water release curves in the very low tension range (< 100 cm water).

The objective of the present study was to investigate changes in physical properties of peat-based container media with increased addition of amendment (sand, perlite, pumice, sawdust, bark chips, and soil) to ascertain their suitability as peat-substitutes in container plant production

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TABLE 1 — Distribution (%) of particle size of constituents used in potting media from dry sieve analysis

Particle size (mm)	Peat	Sandy gravel	Perlite	Pumice	Sawdust	Bark
> 5	13.8	21.7	1.4	7.9	6.2	54.1
5.0–2.0	14.0	36.6	17.1	27.7	25.4	18.5
2.0–1.0	19.1	20.2	22.3	37.8	45.2	16.1
1.0–0.5	17.5	9.2	16.5	18.0	16.7	6.2
0.5–0.3	16.4	5.4	18.7	6.3	3.8	2.0
0.3–0.06	16.8	5.6	14.5	1.2	1.6	1.9
< 0.06	2.2	0.9	9.1	0.8	0.7	1.5

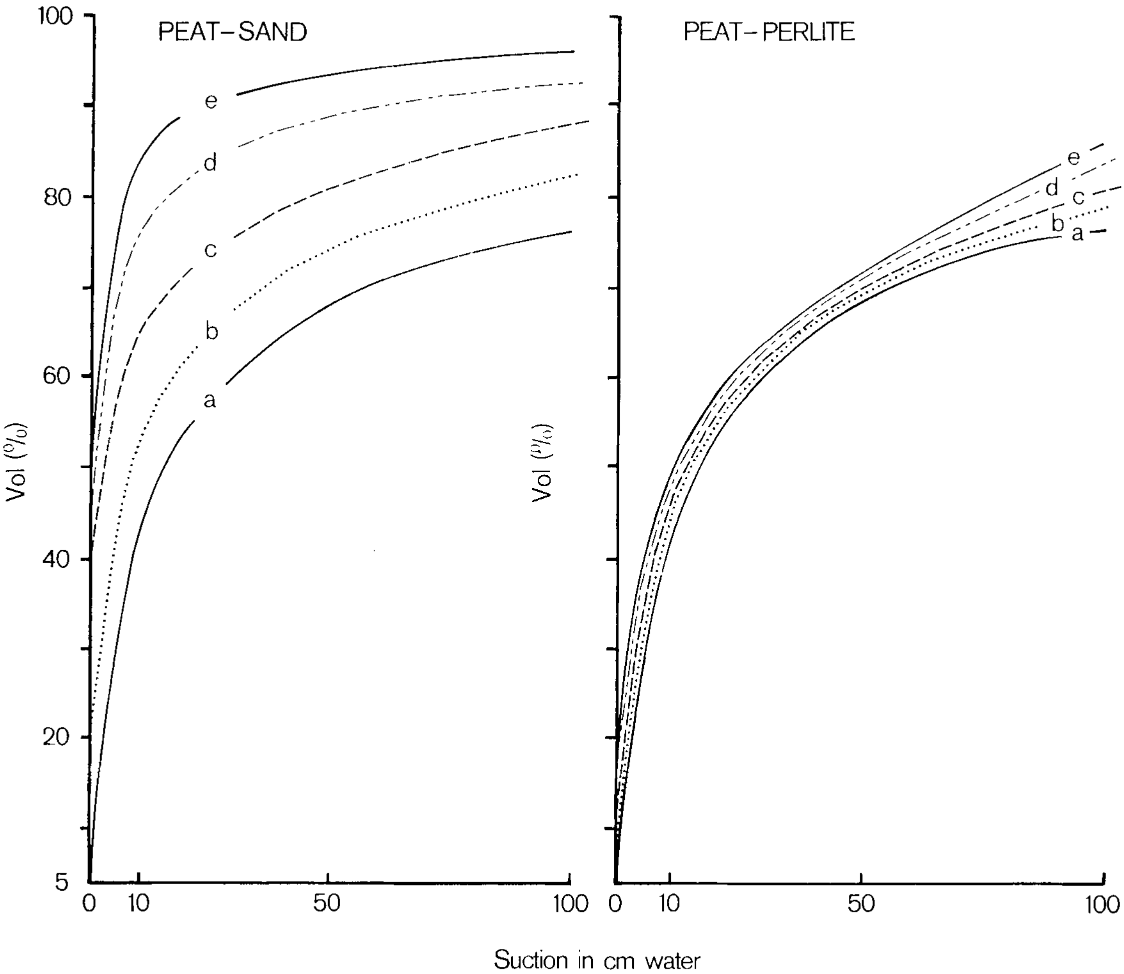

Fig. 1 — Water-release curves of peat-sand and peat-perlite media.

a = peat
b = peat-amendment 3:1
c = peat-amendment 1:1
d = peat-amendment 1:3
e = amendment

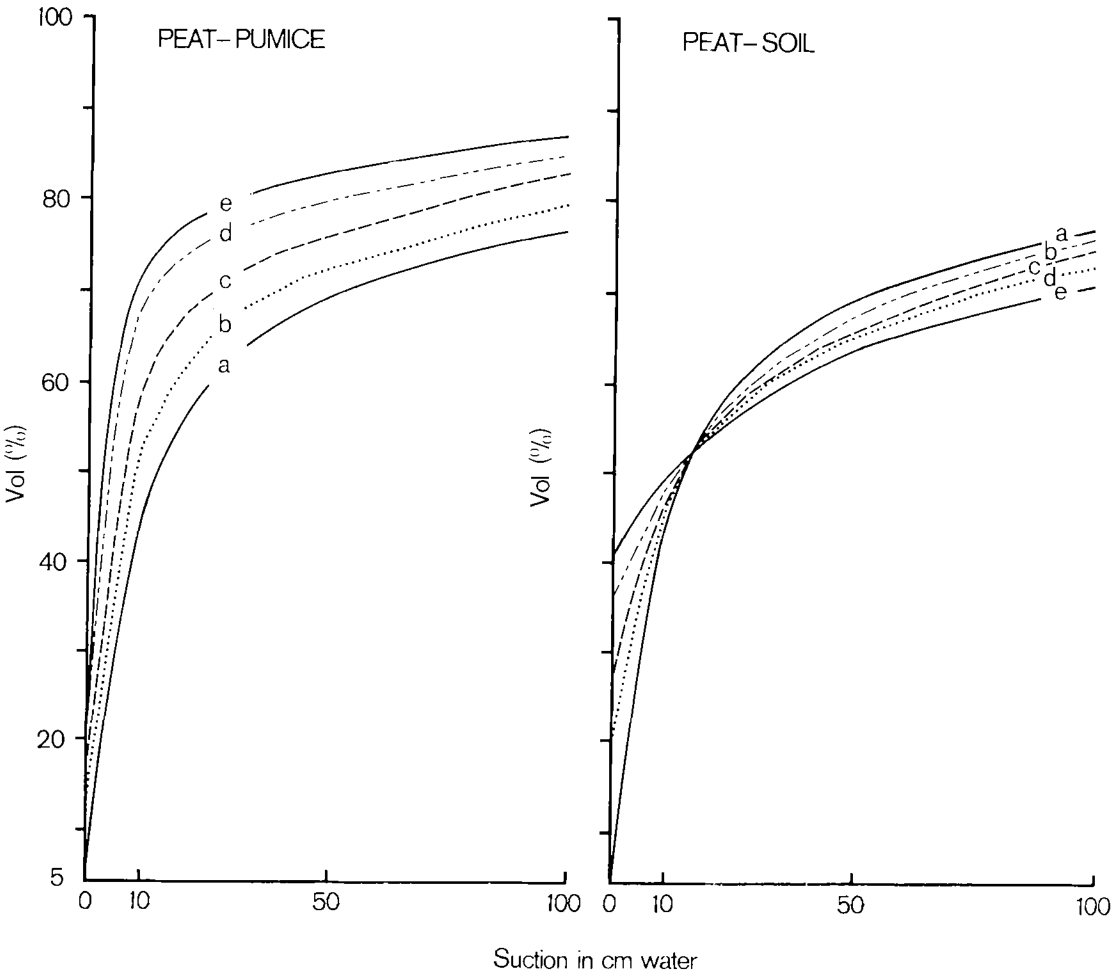

Fig. 2 — Water-release curves of peat–pumice and peat–soil media. For explanation of terms see Fig. 1.

MATERIALS AND METHODS

The soil, Waimakariri sandy loam, and the Mataura peat used in the present study have been described previously (Goh & Haynes 1977). Some characteristics of peat, sand (a sandy gravel), perlite, pumice, sawdust, and bark chips used from dry sieve analysis are shown in Table 1. Water release data were determined as previously (Goh & Haynes 1977). Definitions of the terms used to describe the physical properties of the media are presented in the Appendix.

RESULTS AND DISCUSSION

Water-release curves are shown in Figs 1, 2, and 3. Characteristics of the water and air capacity of the various potting media together with the values proposed by De Boodt & Verdonck (1972) for an ideal substrate are presented in Table 2. Water-release curves for peat sand, sawdust, and soil have been presented and discussed previously (Goh & Haynes 1977), although materials used in the present study were slightly different (see Table 1).

Water-release data are an important measure of the suitability of growth media for container plant production, since high rates of fertilisers are often used, resulting in a soil solution with a high osmotic pressure. Furthermore, the demand for water from a restricted volume of the container medium is high, particularly under glass Consequently, water must be made available at a low energy status, but air must also be available. It is not clear at what energy status the water should be, since Puustjarvi & Robertson (1975) claimed that it should be held in the region of

TABLE 2 — Some physical characteristics of container potting media

Medium	Total pore space (% volume)		Air space (% volume)	Easily available water (% volume)	Water buffering capacity (% volume)	Water tension (cm) at volume % water/volume % air = 1	Micropore water (% TPS)	Macropore water (% TPS)	Bulk density (g/cm³)	
Peat (P)	93.0	(90.0–98.1)‡	38.0	23.6	8.3	17	24.8	75.2	0.11	(0.09–0.14)
P-s 3:1	77.9	(73.9–82.3)	32.6	20.2	7.8	15	22.2	77.8	0.67	(0.64–0.70)
P-s 1:1	62.3	(59.8–65.0)	28.5	15.2	6.5	12	19.4	80.6	1.10	(0.98–1.14)
P-s 1:3	51.0	(50.1–51.7)	27.9	11.6	3.7	9	15.3	84.7	1.41	(1.38–1.44)
Sand (s)	40.8	(40.6–50.1)	26.9	7.8	2.3	6	9.3	90.7	1.62	(1.59–1.65)
P-perl 3:1	90.4	(87.9–91.3)	36.7	22.8	10.0	17	23.1	76.9	0.16	(0.13–0.18)
P-perl 1:1	85.9	(84.1–88.4)	32.9	22.5	11.4	17	22.2	77.8	0.16	(0.12–0.19)
P-perl 1:3	82.3	(80.2–83.5)	30.4	21.9	13.7	17	19.8	80.2	0.17	(0.14–0.20)
Perlite (perl)	80.8	(80.1–91.0)	30.3	21.0	15.4	17	17.5	82.3	0.16	(0.10–0.19)
P-pum 3:1	87.1	(80.6–92.3)	37.0	22.0	8.0	12	23.1	76.9	0.32	(0.28–0.37)
P-pum 1:1	83.2	(77.4–90.8)	40.2	18.8	6.8	11	20.9	79.1	0.43	(0.39–0.46)
P-pum 1:3	76.3	(69.8–83.9)	43.9	12.6	4.5	8	20.3	79.7	0.51	(0.50–0.34)
Pumice (pum)	74.1	(68.2–79.6)	46.4	10.4	3.9	7	18.1	81.9	0.62	(0.61–0.64)
P-soil 3:1	80.1	(77.4–84.9)	25.3	21.7	8.9	35	30.2	69.8	0.52	(0.50–0.56)
P-soil 1:1	72.8	(70.2–76.8)	18.8	19.6	9.4	47	34.3	65.7	0.81	(0.78–0.84)
P-soil 1:3	64.1	(60.8–67.1)	10.9	17.4	9.4	75	41.2	58.8	1.05	(1.01–1.08)
Soil	58.2	(57.8–58.9)	7.7	14.0	8.0	99	49.0	51.0	1.12	(1.10–1.15)
P-saw 3:1	91.5	(86.0–96.3)	39.1	22.1	7.1	14	25.4	74.6	0.11	(0.10–0.11)
P-saw 1:1	89.0	(83.7–93.7)	41.0	18.6	6.1	12	26.2	73.8	0.13	(0.11–0.14)
P-saw 1:3	87.9	(83.2–94.2)	44.2	15.1	5.3	9	26.5	73.5	0.14	(0.12–0.16)
Sawdust (saw)	86.1	(79.4–93.6)	47.0	11.3	4.6	8	26.9	73.1	0.15	(0.14–0.17)
P-bark	88.9	(82.4–96.3)	37.0	20.9	7.4	9	26.5	73.5	0.21	(0.19–0.23)
P-bark	87.0	(78.8–95.0)	40.4	16.0	5.9	14	28.4	71.6	0.23	(0.20–0.25)
P-bark	84.0	(75.6–93.6)	42.7	11.3	5.1	12	29.6	70.4	0.24	(0.22–0.26)
Bark	81.5	(68.9–91.1)	42.5	8.9	4.2	10	30.7	69.3	0.24	(0.23–0.25)
Ideal substrates†	85.0		20–30	20–30	4–10	15–25				

Each is the mean of 4 determinations
† From De Boodt & Verdonck (1972)
‡ Range values

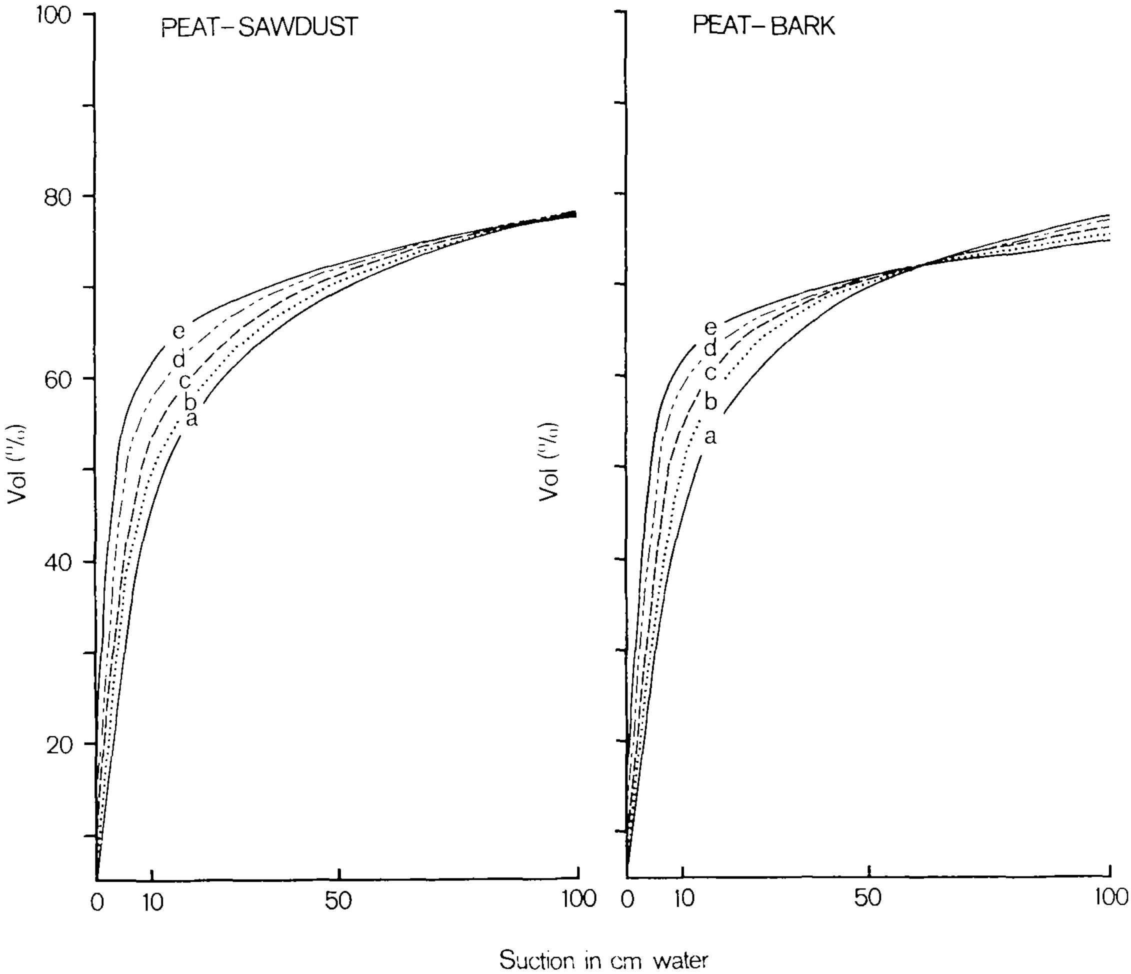

Fig. 3 — Water-release curves of peat–sawdust and peat–bark media. For explanation of terms see Fig. 1.

50–100 cm, and De Boodt & Verdonck (1972) stated that 75–90% of the total available water (easily available water, E.A.W.) should be relesed from 10–50 cm water tension. The proportion of air and water in the medium is impor tant, and results have shown that the ratio of volume % water to volume % air should be ± 1 between 15 and 25 cm water tension to provide optimal amounts of water and air in the root zone (Verdonck *et al.* 1974). Analysis of the water release curves (Figs 1–3) in terms of these considerations is presented in Table 2.

Peat and perlite show water-release curves which are very similar and approach those of an ideal substrate as proposed by De Boodt & Verdonck (1972) (see Table 2). At tensions greater than 50 cm, perlite loses its water more readily than peat, also reflected in the increase in the water buffering capacity (WBC) after perlite additions to peat. The proportion of total pore space (TPS) occupied by macropore water is much greater in perlite than peat (Table 2), indicating a different pore size distribution in these two media. The volume % water–volume % air ratio is 1 at 17 cm for both peat and perlite, which implies that both these media have a water–air distribution favourable for plant growth.

Pumice, because of its porous nature, holds more water than sand at all tensions, but the two substrates have very similar water release characteristics (Figs 1 and 2). Both have low WBC, showing that a large proportion of the water is released below 50 cm tension. Furthermore, most of their absorbed water is completely released at 100 cm tension, since the macropore

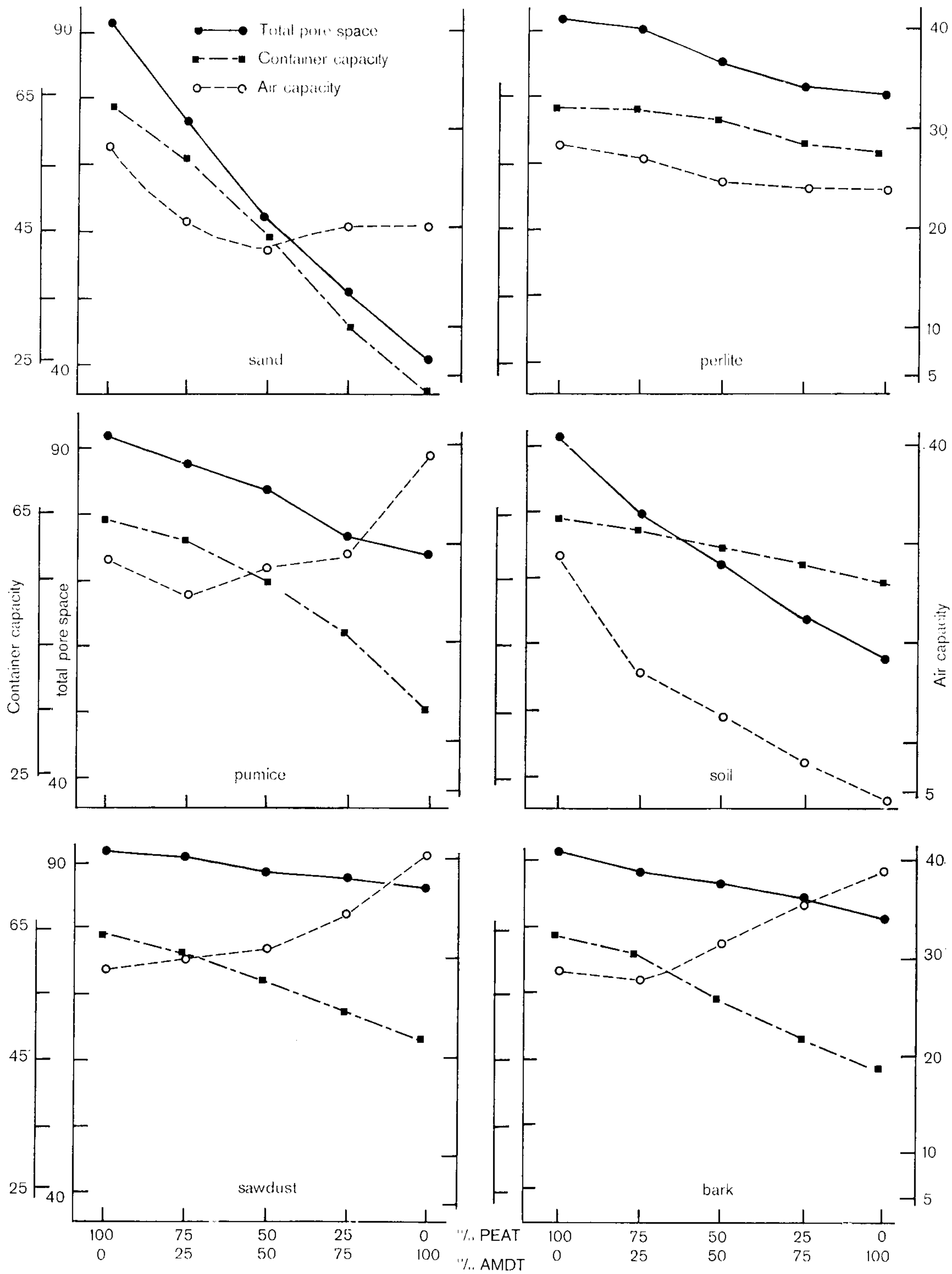

Fig. 4 — Effect of peat: amendment ratio on total pore space and air and container capacity of the medium. AMDT = amendment.

water accounts for 91 and 81% in sand and pumice respectively. Both media have rather low values of water–air ratios (6 and 7 cm respectively), indicating that there is a large amount of air in these media at 15–25 cm tension.

Sawdust and bark both release water very quickly, and, like sand and pumice, a high proportion of water is lost below 50 cm tension. However, micropore water is greater than that for peat although the volume of water held at 100 cm is similar. This probably reflects two components of moisture retention in these wood substrates. Water held around and between the wood particles is of low energy and is easily removed, and the water of high energy, which is more difficult to remove, is probably absorbed into the wooden materials. Like sand and pumice, these media have water–air ratios of 1 at low tensions.

The soil (sandy loam) releases its water very slowly. Micropore water accounts for 49% of TPS compared with 25% in peat. This reflects the fine aggregate structure of soil compared with the other horticultural substrates. The extremely high value for water–air ratio (99 cm) indicates there is too much water present in the soil media for optimal plant growth.

In general, water-release curves for the various mixed media varied according to the proportions of amendment added to peat.

Bulk density data (Table 2) show that peat, perlite, and sawdust have similar low values. Bark also has low bulk density, and densities for soil, sand, and pumice are much higher.

The results presented in Fig. 4 demonstrate that TPS is not necessarily a good measure of aeration. For instance, TPS decreases with increasing increments of pumice, sawdust, and bark additions, but air capacity increases. With soil and perlite additions, air capacity and TPS both decrease. Bunt (1974) observed that with the addition of sand to peat there was a linear reduction in TPS and air capacity showed a curvilinear reduction. However, it was pointed out that both peat and sand particle sizes are variable; thus there are no absolute values for a particular peat–sand ratio. With the peat and sand used in the present study, sand additions to peat resulted in a linear reduction in TPS, but air capacity first decreased and then increased. The addition of perlite to peat had little effect on TPS or air or container capacity. This is consistent with the very similar water-release characteristics of peat and perlite. Air capacity and TPS decreased rapidly with soil additions and container capacity was reduced slightly.

The phenomenon of a decrease in air capacity preceding an increase is observed after either sand, pumice, or bark additions to peat. This is probably due to a fitting together of the particles, the amendment filling the interpores of the peat. A similar observation was reported by Spomer (1974b) for the addition of a monodispersed river sand to a compacted silty loam which resulted first in a decreased porosity (aeration) until a minimum threshold proportion was reached before it increased until the medium was composed of 100% amendment. This was used by Spomer (1974b) as the basis of a theoretical method of predicting total porosity and aeration in a container soil mixture. However, in practice, horticultural growth substrates are not monodispersed but consist of many different sized particles (Table 1), thus complicating the matter greatly.

Air capacity is the difference between container capacity and TPS. Thus when container capacity decreases at a much faster rate than TPS, air capacity increases. This occurs with increasing additions of pumice, sawdust, and bark to peat.

CONCLUSIONS

The use of perlite as a peat amendment changes the physical properties of a growth medium very little; hence management techniques do not need to be altered.

However, with increasing additions of either sand, pumice, sawdust, or bark to peat, more air and less water is present in the medium at low water tensions. To maintain optimal plant growth, more frequent irrigation would be required. These media would be suitable for plants that are sensitive to waterlogging or where frequent irrigation is thought desirable, such as with a trickle irrigation system.

The use of a high proportion of soil in a medium may result in excess water and consequent oxygen deficiency in the medium, particularly with frequent irrigation. Increasing the amounts of sand, pumice, or soil in peat-based media increases their bulk densities and hence transport costs.

Our results indicated that total pore space is not necessarily related to the aeration of the container medium and that air capacity provides a much more meaningful measure of container aeration.

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APPENDIX

Definitions of terms:

Total pore space — the volme of water held by the medium at zero water tension.

Air space — the volume of water released between 0–10 cm water tension.

Easily available water — the volume of water released between 10–50 cm water tension.

Water buffering capacity — the volume of water released between 50–100 cm water tension. 21–6.

Macropore water — the volume of water released between 1–100 cm water tension.

Micropore water — the volume of water held at 100 cm water tension.

Container capacity — the volume of water held by a saturated medium in a pot after 48 h of drainage with no evaporation.

Air capacity — The difference in the volume of water held at zero water tension and at container capacity.