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The Effect of Natural Zeolite in Peat Based Growing Media on *Pelargonium zonale* Plants

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Summary

Zeolite amendment changes the properties of growing media. The effect depends on the rate and grading of the added zeolites. The aim of the work was to compare the effect of granulated and powdered zeolites on the physical and chemical properties of peat based growing media and on the growth of *Pelargonium zonale*, to compare these zeolite amended growing media with commercial growing medium used in Slovenian horticultural enterprises for growing Pelargoniums and other balcony plants and to find out whether it was possible to prepare quality peat based growing medium amended with granulated zeolite in both low and high quantities, 50 kg m^{-3} and 150 kg m^{-3}.

The plants were grown in peat based growing media amended with powdered or granulated zeolite (30 or 40 kg m^{-3} of powdered zeolite, 50 or 150 kg m^{-3} of granulated zeolite). Peat based medium amended with 50 kg m^{-3} of clay was used as a control. The chemical and physical properties of the growing media were analysed according to European standards. Retention curves were determined in a sand box in the range of −0.25 to −10 kPa. At the end of the experiment, the plants were evaluated for fresh weight, dry weight, and dimensions. All tested growing media had good physical properties for plant growth, in terms of total pore space, easily available water and air pore space. Growing media with powdered zeolite had rather higher water holding capacity over the entire measured water potential range. The best growth was recorded in growing media with powdered zeolite but plants of good marketable quality were also grown in growing medium with 50 kg m^{-3} of added granulated zeolite. The experiment showed that it is possible to use growing media amended with granulated zeolite with a lower price but only in quantities of 50 kg m^{-3}.

Key words. chemical properties – clinoptilolite – heulandit – physical properties – *Pelargonium zonale* L. 'Esprit' – sand box – water retention curve

Introduction

Zeolites and other mineral components are used as additives to growing media for changing their chemical and physical properties. Zeolites are crystalline, hydrated aluminosilicates of alkali and alkaline earth cations, which have an infinite, open, three-dimensional structure with cavities and channels. They are able to lose and gain water reversibly and to exchange weakly bonded extra framework cations, both without a change in the crystal structure (Cativello 1995; Mumpton 1999). The CEC of natural zeolites ranges from 2 to 4 meq g^{-1}, and is about twice the CEC of bentonite clay (Mumpton 1999; Polat et al. 2004). More than forty natural zeolites are known, clinoptilolite being the most abundant. Its CEC is 2.16 meq g^{-1}, with a preference for large cations: Cs > Rb > K > NH_4 > Ba > Sr > Na > Ca > Fe > Al > Mg > Li (Mumpton 1999; Polat 2004).

There are important sources of natural zeolites in Cuba, USA, Russia, Japan, Italy, South Africa, Hungary, Bulgaria and Turkey (Polat et al. 2004) but there are also smaller local deposits elsewhere (Držaj 1990).

The unique properties of zeolites enable many applications. In agriculture and horticulture, they are used as components of growing media for hydroculture (Challinor et al. 1995; Samartzidis et al. 2005), as soil amendment (Mumpton 1999; Baninasab 2009) and growing media amendment (Cativello 1995), in which a positive effect on plant growth is documented. The addition of zeolite induced a marked growth increase with *Tagetes patula* and improvements in germinability, number of plants and flowers with *Gladiolus primulinus* hybrids (Cativello 1995). Granulated and powdered zeolites added to commercially produced growing media increase the water volume at −1 kPa and −10 kPa and reduce total pore space (porosity), air volume and EAW (for definition see De Boodt et al. 1974). The effect of granulated zeolites is weaker than the effect of powdered zeolite. Growing media with granulated zeolites have better levels of air volume than those with powdered zeolites at the same percentage (Cativello 1995).

Verhagen (2004) also observed a similar effect of grading in the case of clay. Fine graded clay had a stronger ef-

fect on the EAW of peat growing media than coarse graded clay. It also had a significant influence on water uptake in very dry conditions.

Producers of growing media often tend to add zeolites to peat based growing media instead of clay and also to use them for adjusting the pH value, instead of limestone. Because powdered zeolite in very expensive, they would like to replace it with the much cheaper granulated one but there is not enough experience with it.

The aim of the work was to compare the effect of granulated and powdered zeolites on the physical and chemical properties of peat based growing media and on the growth of *Pelargonium zonale*, to compare these zeolite amended growing media with commercial growing medium used in Slovenian horticultural enterprises for growing Pelargoniums and other balcony plants and to discover whether it was possible to prepare quality peat based growing medium amended with granulated zeolite, in both low and high quantities, 50 kg m^{-3} and 150 kg m^{-3}.

Materials and Methods

Zeolite tuff

In this research, Slovenian zeolite tuff from the Celje region was used. The particle size of the granulated zeolite fraction was 0–4 mm resp. 300 μm at powdered zeolite. The used Slovenian zeolite consists mainly of clinoptilolite and heulandit (Držaj 1990), with the following chemical composition: SiO_2 67.00 % (w/w), Al_2O_3 13.83 % (w/w), K_2O 2.45 % (w/w), Na_2O 1.60 % (w/w), MgO 1.25 % (w/w), CaO 5.26 % (w/w), Fe_2O_3 3.75 % (w/w). Its cation exchange capacity (CEC) was 1.41 meq g^{-1} (141 cmol kg^{-1}).

Growing media

Experimental growing media were made from Lithuanian blond peat 0–20 mm, Lithuanian fractionated blond peat 8–16 mm, Austrian black peat 0–10 mm, Slovenian Oasis fenolic foam 0–20 mm and natural zeolite from the Celje region. Clay fraction 0–6 mm from the Domžale region (Slovenia) was used instead of zeolites in a control growing medium. This growing medium is used in Slovenian horticulture for growing Pelargoniums and other balcony plants.

There were four growing media with different amounts and fractions of zeolite, which were prepared on a volume basis and mixed by hand. Blond peat, fractionated blond peat, black peat and phenolic foam were mixed at a ratio of 5:2:2:1 (by volume). Mixtures Z30 and Z40 contained 30 and 40 kg m^{-3} of powdered zeolite, respectively. Mixtures Z50 and Z150 contained 50 and 150 kg m^{-3} of granulated zeolite, respectively. The quantities of zeolites were added according to the experience of the manufacturer, who had made some preliminary experiments (unpublished). Powdered zeolite was used in lower rates because of the expected higher effect on hydrophysical properties (Cativello 1995). Growing media with zeolites were compared with a Slovenian standard commercial growing medium with clay Humko (H), which consisted (according to the manufacturer's information) of blond peat, fractionated blond peat, black peat and phenolic foam mixed at a volume ratio of 4:1:3:2 and 50 kg m^{-3} of clay. All growing media were provided with 1.5 kg m^{-3} slow release fertilizer (SRF) Osmoform Premix (8–10 weeks) (Scotts) containing (%) 18N:4P:10.8K and with 3.5 kg m^{-3} controlled release fertilizer (CRF) Osmocote Exact (3–4 months) (Scotts) containing (%) 16N:3.9P:10K before planting (Willenborg et al. 2004).

Physical properties and water retention characteristics

The physical properties of the growing media were evaluated in standard 5.3 cm high rings En 13 651 (2001). The moisture retention curves of the growing media were measured in a sand box in the range of −0.25 to −10 kPa of water potential, (Fig. 1). The measurements were carried out with three replications. Preparation and saturation of the samples were carried out according to En 13 041 (1999), which was slightly modified in order to be able to measure the water potential from −0.25 kPa. After the sample had been placed in a sand box for 48 h at −1 kPa water potential (En 13 041, paragraph 7.3 1999), it was saturated once more. The upper ring was then removed and the fully saturated sample was put in the sand box (−0.25 kPa). After measurements in the sand box, the samples were oven dried and bulk densities (BD) were calculated. The particle density for calculating the total pore space was measured using a water pycnometer and total pore space was calculated:

$$PS = (PD-BD)*100/PD,$$

where PS is the total pore space (% vol.), PD is the particle density (kg m^{-3}) and BD is the dry bulk density (kg m^{-3}).

Air pore space and categories of water available to the plants were calculated: air pore space as the difference between the total pore space and the volume of water at water potential −1 kPa, easily available water (EAW) as the volume of water (% vol.) released from the growing medium when the water potential decreased from −1 to −5 kPa and water buffering capacity (WBC) as the volume of water (% vol.) released from the growing medium when the water potential decreased from −5 to −10 kPa (De Boodt et al. 1974; Bohne and Wrede 2005).

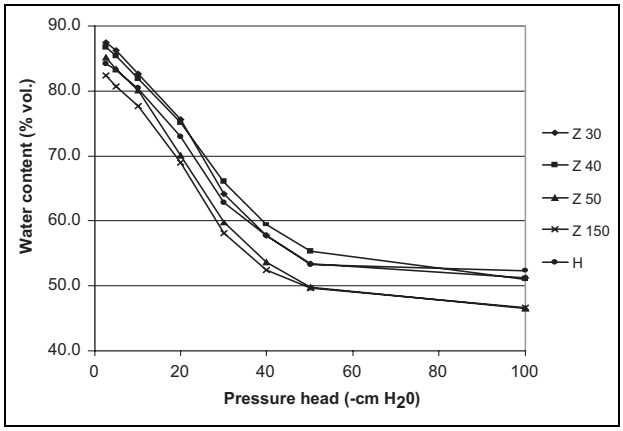


Fig. 1. Water retention characteristics of the growing media according to EN 13 041 (1999). The growing media Z30 and Z40 are amended with 30 kg m^{-3} and 40 kg m^{-3} of powdered zeolite and growing media Z50 and Z150 are amended with 50 kg m^{-3} and 150 kg m^{-3} of granulated zeolite. The control growing medium (H) contains 50 kg m^{-3} of clay.

Chemical properties

Before adding controlled release fertilizer (CRF) and slow release fertilizer (SRF), the growing media were analysed for electrical conductivity, pH value and content of available nutrients according to European standards. Electrical conductivity (EN 13 038 1999) and pH value (EN 13 037 1999) were determined in water extract (1:5 vol-vol). The content of available nutrients was determined in $CaCl_2$/DTPA extraction (0.01 mol L^{-1} $CaCl_2$ and 0.002 mol L^{-1} DTPA) with an extract ratio 1:5 vol:vol (EN 13 651 2001).

Greenhouse experiment with plants

Pelargonium zonale L. 'Esprit' was used as an experimental plant because it is fast growing and easy to manage. It is susceptible to potassium deficiency, which is why it thrives in growing media containing components with high CEC (ELSNER et al. 1995). The important plant parameters that indicate marketable quality are as follows: growth intensity and final plant size (plant diameter, plant weight), number of leaves (they should be hard, dark green, without lesions), rich flowering, the roots should be white and abundantly branched (RIVIERE et al. 1995; STROJNY and NOWAK 2004).

The experiment was set up in a randomised design, in which 50 plants of *Pelargonium zonale* L. 'Esprit' were tested in five growing media. The plants were grown individually in 12 cm diameter pots to the stage ready to sale. The average day/night temperature in the greenhouse was 17/22 °C. Until a vigorous rooting system had developed, the plants were irrigated by hand. From the beginning of running evaluation, they were irrigated by an ebb-and-flood irrigation system. The pots with plants were weighed daily to determine the amount of water held in the pot. The next irrigation cycle started when the water content in the growing media decreased to 45 % of water volume at −1 kPa, when EAW was partly lost by evapotranspiration. The plants that required flooding were put on a bench with an ebb-and-flood irrigation system. Their weights were recorded when there was no water on the bench for an hour and they were then put back in their original place. There were an additional 5 plants in each of the growing medium, which helped to control the irrigation. One plant from these additional plants in each growing medium was destroyed each week to determine the weekly increase.

The parameters of plant diameter, leaf number, flower number, fresh plant weight, dry shoot weight, dry root weight, dry shoot weight/dry root weight ratio were recorded from ten plants per growing medium at the end of experiment.

Statistics

The results were analyzed by one-way ANOVA and Duncan's Multiple Range test for 5 % level of significance (Stat Graphics Plus 7.0).

Results

Physical properties and water retention characteristics

There were differences among the growing media in their physical properties due to their composition. Particle density and bulk density significantly increased with increasing zeolite content. The lowest particle density was measured for the growing medium Z30 (1770 kg m^{-3}) and, consequently, highest for the growing medium Z150 (2590 kg m^{-3}). The lowest bulk density was measured for growing medium Z30 (157.9 kg m^{-3}) and, consequently, the bulk density for Z150 (306.2 kg m^{-3}) was highest and significantly different. Growing medium Z150, which contained the highest amount of granulated zeolite had the smallest total pore space (88.2 % vol.).

All retention curves had a similar shape (Fig. 1). Growing media amended with powdered zeolites had higher water volume than growing media with granulated zeolites through the whole measured water potential range. While differences at −1 kPa were not significant, differences at −10 kPa were. The water holding characteristics of growing medium H was similar to growing media Z30 and Z40. They retained most water at a suction level of 10 kPa.

Due to the similarity of retention curves among all the growing media, there were no significant differences in EAW. Growing media with granulated zeolites and growing medium H had insignificantly larger air volumes than growing media with powdered zeolites. The smallest value of WBC was determined for growing medium H, which was significantly different only from growing medium Z40.

Chemical properties

The chemical properties of growing media before CRF and SRF application are shown in Table 2. The pH values increased with the addition of zeolite because limestone was not added and the pH value of the zeolite was 9.9. There were no great differences in EC values among the growing media; the highest was determined in growing medium H. Levels of available phosphorus and potassium were similarly low in all growing media. Available nitrogen was relatively high (EN 13 651 2001). Levels of Mg are higher in the growing media with granulated zeolites, (Table 2).

Greenhouse experiment with plants

The growing media composition did have impact on plant growth (Table 3). The biggest differences were recorded in fresh and dry weights between Z30 and Z40 plants, on the one hand, and Z50 and Z 150 plants, on the other. Plants from the growing media Z30, Z40 and H reached significantly higher fresh weight than plants from growing media Z50 and Z150. The dry shoot weight of Z30 and Z40 plants was significantly higher than dry shoot weight of Z150 plants. The highest number of leaves was recorded for plants in growing medium Z40 and lowest in growing media Z150 and H. Plants grown in the growing medium Z150 produced a significantly lower average diameter than plants in all other growing media. There were no significant differences among Z30, Z40, Z50 and H plants in number of flowers and dry root weight, but values for Z150 plants were lower. On the whole, a small but significant growth reduction was observed in medium Z50 and, above all, Z 150.

Discussion

The results are consistent with those of CATIVELLO (1995), who also recorded a higher water volume in growing media

Table 1. Particle density, bulk density, total pore space, air volume, water volume at –1 kPa, easily available water (EAW) (difference between water content at –1 and –5 kPa water potential), water buffering capacity (WBC) (difference between water content at –5 and –10 kPa water potential), water volume at –10 kPa of five growing media. * Means followed by the same letter are not significantly different according to Duncan's multiple range test, P<0.05 (N=3).

Growing medium	Particle density (kg m^{-3})	Bulk density (kg m^{-3})	Total pore space (% vol.)	Air volume (% vol.)	Water volume at –1 kPa (% vol.)	EAW (% vol.)	WBC (% vol.)	Water volume at –10 kPa (% vol.)
Z30	1770 e*	157.9 d	91.1 ab	8.5 a	82.6 a	29.2 a	2.2 ab	51.3 ab
Z40	1960 d	174.1 c	91.2 ab	9.2 a	82.0 a	26.7 a	4.4 a	51.0 abc
Z50	2160 b	178.3 bc	91.8 a	11.6 a	80.2 a	30.4 a	3.3 ab	46.5 c
Z150	2590 a	306.2 a	88.2 c	10.5 a	77.8 a	28.1 a	3.1 ab	46.6 bc
H (control)	2100 c	192.8 b	90.8 b	10.5 a	80.4 a	27.2 a	1.0 b	52.3 a

Table 2. Chemical properties of the growing media measured according to European standards before the application of slow release fertilizer (SRF) and controlled release fertilizer (CRF).

Growing medium	pH*	EC* (mS cm^{-1})	N-NH_4** (mg L^{-1})	N-NO_3** (mg L^{-1})	P** (mg L^{-1})	K** (mg L^{-1})	Mg** (mg L^{-1})
Z30	4.5	0.30	49	24	2	5	89
Z40	4.7	0.32	39	21	3	6	92
Z50	5.3	0.31	54	37	2	8	138
Z150	6.3	0.29	48	42	1	12	235
H (control)	4.3	0.35	51	36	5	11	109

* pH, EC: water extract 1v/5v;
** N, P, K, Mg: CAT extract 1v/5v.

amended with powdered zeolite at the same water potential range. He also found that the air capacity of growing media amended with granulated zeolite was superior to growing media with powdered zeolite. Recommended air capacities for geraniums cultivated with an ebb-and-flood irrigation system range between 16–20% vol. (Bos et al. 2003). In this experiment, the values for all tested growing media were smaller, which should not be a great drawback provided that irrigation is properly controlled (Table 1).

The small phosphorus and potassium content (En 13 651 2001) determined in all growing media can be explained by the fact that they were measured before fertilizer application. The relatively high content of available nitrogen (En 13 651 2001) could be caused by using phenolic foam as one of the growing medium components, because it can release nitrogen. The amount of determined magnesium corresponded to the zeolite rates in the growing media, so the levels are higher in the growing media with granulated zeolite. An important question is why plants in Z30 and Z40 grew better than plants in Z50 and Z150. In terms of physical properties, there were no significant differences in EAW but the higher water retention ability of Z30 and Z40 recorded throughout the whole measured range (Fig. 1, Table 1) could support better growth in these growing media. In terms of chemical properties, only differences in pH values and available magnesium were observed. The recommended pH range is 5.5–6.5 (Maatsch et al. 1977). From this point of view, Z50 and Z150 were better but the low pH values determined in Z30 and Z40 would be drawback only in a situation in which peat with excess iron was used and iron toxicity occurred (Armitage and Kaczperski 1992; Grantzau 2004; Wik et al. 2006).

In the investigated growing media, it was observed that the addition of zeolite influenced the pH value of the growing media. The growing media with higher amount of added zeolite (Z50 and Z150) had suitable pH values, so limestone application was not required. The data confirmed that it is possible to use zeolite instead of limestone for setting the pH value of the growing media (Bugbee and Frink 1983).

The best growing results were obtained in growing media with powdered zeolite but the experiment also showed that it is possible to use cheaper granulated zeolite but only at a low rate, 50 kg m^{-3}. For example, in Slovenia, the prices for powdered and granulated zeolite are 150 and 20 € m^{-3}, respectively. The growing medium with 50 kg m^{-3} had good physical properties in terms of EAW and air pore space. The slightly lower water holding ability in the water potential range from –1 to –10 kPa (Fig. 1) can be compensated by more frequent irrigation.

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Table 3. Plant diameter, number of leaves, number of flowers, fresh weight (whole plant), dry shoot weight, dry root weight, dry shoot weight *vs*. dry root weight (DSW:DRW) ratio of *Pelargonium zonale* L. 'Esprit' in five growing media. *Means in a column followed by the same letter do not differ at the level of significance P<0.05 according to Duncan's range test (N=10).

Growing medium	Plant diameter (cm)	Leaves (plant^{-1})	Flowers (plant^{-1})	Fresh weight (g plant^{-1})	Dry shoot weight (g plant^{-1})	Dry root weight (g plant^{-1})	DSW:DRW ratio
Z30	33.21 a*	64.2 ab	3.2 a	129.2 a	12.34 ab	1.55 a	8.12 ab
Z40	32.00 ab	71.0 a	3.7 a	125.9 ab	12.49 a	1.74 a	7.35 ab
Z50	32.32 ab	63.7 ab	4.0 a	108.5 cd	10.92 abc	1.65 a	5.74 b
Z150	29.75 c	60.8 b	4.3 a	102.9 d	9.98 c	1.19 b	9.45 a
H (control)	31.46 abc	59.9 b	4.2 a	116.6 abc	10.78 abc	1.63 a	7.01 b

useful information about the composition of the growing media and valuable discussions. We would like to thank Mr. Korpar for his help in the laboratory and Mrs. Miličić and Mr. Jeraša for their help in the greenhouse. Water retention curve measurement was performed within the framework of project no. 0002707301, supported by the Czech Ministry for the Environment.

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