The effects of growing media on morphological attributes of containerized oriental spruce seedlings

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Running Title: Morphological attributes of containerized Oriental Spruce seedlings

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Abstract

This study was designed to investigate the influence of growing media consisted of different components on morphological attributes of oriental spruce seedlings. Eighteen different components of Barma peat (BP), tea residue compost (CTR), fine pumice (FP), coarse pumice (CP), perlite (P) and zeolite (Z) were prepared as a growing medium component.

Growing medium component did not significantly affect shoot height (SH), root collar diameter (RCD), shoot root ratios and dry root percentage (DRP) of 2-year-old seedlings. However, root dry weight (RDW) and shoot dry weight (SDW) showed significant differences among different growth media. The maximum SDW (3.244 g) were determined for the mixtures of BP (0.5) + CTR (0.2) + CP (0.2) + Z (0.1) medium while the mixtures of BP (0.6) + P (0.2) + Z (0.2) medium produced minimum SDW (1.593 g). In addition, the maximum RDW (1.824 g) was determined for BP (0.5) + CTR (0.2) + CP (0.2) + Z (0.1) medium while BP (0.6) + CP (0.2) + Z (0.2) medium resulted in the lowest RDW (1.013 g). Zeolite added to mixtures of growing media increased the SDW and RDW of oriental spruce seedlings, and therefore, natural zeolite could be used as a substrate such as pumice and perlite in nurseries in Turkey. Since Turkey has 45.8 billions of zeolite potential, using zeolite in nurseries may reduce the costs significantly.

Key words: Growing media, *Picea orientalis*, seedling attributes, zeolite

1. Introduction

Planting nursery stock is both reliable and economical, and potting media for growing seedlings in containers is very important to increase the desired morphological attributes of the seedlings. Several materials and mixtures of them can be used for germination of seeds and rooting of cuttings. Most growing media consist of two or more different organic and inorganic components that are selected to provide certain physical, chemical or biological properties.

Peat has a long history of use in greenhouse production even though it is not a readily renewable resource. However, low-quality degraded peat (≥ H4 on the von Post scale) which has small fibers holds larger amounts of water and less air as compared to the less degraded peat (Allaire et al., 2005). Puustjärvi (1973) reported that the structure of the peat may be too coarse or too fine. However, the most common problem with structure is that it is too fine. In that case, the water space becomes too great and the air space too small. In addition, the stability of physical properties of substrates is of primary concern for container-grown plants because changes in these properties may negatively affect plant growth (Allaire-Leung et al., 1999). Moreover, the organic substrates as peat with low homogenity and high decomposition ratio create pathological problems and cause toxicity (Koksaldi, 1999).

Developing of peat alternatives substrates is necessary for three different reasons: the resources of peat are limited; the pressure for using waste coming from human or industrial activities increases rapidly and the economic necessity to use locally produced waste products (Guérin et al., 2001). Substrates quality and stability are releated to physical attributes such as particle-size and geometries, pore-size distribution, arrangement, which influence water and gas storage, and exchange properties (Allaire-Leung et al., 1999).

The fertilization techniques normally used in container nurseries are not efficient for the management of nutrients. Moreover, control of substrate fertility potential is difficult due to moisture and nutrient variability inside the container and uncertainty of the relationship between the chemical composition of substrate and nutrient status of plants (Lemaire et. al., 1995). The reasons behind these difficulties are: (1) seedlings grow in such a small containers that little change in physical (porosity etc,) and chemical (asidity, electrical conductivity, etc,) properties of growing media could easily influence their growth and (2) low or moderate biostability of organic substrates. The organic substrates with moderate or low biostability will release available nutrients and vary in their chemical properties such as pH, electrical conductivity (EC) and cation exchange capacity (CEC) as a consequence of the decomposition of the substrate's organic matter (Lemaire, 1997). Consequently, peat substrates are routinely amended with various materials such as large-particle-size perlite, rockwool, expanding clay, sand wood bark, compost, polystyrene and polyurethane to obtain air filled porosity (Nkongolo and Caron, 1999).

Zeolites, a naturally occurring mineral group consisting about of 50 mineral types, draw attention as a good growing medium substrate for a long period due to its good physical and chemical characteristics (Markovich et. al., 1995). They have a rigid three-dimensional crystal structure with voids and channels of molecular size and high CEC arising from substitution of Al for Si in the silicon oxide tetrahedral units that constitute the mineral structure (Pickering et. al., 2002; Ayan, 2001 and 2002a). Zeolite has many good features that make it very attractive for nursery use as a growing media compared to other growing media types such as perlite, pumice and river sand. Some of these features are: (1) it has high ammonium absorption capacity, (2) it retains water and nutrients, and (3) it slowly releases N and P into soil as slow release fertilizers do (Koksaldi, 1999).

Oriental spruce (*Picea orientalis* (L.) Link) is naturally distributed approximately on 350 000 hectares in Turkey and used as commercial forest tree. Approximately 93 000 ha of the oriental spruce pure stands are subject to artificial regeneration and 140 000 ha of mixed stands are subject to planting (Genç, 1995).

There is little research on the effects of growing medium on seedling attributes of oriental spruce and no research on zeolite to use as inorganic components in growing media in container tree nurseries in Turkey. Turkey has 45.8 billions tone of zeolite potential and using zeolite for growing seedlings in nurseries can be economical. Thus, the objectives of this research were to investigate the influence of eighteen different growing media consist of six different materials on morphological attributes of containerized oriental spruce seedlings.

2. Materials and Methods

The study was carried out in Of Forest Nursery in Trabzon, Turkey (elevation of 5 m) with seedlings of oriental spruce which is the nature and paleoendemic species of Eastern Blacksea Region in Turkey.

Mixtures of peat (BP), tea residue compost (CTR), perlite (P), fine pumice (FP), coarse pumice (CP) and natural zeolite (Z) were used as growing medium. Peat was taken from Barma plateau at 1800 m altitude in Caykara, Trabzon. These growing media types were used because they provide better aeration and water permeability in pots, and absorb nutrients. Eighteen different volume combinations (%) (7:3, 5:2:3, 6:2:2, 7:2:1, 5:2:2:1) of the six different potting media with or without Z were used as growing media (Table 1). BP was used as main additive material in pots. It had 22% of air capacity, 60% of water holding capacity and 88% of total porosity. Electrical conductivity of this material was 0.93 mS/cm, and pH was between 4.9 and 6.0. BP was mainly sphagnum type with small amount of grass mixture. Salt and lime contents of it were close to zero. CEC was between 49 to 76 meq/100 g. Nevsehir originated pumice was consisted of 60-75% SiO_2, 13-15% Al_2O_2, 1-3% Fe_2O_3, 1-2% CaO, 1-2% MgO and 7-8% Na_2O-K_2O. It also had very low amount of TiO_2, SO_3, Cl and its pH ranged from 7 to 7.5 with very low salt content. The chemical composition of Manisa-Gordes originated natural Z was 71.29% SiO_2, 13.55% Al_2O_3, 1.15% Fe_2O_3, 3.50% K_2O, 5.90% H_2O, 1.96 % CaO, 0.70% MgO, 0.60% Na_2O, 0.02% Ti, 0.04% Ag and 30 ppm B.

2.1. Seedling production

Seeds from Kapıkoy provenance of Macka, Trabzon were sown into Enso-Finland Model Type containers (32 x 45 x 10 cm) in March using a sowing machine. Containers were kept in greenhouse for two months after sowing, and then they transferred into a shaded area for approximately one year for acclimatization. Seedlings were then kept in outdoor conditions until the end of the second growing season.

2.2. Fertilization

Fertilizer applications were done following the recommendations of Richard and McDonalds (1979) for pH, nitrate and EC of growing media (Table 2).

2.3. Physical, chemical and biostability characteristics of the growing media

Before seed sowing and fertilization, growing media samples were analysed for their physical and chemical properties such as bulk density, water holding capacity, specific gravity, porosity and air capacity (Tables 3 and 4). Bulk density was determined on 1000 cm^3 samples with 80 % moisture content. Samples were oven-dried at 105 ˚C for 24 h and weighed. To determine water holding capacity (%) 500 cm^3 samples were taken and put under 1 g/cm^3 pressure before wetting them in a tray for one night. After that, samples were oven-dried at 105 ˚C for 24 h and weighed. Specific gravity was determined according to picnometer method. Porosity was calculated using the following formula: Porosity (%) =

[(Specific gravity – bulk density)] x 100 / Specific gravity. Air content was estimated as follows: Air content (%) = porosity (%) – water holding capacity (%).

Organic matter content was determined by wet digestion (modified Walkley-Black Procedure) method (Kalra and Maynard, 1991). Soil pH was measured with a combination glass-electrode in H_2O (soil-solution ratio 1:2.5) and CEC by saturating soil samples with NH_4 by leaching buffered NH_4OAc solution (Kalra and Maynard, 1991). Phosphorus was determined according to Brayl (Dilute acid-fluoride) procedure (Kalra and Maynard, 1991). Exchangeable cations (Na^+, Ca^{++}, Mg^{++}, K^+) and micronutrient cations (Fe, Mn, Cu, Zn) were extracted from the neutral ammonium acetate solution and measured by atomic absorption spectrophotometry according to Kacar (1996). Electrical conductivity and loss of ignition were determined following the procedure described by Kalra and Maynard (1991). Total nitrogen (%) was determined by using Kjeldahl method (Kjeltec Auto1030) (Kalra and Maynard, 1991). Biological stability was calculated as C/N.

2.4. Seedling morphology

Thirty seedlings with three replications from each treatment after the second growing season were destructively harvested and a variety of morphological traits measured. The potting mix was carefully removed from the roots using both water and tweezers. The shoot height (SH) (cm) and root collar diameter (RCD) (mm) were measured and recorded. The seedlings shoots and roots dried at 105 °C for 24 hours and then weighed. Root dry weight (RDW) (g), shoot dry weight (SDW) (g) and shoot root ratios calculated. In addition, dry root percentage (DRP) was obtained using RDW and the total seedling dry weights (TSDW).

2.5. Experimental design and data analysis

Experiment was arranged in a completely randomized block design with three replications for each treatment. Totals of 18 treatments were randomly assigned into each block. Thirty seedlings per treatment were sampled in each sampling time.

Data were subjected to one-way analysis of variance (ANOVA). Variables were tested for normality, and homogeneity of variances and transformations were made when necessary to meet the underlying statistical assumptions of ANOVA. All pair wise comparisons of individual means were done by the least significant differences (LSD) *t*-test at $P<0.05$. Relationships between growing media properties and seedling morphological parameters were tested using correlation analyses.

3. Results and Discussion

3.1. Seedling Shoot Height (SH) and Root Collar Diameter (RCD)

No significant differences were found in SH and RCD among treatments ($P<0.001$) (Table 5). General mean of the SH and RCD are 11.575 cm, 4.44 mm, respectively in zeolite additive media and 12.193 cm and 4.6 mm in media mixtures without zeolite. But, SH values found in this study were significantly lower than values by Ayan (2002b) and Ayan and Bahadir (1995). RCD values were close to the values observed by Ayan (2002b) and significantly higher than values found by Ayan and Bahadir (1995**)**. The low SH values in this study can be explained with inadequate air capacity (minimum 8-17%) in the growing media (Table 3). De Boodt and Verdock (1972) stated that a growing media for perfect growing condition must have both 20-25% of air volume and 20-30 % of available water capacity at the same time. Aslan (1998) reported that sizes of aggregates in the growing media significantly affected the root and shoot growth of seedlings. Similarly, pore spaces of growing media could be negatively influenced by the dust-size zeolite used in this study. This could be the reason why zeolite had no positive effect on SH. Similar reports had been made by Tuzuner and Timay (1984) and Koksaldi (1999).

As shown in Table 5, there is no significant difference among the media with or without zeolite in terms of the SH and RCD. Thus, zeolite can be used instead of other additive materials (CP and FP). In the 3rd and 6th groups media in which zeolite compared with perlite, 10% volume mixture of the zeolite showed effect as perlite, but 20% volume mixture of the zeolite showed negative effect on SH. On RCD, both 10% and 20% volume mixture of the zeolite showed effect as FP, CP and perlite (Table 6).

Guérin et al. (2001) found a relationship between height growth of *Viburnum* and physical parameters of substrates: the tallest plants were obtained in ubstrates with the highest water availability and highest water content. No significant relation can be established between height and chemical parameters of EC and CEC. Chong et al. (1994) using mushroom compost as a growing media for *Weigela* culture have also found that growth was a function of total pore space and not of chemical properties as assessed by EC value at the start of the experiment. In the present study, there was no correlation between soil chemical and physical properties and seedling characters (Table 7) except the positive correlation with EC and RCD and SH. And also, it was found a positive correlation with Cu nutrient of growing media and RCD. Ayan and Tufekcioglu (2006) found a negative correlation between Scots pine SH and nutrients of K. They also found that there was a significant positive correlation between RCD and Mg and Mn content of the growing media.

3.2. Seedling Shoot and Root Dry Weight (SDW, RDW)

SDW ($P<0.05$) and RDW ($P<0.01$) differed significantly with growing medium types. The highest SDW value (3,244 g) was observed in the mixtures of BP + CTR + CP + Z (5:2:2:1) growing media while the lowest value (1,593 g) observed in the mixtures of BP + P

+ Z (6:2:2) growing media. The maximum value of the SDW observed in 10% volume mixture of Z, while the 20% volume mixture of Z reduced the SDW value significantly. Besides, the highest RDW value determined in the BP + P (7:3) and BP + CTR + CP + Z (5:2:2:1) media as 1.87 g and 1.824 g, respectively. The lowest RDW value (1.013 g) observed in BP + CP + Z (6:2:2) medium. 20% volume mixture of the Z affected RDW negatively as affected SDW (Table 5).

The mixtures of FP and CP with or without zeolit in the 1st and 2nd groups did not affect SDW and RDW. Moreover, in the 4rd group media with CTR, 10% of zeolite additive to CP showed positive effect. But, in the media (Group 3) in which zeolite used with perlite, 20% of the zeolite additive reduced SDW and RDW values (Table 6).

In this study, EC and Cu showed significant relation with RCD, SDW and RDW of the seedlings, and also EC had a positive relation with SH ($P<0.05$). The other soil properties did not show significant relation with SH, RCD, SDW and RDW of the seedlings. Ayan and Tufekcioglu (2006) found a negative correlation with pH, Ca, Na, K content of the growing media and RDW in Scots pine seedlings, and RDW had a significantly positive correlation with Fe content and negative correlation with pH of the media. There was also negative correlation between Na and K content of the growing media and SH in that study.

3.3. Dry Shoot/Root Ratio (SDW/RDW) and Dry Root Percentage (DRP)

No significant differences were found in SDW/RDW and DRP among treatments. General mean of SDW/RDW ratio and DRP were 1,676 g and 37,94% for zeolite added media, and 1,631 g and 38,38% for non-zeolite media, respectively (Table 5). Thus, high quality oriental spruce seedlings were propagated in terms of DRP and SDW/RDW parameters in zeolite added media. In general, there were higher DRP values and more suitable SDW/RDW values in this study than in the study done by Ayan (2002b).

As shown in Table 5, there was no significant difference between growing media with zeolite and growing media without zeolite in terms of SH, RCD, SDW/RDW and DRP characters. Therefore, zeolite can be used as an additive material instead of CP, FP and perlite.

4. Conclusions

The present study showed that zeolite could increase the SDW and RDW of oriental spruce seedlings when it was used as a mixture of growing media, and had more positive effect on these attributes than FP, CP and perlite. Thus, zeolite can be used as an additive material although potting mixtures of zeolite and perlite (20% zeolite) reduced SDW and RDW. Among the potting media of Z, FP, CP and perlite, no significant differences were determined in terms of SH, RCD, SDW/RDW and DRP of the seedlings' attributes. In conclusion, as in the production of Scots pine seedlings (Ayan and Tufekcioğlu, 2006), zeolite from Turkey can be used as an additive material in the propagation of containerized oriental spruce seedlings. Since Turkey has 45.8 billions of zeolite potential, using zeolite in container tree nurseries in Turkey may reduce the costs significantly.

5. Acknowledgements

We thank to Prof. Dr. Hasan Vurdu, Assoc. Prof. Dr. Aydın Tufekcioglu and Assist. Prof. Dr. Ahmet Sivacioglu for their help and valuable comments on the research and we also sincerely acknowledge Ms. Vildane Gercek and Ms. Aysegul Sahin's support in the experimental work. This study was supported in part by Eastern Black Sea Region Forestry Research Institute of Trabzon.

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Table 1. Volume combinations of growing media used in pots for each treatment

Growing medium symbols	Growth medium component (%)					
	BP (1-3 mm)	CTR	P	FP (2-4 mm)	CP (4-8 mm)	Z (Dust-size)
BP + P (7:3)	70		30			
BP + FP (7:3)	70			30		
BP + CP (7:3)	70				30	
BP + CTR + P (6:2:2)	60	20	20			
BP + CTR + FP (6:2:2)	60	20		20		
BP + CTR + CP (6:2:2)	60	20			20	
BP + CTR + P (5:2:3)	50	20	30			
BP + CTR + FP (5:2:3)	50	20		30		
BP + CTR + CP (5:2:3)	50	20			30	
BP + P + Z (7:2:1)	70		20			10
BP + P + Z (6:2:2)	60		20			20
BP + FP + Z (7:2:1)	70			20		10
BP + FP + Z (6:2:2)	60			20		20
BP + CP + Z (7:2:1)	70				20	10
BP + CP + Z (6:2:2)	60				20	20
BP + CTR + P + Z (5:2:2:1)	50	20	20			10
BP + CTR + FP + Z (5:2:2:1)	50	20		20		10
BP + CTR + CP + Z (5:2:2:1)	50	20			20	10

Table 2. Application of fertilizers

Fertilizer	Chemical Content	Application Time
Superex-9	N 19% + P 5% + K 20% + micro elements	At the beginning of the vegetation season
Superex-5	N 11% + P 4% + K 25% + micro elements	At the middle of the vegetation season
Superex-7	N 0% + P 16% + K 20% + micro elements	Before the end of the vegetation season

Table 3. Initial physical properties of the growing media.

Growing media symbols	Water capacity (% volume)	Air capacity (% volume)	Porosity (% volume)	Volume weight (g/cm^3)	Loss of ignition (%)	Specific gravity (g/cm^3)	Organic matter (%)
BP + P (7:3)	75	11	86	0.192	69.57	1.32	50.51
BP + FP (7:3)	71	13	84	0.212	43.36	1.59	46.10
BP + CP (7:3)	72	9	81	0.301	55.98	1.42	69.75
BP + CTR + P (6:2:2)	76	11	87	0.118	70.21	1.37	55.21
BP + CTR + FP (6:2:2)	72	13	85	0.208	63.34	1.67	57.84
BP + CTR + CP (6:2:2)	74	14	88	0.229	65.20	1.52	54.57
BP + CTR + P (5:2:3)	80	9	89	0.124	64.23	1.37	48.74
BP + CTR + FP (5:2:3)	74	10	84	0.300	49.72	1.59	51.56
BP + CTR + CP (5:2:3)	73	8	81	0.301	62.75	1.40	51.77
BP + P + Z (7:2:1)	76	10	86	0.204	62.40	1.37	35.10
BP + P + Z (6:2:2)	72	12	84	0.284	51.28	1.58	28.79
BP + FP + Z (7:2:1)	77	9	86	0.296	60.34	1.61	56.29
BP + FP + Z (6:2:2)	71	11	82	0.344	40.39	1.71	52.73
BP + CP + Z (7:2:1)	69	17	86	0.308	52.74	1.75	45.44
BP + CP + Z (6:2:2)	69	15	84	0.336	51.18	1.77	47.88
BP + CTR + P + Z (5:2:2:1)	74	13	87	0.328	46.67	1.63	38.82
BP + CTR + FP + Z (5:2:2:1)	67	13	80	0.296	40.00	1.68	41.52
BP + CTR + CP + Z (5:2:2:1)	71	13	84	0.376	61.35	1.54	43.74

Table 4. Initial chemical properties of growing media used in the study.

Growing media symbols	pH (1 / 2,5 as volume)	CEC (me/ 100g)	ECx10^3 mhos/cm	Total N (%)	C/N	Ca^{++} ppm	Mg^{++} ppm	Na^{++} ppm	K^+ ppm	P ppm	Fe^{++} ppm	Cu^{++} ppm	Zn^{++} ppm	Mn^{++} ppm
BP + P (7:3)	5.30	57.65	0.80	1.270	23.1	1267	246	224	11200	18.34	71	0.20	9	68
BP + FP (7:3)	5.90	78.35	0.06	1.133	23.6	1013	106	169	85	5.32	70	0.10	6	24
BP + CP (7:3)	5.50	89.21	0.18	1.411	28.7	1797	172	237	194	5.44	101	0.0	7	42
BP + CTR + P (6:2:2)	5.50	102.26	0.35	1.773	18.1	2625	425	201	1098	63.61	62	0.0	11	127
BP + CTR + FP (6:2:2)	5.80	104.69	0.23	1.690	19.9	2898	461	201	1142	69.22	56	0.0	10	163
BP + CTR + CP (6:2:2)	5.60	99.82	0.23	1.679	18.9	2257	313	246	627	41.36	84	0.0	10	121
BP + CTR + P (5:2:3)	5.50	98.26	0.25	1.701	16.7	2169	397	203	1017	67.08	54	0.0	9	158
BP + CTR + FP (5:2:3)	5.80	96.26	0.22	1.803	16.6	2739	423	216	972	64.45	54	0.0	8	112
BP + CTR + CP (5:2:3)	5.40	126.78	0.46	2.007	15.0	3162	519	216	1188	66.91	71	0.20	11	155
BP + P + Z (7:2:1)	6.00	104.28	0.06	0.734	27.8	2134	149	562	4680	1.18	71	0.0	3	17
BP + P + Z (6:2:2)	5.80	96.52	0.05	0.587	28.5	4204	208	1221	10212	16.82	47	0.0	3	12
BP + FP + Z (7:2:1)	5.40	89.28	0.09	1.284	25.4	2242	164	533	3552	11.10	60	0.0	3	28
BP + FP + Z (6:2:2)	5.50	90.04	0.12	1.147	26.7	3893	204	1090	7412	3.04	60	0.0	3	21
BP + CP + Z (7:2:1)	5.60	103.30	0.14	1.157	22.8	3499	216	972	7560	8.28	70	0.0	4	24
BP + CP + Z (6:2:2)	5.80	98.60	0.10	1.091	25.5	3499	259	1188	9720	8.14	50	0.0	3	19
BP + CTR + P + Z (5:2:2:1)	5.70	103.76	0.18	1.352	16.7	3432	448	622	4884	54.67	48	0.0	7	79
BP + CTR + FP + Z (5:2:2:1)	5.40	105.65	0.48	1.758	13.7	4020	492	821	6912	74.19	31	0.0	7	144
BP + CTR + CP + Z (5:2:2:1)	5.70	120.65	0.48	2.068	12.2	4129	541	844	7992	72.79	46	0.0	7	88

Table 5. Mean values and multiple comparisons of morphology of 2-year old seedlings.

Growing media symbols	Seedling morphology					
	SH (cm)	RCD (mm)	Dry weight			
			SDW (g)	RDW (g)	SDW / RDW	DRP (%)
BP+P (7:3)	13.104a	4.982a	3.198ab	1.87a	1.76a	37.2a
BP+ FP (7:3)	11.984a	4.570a	2.235abcd	1.4abcdef	1.602a	38.6a
BP+CP (7:3)	11.902a	4.626a	2.163abcd	1.352abcdef	1.582a	38.8a
BP+CTR+P (6:2:2)	12.773a	4.676a	2.221abcd	1.307bcdef	1.711a	36.9a
BP+CTR+FP (6:2:2)	11.536a	4.437a	2.307abcd	1.541abcdef	1.506a	40a
BP+CTR+CP (6:2:2)	11.808a	4.333a	1.935cd	1.091ef	1.792a	36a
BP+CTR+P (5:2:3)	10.498a	4.343a	2.097cd	1.454abcdef	1.453a	41.1a
BP+CTR+FP (5:2:3)	12.305a	4.575a	2.439abcd	1.638abcd	1.494a	40.3a
BP+CTR+CP (5:2:3)	13.831a	4.890a	2.875abc	1.635abcde	1.781a	36.5a
Mean	**12.193**	**4.6**	**2.385**	**1.476**	**1.631**	**38.38**
BP+P+Z (7:2:1)	12.394a	4.386a	2.458abcd	1.416abcdef	1.757a	36.3a
BP+P+Z (6:2:2)	9.367a	4.180a	1.593d	1.145def	1.385a	42.4a
BP+FP+Z (7:2:1)	11.217a	4.303a	1.941cd	1.224cdef	1.577a	39.1a
BP+FP+Z (6:2:2)	12.892a	4.912a	2.676abcd	1.722abc	1.543a	40.2a
BP+CP+Z (7:2:1)	13.053a	4.737a	2.124bcd	1.197cdef	1.722a	37.6a
BP+CP+Z (6:2:2)	9.958a	3.655a	1.788cd	1.013f	1.79a	35.9a
BP+CTR+P+Z (5:2:2:1)	10.617a	4.453a	1.788cd	1.148def	1.555a	39.2a
BP+CTR+FP+Z (5:2:2:1)	11.508a	4.490a	2.209abcd	1.099def	1.947a	34.4a
BP+CTR+CP+Z (5:2:2:1)	13.167a	4.857a	3.244a	1.824ab	1.811a	36.4a
Mean	**11.575**	**4.44**	**2.202**	**1.310**	**1.676**	**37.94**
General Mean	**11.884**	**4.52**	**2.294**	**1.393**	**1.654**	**38.16**
F value	**1.677 ns**	**0.918 ns**	**2.010 ***	**2.3514 ****	**0.843 ns**	**0.812 ns**

1) Values are the means of three replications.

2) For each character, mean values with the same letter are not significantly different at %1 level

3) ***: significant at $P < 0.001$; **: significant at $P < 0.01$; *: significant at $P < 0,05$; ns: none significant

Table 6. ANOVA results of zeolite added treatments grouped with treatments without zeolite but same media types (n=18).

Group	Growing media symbols	Seedling morphology					
		SH (cm)	RCD (mm)	Dry weight			DRP
				SDW (g)	RDW (g)	SDW / RDW	
1	BP + CP (7:3)	11.902	4.626	1.854	1.352	1.582	38.833
	BP + CP + Z (7:2:1)	13.053	4.737	1.772	1.197	1.722	37.600
	BP + CP + Z (6:2:2)	9.958	3.655	1.978	1.013	1.790	35.900
	F value	**2.568 ns**	**1.244 ns**	**0.051 ns**	**0.741 ns**	**0.308 ns**	**0.256 ns**
2	BP + FP (7:3)	11.984	4.570	1.872	1.400	1.602	38.633
	BP + FP + Z (7:2:1)	11.217	4.303	1.798	1.224	1.577	39.133
	BP + FP + Z (6:2:2)	12.892	4.912	2.570	1.722	1.543	40.167
	F value	**0.501 ns**	**0.764 ns**	**0.666 ns**	**2.801 ns**	**0.026 ns**	**0.086 ns**
3	BP + P (7:3)	13.104a	4.982	3.015a	1.870a	1.760	37.200
	BP + P + Z (7:2:1)	12.394a	4.386	2.162ab	1.416ab	1.757	36.333
	BP + P + Z (6:2:2)	9.367b	4.180	1.346a	1.145b	1.385	42.400
	F value	**6.778 ***	**1.940 ns**	**3.816 ***	**5.719 ***	**1.033 ns**	**1.106 ns**
4	BP + CTR + CP (6:2:2)	11.808	4.333	1.935b	1.091b	1.792	36.000
	BP + CTR + CP (5:2:3)	13.831	4.890	2.874ab	1.635a	1.781	36.500
	BP + CTR + CP + Z (5:2:2:1)	13.167	4.857	3.244a	1.824a	1.811	36.400
	F value	**2.189 ns**	**0.881 ns**	**5.141 ***	**10.763 ***	**0.005 ns**	**0.007 ns**
5	BP+CTR+FP (6:2:2)	11.536	4.437	2.307	1.541a	1.506	39.967a
	BP+CTR+FP (5:2:3)	12.305	4.575	2.439	1.638a	1.494	40.267a
	BP+CTR+FP+Z (5:2:2:1)	11.508	4.490	2.209	1.099b	1.947	34.367b
	F value	**0.140 ns**	**0.039 ns**	**0.120 ns**	**5.808 ***	**0.711 ns**	**8.718 ***
6	BP + CTR + P (6:2:2)	12.773a	4.676	2.221	1.307	1.712	36.933
	BP + CTR + P (5:2:3)	10.498b	4.343	2.113	1.454	1.453	41.100
	BP + CTR + P +Z (5:2:2:1)	10.617b	4.453	1.788	1.302	1.555	39.200
	F value	**7.902 ***	**0.410 ns**	**0.505 ns**	**0.240 ns**	**2.167 ns**	**1.805 ns**

1) Values are the means of three replications,

2) For each character. mean values with the same letter are not significantly different at $P < 0.05$ level.

3) *** : significant at $P < 0.001$; **: significant at $P < 0.01$; * : significant at $P < 0.05$; ns: none significant

Table 7. Pearson correlation coefficients among growing media properties and seedling morphological parameters (n=18).

Properties	SH	RCD	RDW	SDW
pH	-0.303	-0439	-0.159	-0.271
CEC	0.109	-0.150	-0.119	-0.08
Organic matter	0.315	0.217	0.202	0.158
EC	0.489*	0.560*	0.519*	0.699*
N	0.421	0.373	0.329	0.413
C/N	-0.263	-0.279	-0.194	-0.310
Water holding capacity	-0.051	0.012	0.202	0.005
Air capacity	-0.150	0.245	-0.419	-0.268
Porosity	-0.208	-0.217	-0.141	-0.248
Volume weight	0.015	0.007	-0.033	0.053
Loss of ignition	0.256	0.122	0.262	0.280
Specific gravity	-0.306	-0.348	-0.396	-0.385
Ca	-0.157	-0.099	-0.167	-0.104
Mg	0.166	0.199	0.205	0.277
Na	-0.327	-0.309	-0.317	-0.239
K	-0.139	-0.061	0.11	0.130
P	0.100	0.173	0.178	0.198
Fe	0.369	0.247	0.102	0.097
Cu	0.467	0.475*	0.484*	0.565*
Zn	0.345	0.373	0.295	0.312
Mn	0.167	0.191	0.184	0.201

* significant at $P<0.05$.