Addition of Pumice Affects Physical Properties of Soil Used for Container Grown Plants

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Summary

Aeration of horticultural media is often reported to be a problem. The air filled porosity is generally considered as the quality determining factor for media and is generally determining the shape of the moisture characteristic curve. The objective of this study was to determine affects of different size and rate of pumice mixed with soil on the pore size distribution and bulk density of a mixture medium. Pumice of different size (<4 mm, <8 mm, and 4-8 mm) and rate on volumetric basis (10, 20, 30, 40, 50 % v/v) was mixed with two types of loamy soils passed through an 8 mm sieve. The moisture characteristic curve and bulk density of each mixture media was determined. From the moisture characteristic curve pore size distribution was obtained. Aeration, water conductivity, and water retention of media were evaluated. The results indicated that total porosity increased with increasing rate and size of pumice. The amount of pores important for drainage and aeration increased, but bulk density decreased significantly ($p<0.01$) with the increase in the rates of pumice mixed with soil. At 50 % pumice application, the increase in macropores (>100 μm diameter) were 98.2 % and 70.3 %, and the decreases in bulk density were 24.8 % and 21.0 % for soil I and II, respectively. While the mesopores (100-30 μm diameter), which are important for water conductivity, decreased significantly with pumice application in soil I, no significant changes were obtained for soil II. The amount of water held at 0.01 MPa – 0.10 MPa decreased significantly with 30 % or more pumice application in both soils. The amount of water held at 0.10 MPa or greater suctions decreased with pumice application. Significant changes in physical properties of soil-pumice mixture media were obtained for different sizes of pumice application.

Key words

bulk density; pore size distribution; soil-pumice mixture media

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Introduction

Soil and some soilless media are used as plant-growth media in horticulture. Liquid fertilizers are essential for soilless plant-growth media. In soilless cultures, continuous controlling is required for soil reaction (pH), salinity and plant nutrient equilibrium because of low buffering capacities of these media. On the other hand, although plant-growth media with soil may have several disadvantages due to not providing desirable soil at all times, heavy texture, and need for sterilization, plant nutrition in soil media is easier because the nutrients are retained by soil. In addition, minor element deficiencies are rare because the elements are on the soil exchange sites (Holcomb 2002).

In a medium with soil, the provision of aeration and the improvement of drainage conditions are required. For this reason, pumice is a good amendment for aeration and drainage. Pumice mixed with soil in specific amounts improves soil air and water conductivity, and reduces negative effects of crusting, cracking, flooding, and shrink swelling. It is also used for long periods because of its stable physical and chemical properties (Gur et al. 1997). In general, pumice could be provided easily since there are many pumice deposits distributed around the world (Tuncer 1997). Pumice used only after sieving has a high water retention capacity, and very low bulk density value compared to soil (Sahin et al. 2004).

The most important physical properties of a medium for suitability are good aeration and drainage, optimum water retention, high water conductivity and low bulk density (Cabrera 2003). Within the physical properties, the air-water ratio is the most important (Bruckner 1997; Caron and Nkongolo 1999). The air-water ratio can partly be determined by the granulometry and porosity (Orozco et al. 1997). The relationship between water energy status and water content of the medium is a reflection of the pore size distribution of the medium (Milks et al. 1989). Pore sizes have traditionally been divided into macropores, mesopores, micropores and ultramicropores (Sahin et al. 2002). The macropores (>100 μm diameter) supply drainage and aeration, the mesopores (100-30 μm diameter) supply water conductivity, and the micropores (30-3 μm diameter) supply water retention (Gemalmaz 1993). The water retained in ultramicropores (<3 μm diameter) is unavailable for plant use (Drzal et al. 1999).

The objective of this study was to determine the effects of different size and rates of pumice mixed with soil on the pore size distribution and bulk density of the mixture medium.

Materials and methods

Two soils formed under different climates with 450 mm (Erzurum-Turkey) and 2200 mm (Rize-Turkey) annual rainfalls were used. Some physical and chemical properties of these soils and pumice are given in Table 1. The soils used in this study sampled from Ap horizon (0-20 cm depth) and origin of pumice was Ercis, Van-Turkey.

Pumice is a very light, porous igneous rock that is formed during volcanic eruptions. It is made up of very tiny crystals, since they cool so quickly above ground. The texture of pumice is rough and has many hollows and cavities. Pumice has been used to a large extent as a plant growing media and it lightens the soil, makes tillage easier, improves soil aeration and holds water. Pumice mixed with soil in specific amounts improves soil's air and water conductivity, and reduces negative effects of crusting, cracking, flooding, and shrink-swelling. It can also be used for a long periods because of its stable

Table 1.
Some physical and chemical properties of soils and pumice used

Properties	Soil I	Soil II	Pumice
Soil taxonomy	Ustent	Aquoll	-
Dominant clay type	Montmorillonite	Kaolinite	-
Clay (%)	23.7	24.6	-
Silt (%)	39.8	27.7	-
Sand (%)	36.5	47.7	-
Bulk density (g cm^{-3})	1.05	1.00	0.65 (for < 4 mm) 0.63 (for < 8 mm) 0.40 (for 4-8 mm)
Particle density (g cm^{-3})	2.64	2.61	2.24
Wet Aggregate stability (%)	28.5	50.7	-
pH	8.2	6.7	8.4
Electrical cond. (dS m^{-1})	0.93	0.19	0.11
CEC (cmol$_{(+)}$ kg^{-1})	33.6	26.0	6.9
Carbonates (%)	2.7	0.1	0.8
Organic matter (%)	2.9	3.8	-

physical and chemical properties and it can be provided easily since there are many pumice deposits distributed around the world. Pumice used only after sieving has a high water retention capacity, and very low bulk density value compared to soil (Sahin et al. 2005).

Soil samples were passed through a sieve with openings of 8 mm before mixing them with pumice. The rates of size fractions (<2 mm, 2-4 mm, and 4-8 mm) were 58.6, 26.1 and 15.3 % for Soil I and 44.2, 29.7, and 26.1 for Soil II, respectively, following sieving.

Soil and pumice mixtures were prepared as 9:1, 8:2, 7:3, 6:4, and 5:5 ratio on volumetric basis, resulting in 10 % (M1), 20 % (M2), 30 % (M3), 40 % (M4), and 50 % (M5) of pumice in the mixture media. Similar mixture media were prepared for three different sizes of pumice as S1: <4 mm (50 % 2-4 mm, 25 % 1-2 mm, and 25 % < 1mm), S2: <8 mm (33.3 % 4-8 mm, 33.3 % 2-4 mm, 16.7 % 1-2 mm, and 16.7 % <1 mm), S3: 4-8 mm. Sample with no pumice mixture was used as the control medium (C).

The soil water characteristic curve (pF curve) was determined using pressures plates (Klute 1986), and was used as the basis for the calculation of the pore size distribution. Water held at 0.001 MPa, 0.01 MPa, 0.03 MPa, 0.10 Mpa and 1.5 MPa was obtained when water output stopped for a given suction. The samples for pF curves were packed by dropping the cylinders. Porosity was estimated by calculation (Danielson and Sutherland, 1986). Bulk density was determined by the cylinder method (Blake and Hartge 1986a) on samples packed by dropping the sample cylinders from a height of 10 cm for 20 times.

The percentage of water-stable aggregates was determined by a wet sieving procedure (Kemper and Rosenau 1986). Particle density was determined by the pycnometer method (Blake and Hartge 1986b), pH by a pH-meter in saturation extract (Mc Lean 1982), Electric conductivity (EC) by an EC-meter in saturation extract (Rhoades 1982a), cation exchange capacity (CEC) by the sodium acetate method (Rhoades 1982b), carbonates by the calcimeter method (Nelson 1982) and organic matter by the wet combustion method (Nelson and Sommers 1982).

The experimental design was factorial (soils (2), mixture rates (5), and pumice sizes (3)) with three replications. Analysis of variance (ANOVA) for the data of macropores, mesopores, micropores, ultramicropores and bulk density was performed, and Duncan's multiple range tests were used for important treatments.

Results and Discussion

Total porosity increased with increasing rates and sizes of pumice in both soils. The increasing rates in total porosity were higher for Soil I than Soil II. The initial total porosity was 60.4 for Soil I and 62.1 for Soil II. Since both soils have similar texture, it may be that the differences in total porosity may be related to the degree of soil structure. Therefore, pumice application to Soil I gave better results in improving total porosity which reached up to 12.2 % (M5) and 10.0 % (S3) as compared to the initial porosity value.

The amount of macropores supplies aeration and drainage increased significantly ($p<0.01$) with increasing rate of pumice in the medium. Pumice mixture to soil medium with a rate of 50 % increased the amount of macropores by about 98.2 % in soil I and 70.3 % in soil II compared with the control medium (Fig. 1). Similar results were obtained in all pumice size groups. Maximum increase was obtained for S2 treatment in soil I, and S1 treatment in soil II (Fig. 1). The macropores increased with increasing rates of pumice in the medium in all pumice sizes. The maximum macropores values were obtained in S2 treatment (Fig. 2). More

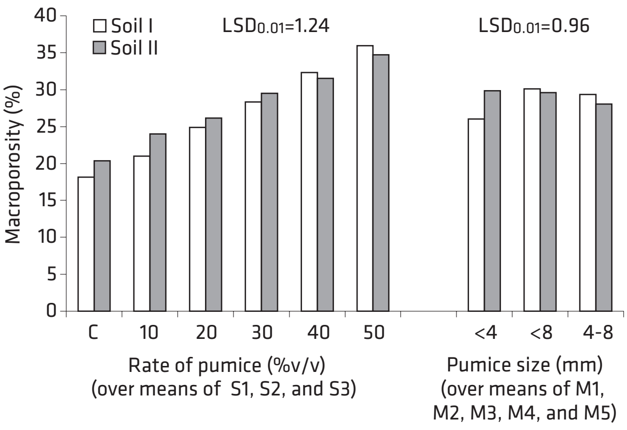

Figure 1.
Changes in macropores with pumice size and rate

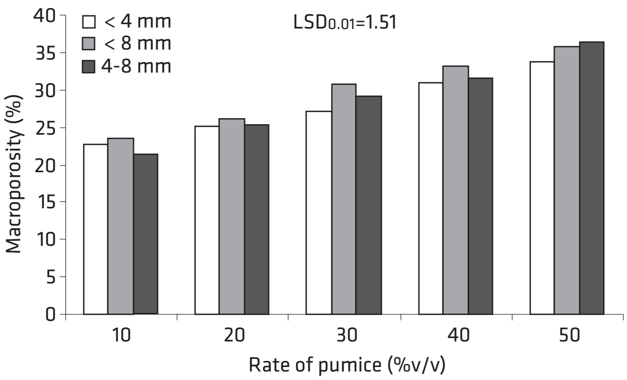

Figure 2.
Changes in macropores with pumice rate in the different pumice size

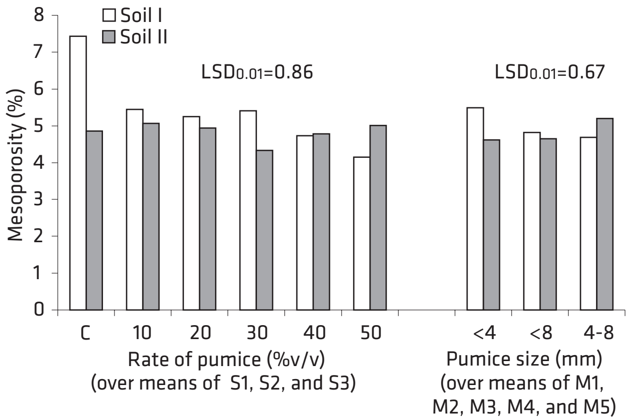

Figure 3.
Changes in mesopores with pumice size and rate

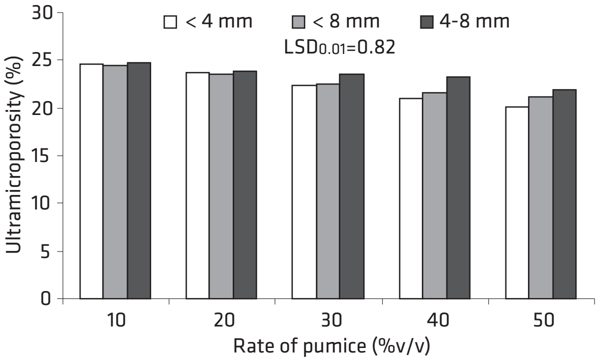

Figure 6.
Changes in ultramicropores with pumice rates in the different pumice size

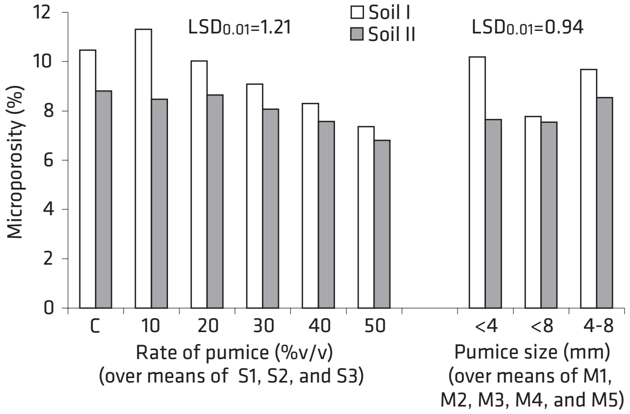

Figure 4.
Changes in micropores with pumice size and rate

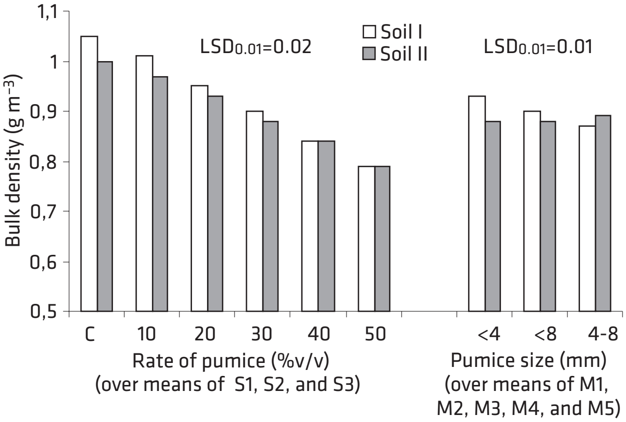

Figure 7.
Changes in bulk density with pumice size and rate

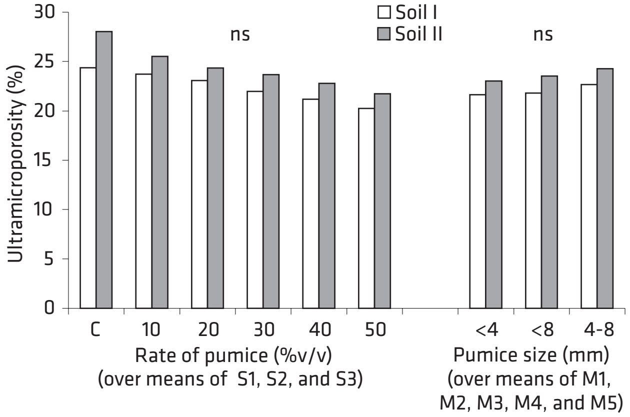

Figure 5.
Changes in ultramicropores with pumice size and rate

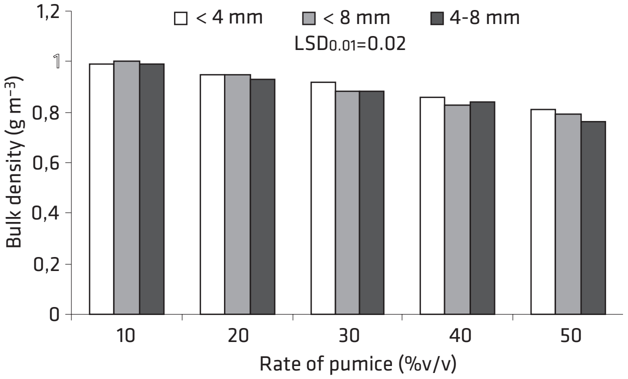

Figure 8.
Changes in bulk density with pumice rate in the different pumice size

suitable air volume conditions were reached; due to the macropores they were greater than 20 % in all treatments (Verdonck 1984).

Pumice caused significant reduction of the amount of mesopores, which effect water conductivity, in soil I, but no significant changes were determined for soil II (Fig.3). This may be related to differences in soil aggregation (Table 1). The effects of mixed ratio with all pumice sizes on the amount of mesopores were not significant.

The amounts of micropores, which affect water retention, also decreased significantly (p<0.01) by higher rates of pumice application. Significant decreases of the amount of micropores occurred with M3-M5 treatments in soil I and M4-M5 treatments in soil II. In soil I, a small increase (8.1 %) in the amount of micropores with M1 treatment was obtained, but it was statistically insignificant (Fig. 4). It means that pumice application to soil medium in small rates has no significant effect on the amount of water retention. On the other hand, different sizes of pumice caused reduction in the amount of micropores. The most significant reduction was obtained with S2 treatment in soil I (25.6 %) and S1 and S2 treatments in soil II (13.2 and 14.3 %, respectively) (Fig. 4). The effects of mixed ratio with all pumice sizes on the amount of micropores were not significant.

Pumice application also reduced the amount of ultramicropores compared to the controls (Fig. 5, and 6), but this may not be important because water in these pores is not available for plant use (Drzal et al. 1999).

Bulk density of the medium decreased significantly (p<0.01) with the rate of pumice applied to soil medium in both soils. In soil II, no significant effect of pumice size on bulk density was obtained, but it became more important with pumice size in soil I (Fig.7). The bulk density decreased significantly (p<0.01) with increasing rates of pumice in the medium in all pumice sizes (Fig. 8). In greenhouse culture, a lower bulk density is desirable due to easier handling and less root losses during pick up and transportation (Sahin et al. 2004).

The results of this study indicated that the optimum air-filled porosity conditions were reached by pumice applications. While the amount of macropores increased significantly (p<0.01) with increasing rate of pumice in the medium, the amount of mesopores in one of the soils decreased. The amounts of micropores decreased significantly (p<0.01) by higher rates of pumice application. Pumice application reduced the amount of ultramicropores compared to the controls. Bulk density of the medium decreased significantly (p<0.01) with increasing rate of pumice applied to soil medium. It was clearly determined that pumice may be effectively used in specific amounts for improving aeration and bulk density conditions of poorly structured soils.

Conclusions

Pumice application to soil increased the amount of macropores and decreased the bulk density. It was clearly determined that pumice may be effectively used in specific amounts for improving aeration and bulk density conditions of poorly structured soils.

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