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Growth responses of scots pine seedlings grown in peat-based media amended with natural zeolite

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Abstract : *Zeolite has many good features that makes it very attractive for nursery use as a growing media over others. This study was designed to investigate influence of different growing media and their mixtures (with zeolite and without zeolite) on morphological characters of scots pine seedlings. Twenty-one treatments of varying amounts of peat, fine pumice, coarse pumice, river sand, perlite and river sand were established and were sown with scots pine seeds. At the end of first growing period, 30 seedlings from each treatment were harvested and measured for height (SH), root collar diameter (RCD), root dry weight (RDW), stem dry weight (SDW) and total dry weight (TSDW). These parameters varied significantly among treatments and were lower in zeolite added media. SH negatively correlated with Na and K content and C/N ratio of growing media but positively correlated with Mn content of media. SDW and TSDW had positive correlation with N, Fe, Mn, total porosity and loss of ignition, and had negative correlation with pH, Ca, Na and K content.*

Key words: *Scots pine, Seedling, Zeolite, Growing media, Morphological character.*

Introduction

A remarkable progress in the development of equipment for managing fertigation of soil-less culture, sensing water status of plants and soils, and computer models and software for control of irrigation has helped the growers to obtain more efficient use of irrigation water and fertilizers (Zazueta, 1993; Marfa *et al*., 2002). Nevertheless, the fertigation 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 (pH, EC, 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). These aspects along with prevailing ambient temperature in containers need to be considered when the guidelines for fertigation are established (Marfa *et al.,* 2002; Handreck, 1992).

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 cation exchange capacity (CEC) arising from substitution of Al for Si in the silicon oxide tetrahedral units that constitute the mineral structure (Ayan, 2001 and 2002a; Pickering *et al.,* 2002). 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; (3) it slowly releases N and P into soil as slow release fertilizers do.

Turkey has 45.8 billions of zeolite potential. Therefore, using zeolite in nurseries will be economical. However, there is lack of information in how zeolite effect growth of seedlings, and in what ratio it needs to be mixed with other growing media types in pots. To answer this, the present study was designed to investigate influence of different growing media and their mixtures (with zeolite and without zeolite) on seedling morphology of scots pine.

Materials and Methods

The study was carried out in Of Forest Nursery in Trabzon, Turkey (latitudes: 40°58′39″ and 40°59′03″ N; longitudes 40°19′34″ and 40°20′19″ E; altitude: 5 m) with seedlings scots pine (*Pinus sylvestris* L.) a most worldwide distributed pine species which also makes its farthest southern extent in Turkey and used as commercial forest tree. It is widely planted for industrial and conservation purposes such as soil erosion control and living snow-fences in Turkey.

Peat (BP), tea residue compost (CTR), perlite (P), fine pumice (FP), coarse pumice (CP), and river sand (RS) were used as potting media. Peat was taken from Barma plateau at 1800 m altitude in Caykara-Trabzon. We preferred these growing media types because they provide better aeration and

water permeability in pots and absorb nutrients. Twenty-one different volume combinations (%) (7:3, 5:2:3, 6:2:2, 7:2:1, 5:2:2:1) of these six different potting media with and without zeolite were established and used as potting material (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 of it was between 4.9 and 6.0. It was mainly sphagnum type with small amount of grass mixture. Salt and lime contents of it were close to zero. Cation exchange capacity of it was between 49 to 76 meq/100 g. It was classified as H1-H3 quality class peat according to Von Post scale. Nevsehir originated pumice was consisted of 60-75% of SiO_2, 13-15% of Al_2O_3, 1-3% of Fe_2O_3, 1-2% of CaO, 1-2% of MgO and 7-8% of 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 zeolite was 71.29% of SiO_2, 13.55% of Al_2O_3, 1.15% of Fe_2O_3, 3.50% of K_2O, 5.90 % of H_2O, 1.96 % of CaO, 0.70 % of MgO, 0.60 % of Na_2O, 0.02 % of Ti, 0.04 % of Ag and 30 ppm of B.

Cultural treatments and production stage: Seeds from Karanlikdere provenance of Gumushane were sown into 45 containers each of dimensions 32 x 45 x 10 cm (breadth x length x depth) (Enso-Finland Model Type) on March 11, 1999 using a sowing machine. Seedlings were kept in greenhouse for two months after sowing. Later, they transferred into a shaded area for one month for acclimatization before letting them outdoor conditions. We kept the seedling in outdoor conditions until they got ready for planting.

Fertilization: Fertilizer applications were done following the recommendations of Richard and McDonalds (1979) for pH, nitrate and EC of growing media. Different fertilizers were applied depending on timely pH, nitrate and EC measurements of growing media types. These fertilizers were:

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

Growing media symbols	Growth media component						
	Barma peat (BP) (%)	Compost tea remnant (CTR) (%)	Perlite (P) (%)	Fine pumice (2-4 mm) (FP) (%)	Coarse pumice (4-8 mm) (CP) (%)	River sand (RS) (%)	Zeolite (Z) (%)
BP + CTR (7:3)	70	30					
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 + RS (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
BP + CTR + RS + Z (5:2:2:1)	50	20				20	10

Physical, chemical and biostability characteristics of the 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

Table – 2: Initial physical properties of the growing media types used in the study.

Growing media symbols	Water capacity (% volume)	Air capacity (% volume)	Porosity (% volume)	Volume weight (g/cm^3)	Loss of ignition (%)	Specific gravity (g/cm^3)
BP + CTR (7:3)	54.40	34.66	89.06	0.196	75.283	1.792
BP + P (7:3)	54.20	34.92	89.12	0.192	62.907	1.766
BP + FP (7:3)	46.80	40.88	87.68	0.212	34.437	1.721
BP + CP (7:3)	50.60	31.36	81.96	0.301	52.626	1.669
BP + CTR + P (6:2:2)	59.00	34.45	93.45	0.118	64.584	1.803
BP + CTR + FP (6:2:2)	46.60	41.64	88.24	0.208	48.058	1.770
BP + CTR + CP (6:2:2)	48.50	38.72	87.22	0.229	68.748	1.792
BP + CTR + RS (6:2:2)	43.60	39.83	83.43	0.276	31.447	1.666
BP + CTR + P (5:2:3)	61.20	31.49	92.69	0.124	58.715	1.697
BP + CTR + FP (5:2:3)	50.40	32.93	83.33	0.300	42.616	1.800
BP + CTR + CP (5:2:3)	51.00	31.83	82.84	0.301	55.659	1.754
BP + P + Z (7:2:1)	53.10	34.99	88.09	0.204	43.140	1.713
BP + P + Z (6:2:2)	52.40	31.28	83.68	0.284	21.126	1.741
BP + FP + Z (7:2:1)	55.00	25.60	80.60	0.296	51.645	1.526
BP + FP + Z (6:2:2)	41.60	39.32	80.92	0.344	42.248	1.803
BP + CP + Z (7:2:1)	48.40	33.67	82.07	0.308	36.324	1.718
BP + CP + Z (6:2:2)	50.10	30.85	80.95	0.336	34.884	1.764
BP + CTR + P + Z (5:2:2:1)	57.40	23.66	81.06	0.328	46.610	1.732
BP + CTR + FP + Z (5:2:2:1)	53.80	29.72	83.52	0.296	44.512	1.797
BP + CTR + CP + Z (5:2:2:1)	44.60	34.15	78.75	0.376	32.649	1.770
BP + CTR + RS + Z (5:2:2:1)	55.60	22.31	77.71	0.412	21.412	1.849

gravity, porosity and air capacity (Table 2 & 3). Bulk density was determined on 1000 cm^3 samples with 80 percent moisture content. Samples were oven-dried at 105 ºC for 24 hr and weighed. Water holding capacity (%) was determined taking 500 cm^3 samples and leaving them under 1 g/cm^3 pressure before wetting them in a tray for a night. After that, samples were oven-dried at 105 ºC for 24 hr 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 based on the formula:

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.

Seedling measurements: The seedling roots extracted from the pot after cutting at root collar were washed and oven-dried at 105 °C for 24 hrs and weighed to nearest 0.001g. Thirty seedlings per treatment were sampled and measured for height (SH), root collar diameter (RCD), root dry weight (RDW), stem dry weight (SDW), total seedling dry weight (TSDW) at the end of first vegetation period.

Experimental design and data analysis: Experiment was arranged in a completely randomized block design with three replications for each treatment. Totals of 21 treatments were randomly assigned into each block. Thirty seedlings per treatment were sampled in each sampling time. The growing media were formulated from binary, ternary and quartet of seven materials.

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. Differences were considered significant at $P < 0.05$ levels. Relationships between growing media properties and seedling morphological parameters were tested using correlation analyses.

Results and Discussion

Seedling height (SH): Seedling heights varied significantly with growing media types ($P < 0.001$) (Table 4). The best SH

Table – 3 : Initial chemical properties of growing media used in the study.

Growing media symbols	pH 1/2.5 as volume	CEC (me/100g)	Organic matter (%)	ECx10³ 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 + CTR (7:3)	430	62.50	28.727	0902	1.868	16.7	820	284	44	789	8,3	79,4	5,7	12,9	123,9
BP + P (7:3)	428	60.97	24.887	0683	1.153	20.1	390	111	20	459	6	112,5	4,7	9,4	37,2
BP + FP (7:3)	491	39.23	18.477	0074	0.712	26.6	470	50	23	31	3,25	101,2	4,3	11,5	26,5
BP + CP (7:3)	446	49.56	19.532	0106	1.438	28.7	670	74	34	63	3,8	112,0	2,3	17,0	24,0
BP + CTR + P (6:2:2)	467	67.06	24.887	0241	1.215	18.1	620	143	23	338	5,8	105,7	2,4	24,0	78,9
BP + CTR + FP (6:2:2)	499	44.23	13.387	0250	1.142	19.9	750	169	25	402	4,7	84,2	2,0	13,8	62,0
BP + CTR + CP (6:2:2)	416	62.50	25.300	0212	1.616	18.9	620	127	28	218	3,8	104,0	2,1	21,0	74,1
BP + CTR + RS (6:2:2)	438	20.66	14.500	0306	1.162	20.0	790	206	25	521	4,25	106,7	1,6	13,5	71,7
BP + CTR + P (5:2:3)	447	41.73	25.642	0234	1.192	16.7	570	160	31	391	3,5	96,0	1,8	17,0	90,5
BP + CTR + FP (5:2:3)	494	50.86	17.229	0230	1.095	16.6	800	198	34	508	4,8	88,0	1,7	36,0	79,8
BP + CTR + CP (5:2:3)	462	32.29	21.886	0254	1.115	16.0	760	176	34	424	5,3	103,7	2,1	25,0	84,3
BP + P + Z (7:2:1)	469	59.45	19.856	0079	0.776	27.8	2000	111	215	2610	3,0	87,8	2,0	15,0	13,6
BP + P + Z (6:2:2)	506	50.86	11.915	0068	0.448	28.5	390	210	662	6980	3,25	75,8	1,4	23,0	11,7
BP + FP + Z (7:2:1)	453	40.54	26.432	0106	0.928	25.4	1700	95	167	1560	4,5	98,6	1,8	37,0	22,9
BP + FP + Z (6:2:2)	460	34.67	23.312	0110	0.945	25.7	2600	136	443	4130	3,0	74,1	2,1	11,0	16,4
BP + CP +Z (7:2:1)	454	55.10	13.560	0114	0.706	22.8	2700	123	351	4830	2,8	88,1	1,9	13,0	15,3
BP + CP +Z (6:2:2)	485	30.21	14.441	0108	1.616	25.5	2900	170	481	3800	2,8	85,9	1,7	17,0	12,1
BP + CTR + P + Z (5:2:2:1)	491	33.47	17.150	0161	0.948	16.7	3000	260	361	4590	5,0	80,0	1,5	16,0	55,4
BP + CTR + FP + Z (5:2:2:1)	454	53.69	16.544	0709	1.291	13.7	2900	351	298	3690	6,7	86,1	1,2	29,0	75,9
BP + CTR + CP + Z (5:2:2:1)	486	45.54	14.597	0354	0.838	12.2	3000	330	364	4360	7,0	76,7	1,8	34,0	104,2
BP + CTR + RS + Z (5:2:2:1)	502	48.15	9.629	0159	0.359	26.9	2100	166	132	1940	4,5	99,9	1,7	15,0	79,7

Table – 4: Mean values and multiple comparisons of some seedling morphological parameters.

Growing media symbols	Morphological seedling parameters															
	Height (cm)		Root collar diameter (mm)		Dry weight								Stem / root	RP
					Stem (g)		Root (g)		Total seedling (g)					
BP + CTR (7:3)	12,973	abcde	3,530	ab	1,725	bcd	0,637	bcd	2,362	bcd			2,695	27,0
BP + P (7:3)	12,133	bcdef	2,990	ef	1,656	cd	0,601	cde	2,257	cde			2,854	26,7
BP + FP (7:3)	11,747	def	2,930	f	1,070	fgh	0,711	bcd	1,781	efghi			1,553	39,5
BP + CP (7:3)	12,260	bcdef	3,023	ef	1,497	cdef	0,638	bcd	2,135	cdef			2,44	30,5
BP + CTR + P (6:2:2)	11,923	cdef	3,387	abcd	2,137	ab	0,879	b	2,683	abc			2,992	29,9
BP + CTR + FP (6:2:2)	11,237	ef	3,480	abc	1,552	de	0,653	bcd	2,205	cdef			1,938	30,1
BP + CTR + CP (6:2:2)	12,747	abcde	3,360	abcd	1,777	bc	1,411	a	2,918	ab			1,555	39,2
BP + CTR + RS (6:2:2)	14,190	a	3,440	abcd	2,298	a	0,836	bc	3,146	a			2,128	37,7
BP + CTR + P (5:2:3)	13,473	abcd	3,460	abc	1,282	defgh	0,602	cde	1,885	defgh			1,715	49,2
BP + CTR + FP (5:2:3)	13,710	abc	3,380	abcd	1,344	cdefg	0,508	de	1,852	defgh			2,653	27,5
BP + CTR + CP (5:2:3)	13,483	abcd	3,280	bcde	1,390	cdefg	0,580	cde	1,970	defgh			2,414	29,4
Mean	**12,716**		**3,296**		**1,612**		**0,732**		**2,290**				**2,267**	**33,4**
BP + P + Z (7:2:1)	11,667	def	3,050	ef	1,341	cdefg	0,615	cde	1,956	defgh			2,157	31,9
BP + P + Z (6:2:2)	11,223	ef	3,183	cdef	1,099	efgh	0,534	de	1,632	fghi			2,054	32,8
BP + FP + Z (7:2:1)	11,780	def	3,003	ef	1,033	gh	0,506	de	1,539	ghi			2,251	32,5
BP + FP + Z (6:2:2)	10,637	fg	2,457	g	0,869	h	0,354	e	1,223	i			2,473	28,8
BP + CP + Z (7:2:1)	11,290	ef	3,027	ef	1,088	fgh	0,548	de	1,636	fghi			1,993	33,5
BP + CP + Z (6:2:2)	9,263	g	3,040	ef	0,957	gh	0,487	de	1,414	hi			2,122	32,5
BP + CTR + P + Z (5:2:2:1)	11,767	def	3,583	a	1,400	cdefg	0,703	bcd	2,103	cdefgh			1,998	33,4
BP + CTR + FP + Z (5:2:2:1)	11,397	ef	2,980	f	1,108	efgh	0,545	de	1,652	fghi			2,029	45,5
BP + CTR + CP + Z (5:2:2:1)	13,957	ab	3,547	ab	1,286	defgh	0,569	de	1,854	defgh			2,272	43,9
BP + CTR + RS + Z (5:2:2:1)	12,497	abcdef	3,153	def	1,137	efgh	0,540	de	1,647	fghi			2,135	33,0
Mean	**11,548**		**3,102**		**1,132**		**0,540**		**1,666**				**2,148**	**34,8**
Overall mean	**12,16**		**3,204**		**1,383**		**0,641**		**1,993**				**2,211**	**34,0**
F value	**3,371*** **		**7,036 *** **		**5,363 *** **		**3,266 *** **		**5,679 *** **				**1,112 ns**	**0,983 ns**
LSD	**1,873**		**0,3**		**0,461**		**0,261**		**0,580**				**-**	**-**

1) Values are the means of three replications,

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

3) *** : significant at $P < 0.001$; **: significant at $P < 0.01$; * : significant at $P < 0,05$; ns: non significant

growth (14.190 cm) was observed in the BP+CTR+RS (6:2:2) medium. The lowest height growth (9.26 cm) was obtained in the BP+CP+Z (6:2:2) growing media with 20% zeolite. SH was significantly lower in 20% zeolite added BP+CP+Z treatment than in the BP+CP treatments with no zeolite (Table 5). Our SH values were close to values observed by Ayan (1998).

A significant negative correlation between SH and Na, K and C/N of growing media was observed (Table 6). However, there was a positive correlation between SH and Mn content of media. Negative correlation between SH and Na and K could indicate excess amount of these nutrients in the media to change its pH and alter availability of some minor elements.

Root collar diameter (RCD): RCD differed significantly with growing media types ($P < 0.001$). The largest RCD value (3.583 mm) observed in the BP+CTR+P+Z (5:2:2:1) growing media while the lowest value (2.457 mm) observed in BP+FP+Z (6:2:2) growing media. RCD was significantly lower in 20% zeolite added BP+FP+Z treatment than in BP+FP treatments with no zeolite (Table 5).

Unlike RCD and C/N, there was a significant positive correlation between RCD and Mg and Mn content of growing media (Table 6). Positive correlation between Mg and RCD could be due to high K content of zeolite which reduces the availability of Mg in the soil solution (Brady and Weil, 1999). Negative correlation between RCD and C/N ratio indicates positive effect of substrate quality on RCD and possibility of N limitations in the pots. The highest RCD value in zeolite added treatment (BP+CTR+P+Z (5:2:2:1)) observed in present study could strengthen the slow-release fertilizer aspect of zeolite.

Stem, root and total dry weight (SDW, RDW, TSDW): SDW, RDW and TSDW varied significantly with growing media types ($P < 0.001$). The highest SDW and TSDW values were observed in the BP+CTR+RS (6:2:2) growing media while the lowest values observed in BP+FP+Z (6:2:2). RDW and TSDW were significantly lower in 20% zeolite added BP+CTR+CP+Z treatment than in BP+CTR+CP (6:2:2:) treatment with no zeolite (Table 5).

SDW and TSDW had positive correlation with N, Fe, Mn, total porosity and loss of ignition and had negative correlation with pH, Ca, Na and K content ($P<0.05$). Positive correlation with total porosity could be an indication of poor aeration in pots due to irrigation in nursery and high rainfall in

Table – 5: ANOVA results of zeolite added treatments grouped with treatments without zeolite but same media types (n=21).

Group No	Growing media symbols	Morphological seedling parameters						
		Height (cm)	Root collar diameter (mm)	Dry weight				
				Stem (g)	Root (g)	Total seedling (g)	Stem / root	RP
1	BP + CP (7:3)	12,260 a	3,023	1,497	0,638	2,135	2,44	30,5
	BP + CP + Z (7:2:1)	11,290 b	3,027	1,088	0,548	1,636	1,993	33,5
	BP + CP + Z (6:2:2)	9,263 b	3,040	0,957	0,487	1,414	2,122	32,5
	F value	**24,097 ****	**0,006 ns**	**3,910 ns**	**2,110 ns**	**4,892 ns**	**0,628 ns**	**0,385 ns**
2	BP + FP (7:3)	11,747	2,930 a	1,070	0,711	1,781	1,553	39,5
	BP + FP + Z (7:2:1)	11,780	3,003 a	1,033	0,506	1,539	2,251	32,5
	BP + FP + Z (6:2:2)	10,637	2,457 b	0,869	0,354	1,223	2,473	28,8
	F value	**1,668 ns**	**20,207 ***	**1,519 ns**	**4,311 ns**	**3,224 ns**	**3,395 ns**	**3,419 ns**
3	BP + P (7:3)	12,133	2,990	1,656	0,601	2,257	2,854	26,7
	BP + P + Z (7:2:1)	11,667	3,050	1,341	0,615	1,956	2,157	31,9
	BP + P + Z (6:2:2)	11,223	3,183	1,099	0,534	1,632	2,054	32,8
	F value	**0,439 ns**	**0,998 ns**	**5,225 ns**	**0,528 ns**	**3,261 ns**	**3,524 ns**	**3,947 ns**
4	BP + CTR + CP (6:2:2)	12,747	3,360	1,777	1,411 a	2,918 a	1,555	39,2
	BP + CTR + CP (5:2:3)	13,483	3,280	1,390	0,580 b	1,970 b	2,414	29,5
	BP + CTR + CP + Z (5:2:2:1)	13,957	3,547	1,286	0,569 b	1,854 b	2,272	43,9
	F value	**1,270 ns**	**6,914 ns**	**4,182 ns**	**14,819 ***	**19,618 ***	**3,492 ns**	**3,333 ns**
5	BP + CTR + FP (6:2:2)	11,237	3,480	1,552	0,653	2,205	1,938	30,1
	BP + CTR + FP (5:2:3)	13,710	3,380	1,344	0,508	1,852	2,653	27,5
	BP + CTR + FP + Z (5:2:2:1)	11,397	2,980	1,108	0,545	1,652	2,029	45,5
	F value	**2,887 ns**	**6,796 ns**	**3,021 ns**	**2,552 ns**	**5,708 ns**	**0,959 ns**	**0,908 ns**
6	BP + CTR + P (6:2:2)	11,923	3,387	2,137	0,879	2,683 a	2,992	29,9
	BP + CTR + P (5:2:3)	13,473	3,460	1,282	0,602	1,885 b	1,715	49,2
	BP + CTR + P +Z (5:2:2:1)	11,767	3,583	1,400	0,703	2,103 b	1,998	33,4
	F value	**1,612 ns**	**0,310 ns**	**5,390 ns**	**0,575 ns**	**66,773 *****	**0,461 ns**	**0,140 ns**
7	BP + CTR + RS (6:2:2)	14,190	3,440	2,298	0,836	3,146	2,128	37,7
	BP + CTR + RS + Z (5:2:2:1)	12,497	3,153	1,137	0,540	1,647	2,135	33,0
	F value	**1,691 ns**	**2,753 ns**	**3,956 ns**	**0,670 ns**	**3,301 ns**	**2,185 ns**	**2,480 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

the area. One of the reasons of relatively poor growth in FP+Z media types could be the poor soil aeration in these treatments due to fine sizes of these two growing media. Similarly, pore spaces of growing media could be negatively influenced by the dust-size zeolite used in this study. This could be a reason for our findings of no positive effect of zeolite on some seedling parameters. Similar reports have been made by and Tuzuner and Timay (1984).

Negative correlations with pH, Ca, Na and K content and positive correlations with Fe and Mn could be an indication of excess and low amount of these nutrients in growing media. Brady and Weil (1999) stated that Mn deficiency was found on poorly drained soils rich in organic matter (e.g., peats). They also mentioned that some micronutrient cations react with some organic compounds and form water-insoluble complexes. However, RDW had significantly positive correlation with Fe content and negative correlation with pH of the media (Table 6).

Dry stem/root ratio (SDW/RDW) and dry root percentage (DRP): No significant differences were found in SDW/RDW and DRP among treatments (Table 4). Overall mean dry stem/root ratio and DRP were 2.148 g and 34.8% for zeolite added, and 2.267 g and 33.4% for non-zeolite media, respectively. Thus, suitable scots pine seedlings were propagated in terms of DRP and SDW/RDW parameters in zeolite added media. In general, scots pine seedlings showed high performance in the non-zeolite media types such as BP+CTR+RS (6:2:2), BP+CTR+P (6:2:2) and BP+CTR+CP (6:2:2). Similarly, Ayan (2002b) found best SH, RCD, DSW/DRW and DRP values in BP+CTR+RS (6:2:2) and BP+CTR+P (6:2:2) media types in a study on seedling of oriental spruce (*Picea orientalis* (L.) Link).

The study revealed that although, there was no positive effects on morphology of scots pine seedlings, Manisa-Gordes originated natural zeolite could be used as a growing media. Also, The 1+0 aged seedlings of scots pine grown in zeolite additive media were classified as first quality class of conifer seedlings according to standards of the EU (European Union) and TSI (Turkish Standard Institute) in terms of SH (11,5 cm), RCD (3,1 mm) and SDW/RDW (2,15) values.

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Table – 6: Pearson correlation coefficients among growing media properties and seedling morphological parameters (n=21). Probability of significance is shown in paranthesis (ns: non significant at P<0.05 level).

Properties	SH	RCD	DRW	DSW	TSDW
pH	-0.279	0.060	-0.423	-0.435	-0.479
	ns	ns	(0.050)	(0.049)	(0.028)
CEC	-0.001	0.054	0.287	0.199	0.188
	ns	ns	ns	ns	ns
Organic matter	0.194	0.029	0.254	0.292	0.274
	ns	ns	ns	ns	ns
EC	0.276	0.242	0.022	0.339	0.283
	ns	ns	ns	ns	ns
N	0.067	0.271	0.379	0.437	0.451
	ns	ns	ns	(0.047)	(0.040)
C/N	-0.524	-0.625	-0.227	-0.324	-0.324
	(0.015)	(0.002)	ns	ns	ns
Water holding capacity	0.026	0.287	0.009	0.073	0.020
	ns	ns	ns	ns	ns
Air capacity	0.057	-0.075	0.322	0.341	0.377
	ns	ns	ns	ns	ns
Porosity	0.099	0.243	0.396	0.494	0.476
	ns	ns	ns	(0.023)	(0.029)
Volume weight	-0.100	-0.232	-0.390	-0.495	-0.480
	ns	ns	ns	(0.022)	(0.028)
Loss of ignition	0.192	0.229	0.421	0.458	0.459
	ns	ns	(0.050)	(0.037)	(0.037)
Specific gravity	-0.041	0.077	0.076	0.047	0.014
	ns	ns	ns	ns	ns
Ca	-0.380	-0.222	-0.514	-0.384	-0.521
	ns	ns	(0.017)	ns	(0.015)
Mg	0.244	0.467	0.049	-0.136	0.009
	ns	(0.033)	ns	ns	ns
Na	-0.551	-0.296	-0.596	-0.430	-0.603
	(0.010)	ns	(0.004)	(0.052)	(0.004)
K	-0.458	-0.210	-0.545	-0.411	-0.552
	(0.037)	ns	(0.011)	ns	(0.009)
P	0.386	0.373	0.382	0.014	0.296
	ns	ns	ns	ns	ns
N	0.067	0.271	0.437	0.379	0.451
	ns	ns	(0.047)	ns	(0.040)
Fe	0.306	-0.011	0.488	0.439	0.508
	ns	ns	(0.025)	(0.046)	(0.019)
Cu	0.072	-0.038	0.230	0.081	0.216
	ns	ns	ns	ns	ns
Zn	0.284	0.218	-0.130	-0.070	-0.153
	ns	ns	ns	ns	ns
Mn	0.715	0.710	0.467	0.269	0.441
	(0.000)	(0.000)	(0.033)	ns	(0.045)

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