A synthesis of results on wastes as potting media substitutes for the production of native plant species

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Abstract

The three major functions of a potting medium for plant production is to provide support, to retain water and nutrients, and to allow oxygen diffusion to the roots. A potting medium should meet the requirements of practical plant production such as: to be available and ready at all times, easy to handle, lightweight and to produce uniform plant growth. Constituents such as natural soil, peat, sand, perlite and vermiculite are commonly used as substrates for container plant production. Nevertheless, these materials might be fully or partially replaced by various organic or inorganic wastes, thus achieving environmental and economic benefits. This study presents a synthesis of results extracted from many trials on waste materials as potting media substitutes for the seedlings production of the following native plant species: *Pinus halepensis, Quercus ilex, Quercus macropleis* and *Ceratonia siliqua.* The studied waste materials were either organic or inorganic components including: spoils of peridotite, raw rice hulls, coconut fiber and kenaf (the ground stem of the plant *H. cannabinus* L). The experimental potting media tested were: peat:perlite (3:1), a common medium used for seedling production, peat:spoils of peridotite (3:1), peat:rice hulls (3:1), peat:rice hulls (1:1), peat:coconut fiber (1:1), kenaf (100%) and kenaf:peat:rice hulls (3:1:1). The main physical (water retention characteristics, bulk density, particle density, total porosity) and chemical (N, K, Ca, Mg, soluble P, exchangeable cations, pH and loss on ignition) properties of each potting medium were measured. For each plant species the following seedling quality parameters were assessed: morphological characteristics (shoot height, root collar diameter), shoot and root biomass, Dickson's quality index and shoot and root nutrient concentrations. Then seedlings were planted in the field and their survival and growth was monitored. The feasibility of replacing peat or perlite with various waste materials as well as their effect on seedling quality and field performance are discussed.

Keywords

Container Seedlings, Field Performance, Growing Media, Nursery, Organic and Inorganic Residues, Seedling Quality

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Contents

1 Introduction

The three major functions of a growing medium are to provide support, to retain water and nutrients, and to allow oxygen diffusion to the roots. The water and aeration conditions not only determine the availability of water and air, but also affect the biological activity and mineral nutrient availability of the medium (Lenox and Lumis 1987; Heiskanen 1993). The maintenance of nutrient levels in a growing medium is a common goal in container plant production because it is directly related to nutrient uptake and plant growth. As such, the monitoring of chemical properties of a growth medium becomes a critical aspect for both production and research purposes (Landis et al. 1990). Although there is not an ideal growth medium suitable for all growing potted plants, a growth medium should incorporate physical, chemical, and biological requirements for good plant growth along with the requirements of practical plant production (to be readily available, easy to handle, lightweight and to produce uniform plant growth) (Heiskanen 1993; Reinikainen 1993; Tsakaldimi 2001; Jacobs et al. 2009; Landis and Morgan 2009).

A potting medium rarely contains a single ingredient, often being composed of two or more materials such as: soil, peat or other organic component, sand, perlite, vermiculite. Nevertheless, these materials might be fully or partially replaced with various organic or inorganic waste products like peridotite, rice hulls, coconut fiber, kenaf core, pine bark, etc., thus achieving environmental benefits since ecosystem damage caused by soil, peat, perlite and vermiculite extraction is avoided and the impact of residue accumulations is minimized (Landis and Morgan 2009). The most common substrate is based on *Sphagnum* peat due to its high physical and chemical stability and low degradation rate. Because of the declining availability of peat in the near future due to environmental constraints (Di Benedetto et al. 2006), the European Union has issued directives to reduce the use of peat in growing media and has encouraged research with composted organic wastes (Bragg et al. 2006). There are also economic benefits, because the use of sphagnum peat moss, vermiculite, and other components are becoming increasingly expensive while the use of residues means lower costs (Webber et al. 1999; Abad et al. 2001; Guerin et al. 2001).

Even though many studies have dealt with a specific waste material as potting media substitute, a comparative study on many such materials and their effect on forest species propagation, growth and field performance is missing.

This study aims to: i) present a synthesis of results extracted from many experimental trials on waste organic or inorganic materials as potting media substitutes for seedling production of native plant Mediterranean species: *Pinus halepensis, Quercus ilex, Quercus macroplepis, and Ceratonia siliqua,* and ii) discuss the feasibility of replacing peat or perlite with any various waste materials as well as their effect on the quality of seedlings and field performance.

2 Materials and Methods

2.1 Layout of experiments

The feasibility of replacing peat or perlite - the commonly used components in a potting medium - with spoils of peridotite, coconut fiber, raw rice hulls and ground kenaf core to grow container seedlings of four Mediterranean native plant species was investigated at two open-air forest nurseries (State Forest Nursery in N. Chalkidona, Northern Greece and The Forest Nursery of the Laboratory of Silviculture, Aristotle University Thessaloniki) in three (3) different sets of experiments (Gounaris et al. 2000; Tsakaldimi 2004; Tsakaldimi 2006). In all experiments the peat used was *Sphagnum* Lithuanian peat of medium structure and the perlite was of coarse structure. Coconut fiber or Coir used is the fibrous material that constitutes the thick mesocarp of the coconut fruit (*Cocos nucifera* L.). Coconut coir is reported to have many characteristics that make it equal or superior to peat as a component in growing media (Stamps and Evans 1999; Rose and Haase 2000; Linderman and Davis 2003). Coir is similar to peat in appearance but it is hydrophilic and rehydrates readily contrary to sphagnum peat (Meerow 1994). Spoils of peridotite were derived from the magnesite mining of the Gerakini quarries, northern Greece and were sieved taking particle size 2-4 mm. This material has not been used as potting medium component in other studies. The rice hulls used were fresh, not composted, and they were obtained directly from the mill. The kenaf was fibrous and was derived by drying and crushing the stem of the plant *Hibiscus cannabinus* L.

After a growth period of eight months in the nursery, the produced seedlings of all experiments were subjected to morphological and biomass measurements and nutrient analysis and then they were transplanted to the field for performance testing. Although seedling quality is described at the nursery, it can only be proven on the outplanting site by seedling field survival and growth (Rose et al. 1990; Landis et al. 1995; Tsakaldimi et al. 2013). The experiments conducted were:

<u>Experiment 1</u>: Consisted of two media treatments: peat:perlite (3:1, v/v) as a control and peat:coconut fiber (1:1, v/v). Two oak species *Quercus ilex* and *Quercus macrolepis* were used, in two different pots, Quick pots T18 (650 cm^3) and Paper pots FS 615 (428 cm^3). The experimental design was a randomized complete block with 3 replications. 30 seedlings were produced per treatment, per replication (a total of 360 seedlings per species). The fertilization, irrigation and hardening protocols were the same for both treatments. Acorns were sown in March and seedlings were transplanted

to the field in early December, in the region of Petsofas (Kaloni, Lesvos Island). The climate of the area is Mediterranean sub humid and the dry-hot period lasts 5.5 months. The vegetation of the area belongs to the *Quercetalia ilicis* floristic zone.

Experiment 2: Consisted of two media treatments; peat:perlite (3:1, v/v) medium was used as a control. Spoils of peridotite was used instead of perlite (3:1, v/v). Three types of containers were used, Paper-pots FS615 (482 cm^3 cell volume), Quick pots T18 (650 cm^3) and PlanteK-35 F (270 cm^3). The experimental design was a randomized complete block with 3 replications. Seeds of *Pinus halepensis* and *Ceratonia siliqua* were sown into pots during March. All potting media used were fertilized with mixed fertilizer (N:P:K 15:30:15 + micronutrients) at 1.3 kg m^{-3}, potassium sulfate at 0.6 kg m^{-3}, super-phosphate (0-20-0) at 1.0 kg m^{-3}, magnesium sulfate at 0.4 kg m^{-3} and lime at 2 kg m^{-3}. The irrigation and hardening protocols were the same for all treatments. Twenty four (24) seedlings per treatment, per replication (a total of 432 seedlings per species) were measured. In early December seedlings were transplanted to the field in the 'Kassandra' peninsula, Chalkidiki, Northern Greece. The climate of the area is Mediterranean and the dry-hot period begins in the middle of April and lasts until the middle of September (Tsakaldimi 2001). The vegetation of the area belongs to *Quercetalia ilicis* (Oleo-lentiscetum) floristic zone.

Experiment 3: This experiment included the replacement of both peat and perlite in the potting medium, in several combinations of waste materials. Five media treatments were applied: peat:perlite (3:1, v/v) as a control, peat:raw rice hulls (3:1, v/v), peat:raw rice hulls (1:1, v/v), kenaf (100%) and kenaf:peat:rice hulls (3:1:1, v/v). The treatments were arranged in a randomized complete block design with three (3) replications. The species used was *Pinus halepensis* and the seeds were sown into plastic containers (Quick pots T18; 650 cm^3) during March. Twenty four (24) seedlings per treatment, per replication (a total of 360 seedlings) were measured. All seedlings were irrigated with an overhead irrigation system, as needed and the fertilization and hardening regime were same as in the experiment 2. In early December, seedlings were transplanted to the field at the same site as in the previous experiment.

2.2 Determination of physical and chemical properties of the potting media

At the beginning of the experiments, three random samples of each potting medium were taken for the estimation of their physical properties. Water retention characteristics (% dry weight) were determined using a pressure plate apparatus at -1/3 atm (field capacity) and -15 atm (permanent wilting point). The plant available water was estimated as water retention at field capacity minus water retention at permanent wilting point (Alifragis and Papamichos 1995). The bulk density was determined as the ratio of dry mass to volume at -0.1 KPa matric potential (Heiskanen 1995a). The particle density was measured using pycnometers with water bath (Heiskanen 1995b). The total porosity was estimated as (particle density-bulk density)/ particle density (Heiskanen 1995b).

Chemical properties of the potting media were measured at the end of the growth period in the nursery (8 months after sowing). Three random samples of each growth medium were taken for the determination of N, K, Na, Ca, Mg total concentrations, soluble P, pH and organic matter. Total N was determined using the Kjeldahl method. The total concentrations of K, Na, Ca and Mg were determined after dry ashing at 500^{o}C for five hours. The ash was diluted by HCL 1:1 v/v and filtered. The sample extracts were analyzed for K, Na, Ca and Mg using an atomic absorption spectrophotometer (PERKIN ELMER A Analyst 300). Soluble P was measured by the Olsen method, using $NaHCO_3$ as an extracted solution and then P was determined by visible spectrophotometry and the molybdenum blue method. The pH was determined by electrometric in a 1 soil : 10 water suspension. The estimation of the organic matter was made by the loss on ignition (L.O.I.) method (Alifragis and Papamichos 1995).

2.3 Seedling morphology, biomass and plant tissue analysis

At the end of the growth period in the nursery (8 months after sowing), the shoot height (H) and the root collar diameter (D) (0.5 cm above root collar) of all seedlings were measured with an accuracy of 0.1 cm and 0.1 mm, respectively. Based on the above measurements the sturdiness index (H/D) was calculated for each seedling. Afterwards, twelve randomly selected seedlings per treatment were collected from each experiment and transferred to the laboratory for biomass estimations and nutrient analysis.

For biomass measurements, the seedlings were divided into two parts: shoot (stem + needles) and root system. Both parts were oven-dried at 70^{o}C for 48 hours and then they were weighed. Based on biomass measurements, the ratio root dry weight / shoot dry weight (R/S) and the Dickson's quality index were calculated. Then, sampled shoots and roots of each treatment were subjected to nutrient analysis. The twelve shoot and root samples per treatment were each divided into three groups of four individuals, giving 3 replications per treatment. All samples were pooled at a mill with a sieve 40 mesh and were collected in plastic bottles. Total N was determined by the Kjeldahl method. Total concentrations of P, K, Ca, Mg and Cu were determined after dry ashing at 500^{o}C for five hours. The ash was diluted by HCL 1:1 v/v and filtered. Then, P was determined by visible spectrophotometry and molybdenum blue method and total K, Ca, Mg and Cu were determined by atomic absorption spectrophotometry (PERKIN ELMER A Analyst 300) (Alifragis and Papamichos 1995).

2.4 Evaluation of seedling performance in the field

Field performance of seedlings from the 2nd and 3rd experiment were evaluated during 24 months after outplanting. All planted seedlings were measured twice a year, in spring before the summer drought, and in autumn after the effect of the summer dry period. Seedling measurements included survival and growth in terms of height and ground diameter increment. Field performance of seedlings from the 1st experiment was evaluated based on their survival rate.

2.5 Statistical analysis

All statistics were calculated with SPSS software. Distribution was tested for normality by Kolmogorov - Smirnov criterion and the homogeneity of variances was tested by Levene's test. Significant differences between treatment means were tested using analysis of variance (one-way ANOVA). Wherever treatment effects were significant the Duncan's Multiple Range Test was carried out to compare the means (Snedecor and Cochran 1988).

3 Results and Discussion

3.1 Physical and chemical properties of the potting media

The physical properties of the studied potting media are shown in Table 1. The water retention characteristics presented great differences between the potting media. Replacing perlite by peridotite spoils greatly reduced field capacity and plant available water while much increased bulk density and total porosity. The addition of the rice hulls resulted in a decrease of the water holding capacity and plant available water. Similar results with fresh and composted rice hulls media were reported by other studies (Dueitt and Newman 1994; Kuczmarski 1994). However, the replacement of perlite with rice hulls increased the total porosity from 71.2% (control) to 80.1% and 84.9% (peat:rice hulls 3:1 and 1:1, respectively). Similar results were reported by Kuczmarski (1994). Comparing all studied potting media, the retained water at field capacity and at the permanent wilting point, was greater in the medium with kenaf 100%; the available water was found greater in the control (peat:perlite 3:1), and kenaf 100% (50.5% and 41.9 % respectively). Wang (1994), reported that the medium fine-grade kenaf 100% presented greater water retention (% final volume) than media with 80% or less kenaf. The media consisting of kenaf presented the lowest bulk density values (0.06 g cm^{-3}), while they exhibited the highest values of total porosity (90.7% and 92.8%). These results are compatible with Webber et al. (1999), who amended various ratios of fine-grade kenaf to peat and perlite, and found that kenaf increased the total porosity, while the bulk density was decreased as the percentage of kenaf was increased.

Table 1. Physical properties of the studied potting media.

Physical properties	peat:perlite (3:1)	peat:peridotite spoils (3:1)	peat:coconut fiber (1:1)	peat:rice hulls (3:1)	peat:rice hulls (1:1)	Kenaf (100%)	Kenaf:peat:rice hulls (3:1:1)
Field capacity (%)	246.6	54.2	-	149.8	140.3	325.6	235.8
Permanent wilting point (%)	196.0	26.6	-	128.1	118.3	283.7	225.3
Plant available water (%)	50.5	27.6	34.0	21.7	22.0	41.9	10.5
Bulk density (g cm^{-3})	0.1	0.45	-	0.1	0.1	0.06	0.06
Particle density (g cm^{-3})	0.33	2.00	-	0.50	0.71	0.67	0.80
Total porosity (%)	71.2	77.6	-	80.1	84.9	90.7	92.8

Similarly, great differentiations were observed in the chemical properties of the studied potting media (Tab. 2). The addition of organic materials (coconut, rice-hulls and kenaf) increased the total concentrations of most nutrients in relation to the control medium. In particular, the total concentrations of N, K and Mg were much higher in the kenaf 100% medium (1.44%, 0.50 mg g^{-1} and 2.34 mg g^{-1}, respectively). Alifragis et al. (1997) also reported that the kenaf stem contains high concentrations of nitrogen and other nutrients. The minimum N concentration was performed by peat:peridotite spoils medium (0.21%). The concentration of soluble P was two or more times greater in the media peat:perlite (3:1), kenaf 100% and kenaf:peat:rice hulls (3:1:1) than in the other media (Tab. 2). The pH of all potting media studied was found to be slightly acidic to alkaline (6.0-7.5). The addition of kenaf significantly decreased the organic matter (29.5 and 32.78%) of the growing medium, compared to the values of the other growing media (58.65-71.11%). Similarly, the addition of peridotite spoils to peat reduced in half the organic matter compared to the control treatment. The peridotite spoils, however, increased the Mg concentration in extreme values (25.85 mg g^{-1}), which in turn highly affected the ratio Ca/Mg. Thus, while in all studied potting media the Ca/Mg ratio ranged between 5:1 and 9:1, in the medium with peridotite spoils an unbalanced ratio (approximately 1:2) was observed. Over the years, a significant amount of conversation and salesmanship has revolved around the concept of the ideal soil Ca/Mg ratio. Most of the claims for the ideal ratio range between 5:1 and 8:1. Some of the claims are that the correct soil Ca/Mg ratio will improve soil structure, reduce weed populations, improve forage quality, reduce leaching of other plant nutrients and generally improve the balance of most soil nutrients (Spectrum Analytic Inc. 2015).

Table 2: Chemical properties of the studied potting media.

Chemical properties	**peat:perlite (3:1)**	**peat: peridotite spoils (3:1)**	**peat:coconut fiber (1:1)**	**peat:rice hulls (3:1)**	**peat:rice hulls (1:1)**	**Kenaf (100%)**	**Kenaf:peat:rice hulls (3:1:1)**
N %	0.54	0.21	0.86	0.62	0.79	1.44	0.74
K mg g^{-1}	0.17	0.20	0.90	0.49	0.43	0.50	0.45
Na mg g^{-1}	0.35	0.20	0.40	0.44	0.39	0.34	0.36
Ca mg g^{-1}	11.65	11.08	3.84	11.90	13.90	12.00	15.00
Mg mg g^{-1}	1.40	25.85	0.81	1.70	1.40	2.34	1.73
pH	7.1	7.5	6.0	6.1	6.4	6.8	7.0
L.O.I. %	58.65	25.07	36.3	65.21	71.11	29.50	32.78
soluble P (mg per 100 g)	10.0	5.0	4.1	5.0	4.0	14.0	16.0

The amounts of the nutrients (N, K, Na, Ca, Mg) are the total concentrations.

3.2 The effect of potting media on plant species growth at the nursery phase

3.2.1 *Pinus halepensis* responses

At the end of the nursery phase, and just before the seedlings are transplanted to the field, data analysis showed that the use of waste materials (both organic and inorganic) as substitutes of peat or perlite significantly affected the growth of *P. halepensis* seedlings resulted in generally smaller seedlings (Tab. 3). Seedlings produced in the control treatment (peat:perlite 3:1), were significantly taller and had a significantly greater diameter than all the other seedlings. However, seedlings produced in peat:rice hulls (3:1) even though they were smaller than the control seedlings, were not significantly different. This means that, at least at the nursery phase, the above rice hulls medium can successfully replace control medium for the production of *P. halepenis* seedlings. However, when the proportion of rice hulls increase, the seedlings' height and diameter decrease. As a consequence, the greater shoot dry weight was obtained in the control medium and in peat:rice hulls (3:1), while the maximum root dry weight and seedling quality index were obtained only in the latter medium (Tab. 3). Similarly, Dueitt et. al. (1993) found that potting media with fresh rice hulls that were used for production of Begonia and Impatiens plants, resulted in plant heights similar to the control, while plant dry weight was decreased in media containing 40-50% fresh rice hulls. On the contrary, in Salvia plants, as the proportion of rice hulls increased, the plant height decreased.

Table 3. *Pinus halepensis* seedlings growth and biomass accumulation at the end of the nursery phase, raised in six potting media.

Potting medium	Shoot height (H) (cm)	Root collar diameter (D) (mm)	H/D (cm/mm)	Shoot dry weight (S) (g)	Root dry weight (R) (g)	Total dry biomass (g)	(R/S)	Dickson's quality index (Q.I.)
peat:perlite (3:1)	21.6 (0.6)[a]	2.9 (0.1)[a]	7.5 (0.2)[ns]	2.4 (0.20)[a]	1.0 (0.1)[b]	3.4 (0.3)[a]	0.4 (0.0)[a]	0.3 (0.0)[ab]
peat:peridotite spoils (3:1)	16.7 (6.1)[b]	2.1 (0.6)[b]	7.9 (1.8)[ns]	1.5 (0.6)[b]	0.6 (0.2)[bc]	2.0 (0.8)[b]	0.4 (0.1)[a]	0.2 (0.0)[bc]
peat:rice hulls (3:1)	22.9 (0.7)[a]	3.1 (0.1)[a]	7.5 (0.2)[ns]	2.9 (0.3)[a]	1.3 (0.2)[a]	4.2 (0.5)[a]	0.4 (0.0)[a]	0.4 (0.1)[a]
peat:rice hulls (1:1)	18.6 (0.7)[b]	2.6 (0.1)[ab]	7.2 (0.2)[ns]	1.7 (0.2)[b]	0.7 (0.1)[b]	2.4 (0.3)[b]	0.4 (0.0)[a]	0.2 (0.0)[bc]
kenaf (100%)	13.5 (0.4)[c]	1.8 (0.1)[c]	7.8 (0.2)[ns]	0.9 (0.1)[c]	0.3 (0.0)[d]	1.2 (0.1)[c]	0.3 (0.0)[b]	0.1 (0.0)[c]
kenaf:peat:rice hulls (3:1:1)	13.8 (0.3)[c]	2.0 (0.0)[bc]	7.1 (0.1)[ns]	0.9 (0.1)[c]	0.4 (0.0)[c]	1.3 (0.1)[c]	0.4 (0.0)[a]	0.1 (0.0)[c]

Values are the means ± St. error of the mean in parenthesis. Within the same column the means followed by different letters are statistically different (P<0.05, Duncan test). (ns): non significant differences (P>0.05).

The use of kenaf in the potting media resulted in a significant reduction of the seedlings' dimensions, and contributed to a considerable decrease in the seedlings' biomass and quality index which fell to below half of that in the control seedlings. This suggests that its use for the production of *P. halepenis* seedlings should be seen skeptically. Similarly, Webber et al. (1999), examining fine-grade kenaf as a substitute for vermiculite in a medium containing peat and perlite as well, found that plant height, shoot, and root dry weights of *Vinca minor* decreased as the percentage of kenaf increased. On the contrary, Wang (1994) reported that *Brassaia actinophylla* 4-month-old plants in the media with 70% or more fine-grade kenaf grew taller, had thicker stems and heavier dry weights than those produced in two commercial mixes. Much of the *P. halepensis* growth reduction can be attributed to the kenaf shrinkage that has been observed in all cases of its use. The volume of a potting medium must be fairly constant, since excessive shrinkage is undesirable for growing plants (Reinikainen 1993; Hartman et al. 1997). In our case, at the end of the nursery growth period, the volume of the kenaf potting media decreased about 50% in the kenaf 100% and about 20-30% in the kenaf:peat:rice hulls (3:1:1). The problem of kenaf shrinkage was also noted by Webber et al. (1999) and Wang (1994), who found that the final volume of 100% fine-grade kenaf medium fell in 50% of the initial volume, while this shrinkage was limited by increasing the proportion of peat in the medium.

Replacing perlite by peridotite spoils, in the peat based medium, contributed to a significant reduction of dimensions and biomass allocation of *P. halepenis* seedlings compared to the control. This may be attributed to the unbalanced Ca/Mg ratio of the potting medium.

The addition of the peridotite spoils, rice hulls and kenaf to the peat, as well as the use of pure kenaf, significantly increased the shoot and root tissue concentrations of nitrogen (Tab. 4). Also, as the proportion of rice hulls increased, tissue levels of nitrogen increased. The use of kenaf in the two potting media as well as the peridotite spoils contributed to markedly higher levels of magnesium and calcium in shoots and roots. However, shoot and root phosphorus and potassium concentrations remained unaffected by the potting media treatments.

Table 4. Averages of nutrient concentrations of *Pinus halepensis* seedlings at the end of the nursery phase, raised in six potting media.

	Shoot					Root				
Potting medium	**N (%)**	**P mg g^{-1}**	**Mg mg g^{-1}**	**K mg g^{-1}**	**Ca mg g^{-1}**	**N (%)**	**P mg g^{-1}**	**Mg mg g^{-1}**	**K mg g^{-1}**	**Ca mg g^{-1}**
peat:perlite (3:1)	0.82 (0.03)	1.58 (0.08)	2.03 (0.06)	5.86 (0.7)	5.55 (0.2)	0.63 (0.03)	0.97 (0.02)	1.46 (0.2)	3.56 (0.3)	6.48 (0.5)
peat:peridotite spoils (3:1)	1.30 (0.05)	1.51 (0.08)	3.50 (0.1)	5.90 (0.7)	11.20 (2.0)	1.00 (0.08)	1.20 (0.05)	3.40 (0.3)	3.02 (0.3)	12.42 (1.2)
peat:rice hulls (3:1)	0.95 (0.06)	1.63 (0.07)	1.74 (0.3)	5.93 (0.3)	4.29 (1.3)	0.67 (0.05)	0.70 (0.03)	1.22 (0.1)	2.79 (0.4)	4.99 (0.8)
peat:rice hulls (1:1)	1.32 (0.1)	1.55 (0.2)	2.17 (0.2)	6.75 (0.6)	4.63 (1.05)	0.89 (0.06)	1.08 (0.07)	1.59 (0.2)	3.14 (0.4)	6.80 (0.3)
kenaf (100%)	2.27 (0.1)	1.10 (0.05)	2.79 (0.4)	6.20 (0.03)	14.29 (3.4)	1.68 (0.1)	1.18 (0.07)	2.93 (0.3)	3.51 (0.01)	22.62 (3.7)
Kenaf:peat:rice hulls (3:1:1)	1.85 (0.1)	1.82 (0.1)	2.34 (0.5)	5.12 (0.2)	9.72 (1.2)	1.38 (0.06)	1.28 (0.02)	3.34 (0.6)	2.78 (0.06)	14.46 (0.3)

Values are the means ± St. error of the mean (in parenthesis)

3.2.2 *Ceratonia siliqua* responses

As in *P. halepensis*, the replacing perlite by peridotite spoils, contributed to a significant reduction of seedlings' dimensions and biomass allocation of *C. siliqua* (Tab. 5). The shoot height and biomass was split in half. However, adding peridotite spoils resulted both in a better balanced H/D ratio and an increase of R/S ratio. The addition of the peridotite spoils to peat increased the shoot and root tissue concentrations of N, P, Mg, K, while shoot tissue concentration of Mg was doubled (Tab. 6). A possible explanation for the reduction of shoot height and biomass could be the high Mg concentration and the low Ca/Mg ratio which in combination with low water retention characteristics, and high bulk and particle density of the potting medium, created unfavorable conditions for seedlings growth.

Table 5. *Ceratonia siliqua* seedlings growth and biomass accumulation at the end of the nursery phase, raised in peat:perlite (3:1) and peat:peridotite spoils (3:1).

Potting medium	**Shoot height (H) (cm)**	**Root collar diameter (D) (mm)**	**H/D (cm/mm)**	**Shoot dry weight (S) (g)**	**Root dry weight (R) (g)**	**Total dry biomass (g)**	**(R/S)**	**Dickson's quality index (Q.I.)**
peat:perlite (3:1)	15.5 (10.7)^a	4.4 (1.0)^a	3.3 (1.8)^a	2.7 (2.1)^a	1.2 (0.5)^a	3.9 (2.4)^a	0.6 (0.2)^b	0.7 (0.1)^a
peat:peridotite spoils (3:1)	7.6 (3.5)^b	3.8 (0.7)^b	2.0 (0.7)^b	1.1 (0.5)^b	0.9 (0.3)^b	1.9 (0.7)^b	0.9 (0.3)^a	0.6 (0.1)^b

Values are the means ± St. error of the mean in parenthesis. Within the same column the means followed by different letters are statistically different (P<0.05, Duncan test).

Table 6. Averages of nutrient concentrations of *Ceratonia siliqua* seedlings at the end of the nursery phase raised in two potting media.

	Shoot						Root					
Potting medium	**N (%)**	**P mg g^{-1}**	**Mg mg g^{-1}**	**K mg g^{-1}**	**Ca mg g^{-1}**	**Cu ppm**	**N (%)**	**P mg g^{-1}**	**Mg mg g^{-1}**	**K mg g^{-1}**	**Ca mg g^{-1}**	**Cu ppm**
peat:perlite (3:1)	1.1	0.6	1.7	5.4	8.6	9.5	1.1	0.6	3.7	6.7	14.6	11.8
peat:peridotite spoils (3:1)	1.6	0.9	3.8	5.6	9.2	13.2	1.3	0.8	5.1	7.8	12.7	15.3

3.2.3 Responses of oak species (*Q. ilex* and *Q. macrolepis*)

At the end of the growth period in the nursery, seedlings of both oak species produced in peat:coconut fiber (1:1) showed an almost similar behavior; they were significantly shorter, but had greater root collar diameter, and a significantly greater root biomass than those raised in peat:perlite (3:1). As a result, the R/S ratio which is one of the indicators of seedlings quality (Ritchie 1984) was found higher (Tab. 7 and 8). This shows that the addition of coconut fiber to peat greatly increased the below ground growth of seedlings of both species, contributed to a more rich root system. According to Linderman and Davis (2003), coconut amendment to peat based media influences positively plant growth possibly due to its nutrient-binding properties while growth responses will vary based on the plant. However, Lopez-Galarza (2002) found that root development of strawberry plants grown in peat moss was better than in coir in most studies. Handreck and Black (2002), reported that since all coir products have extremely high K and low Ca contents (as it was found in the current study), it is critical to add a source of Ca to improve plant calcium uptake. Since the pH is already close to 6, liming materials cannot be used because they would increase the pH above optimum. Handreck and Black (2002) suggested that all coir-based media must be amended with gypsum, which also overcomes their low sulfur status. Handreck (1993) and Offord et al. (1998), reported also that *Pseudotsuga menziesii* seedlings grown in coir-based media tended to have higher pH, P, K, and Na and lower Ca, N foliar concentrations compared to the peat moss medium. Nutrient losses in coir may occur as a result of leaching since coir has lower CEC than peat moss. Many studies have found that coir-based media need supplemental N and may also benefit from liming (Handreck 1993; Martinez 1995; Noguera et al. 1997).

Table 7. *Quercus ilex* seedlings growth and biomass accumulation at the end of the nursery phase, raised in peat:perlite (3:1) and peat:coconut fiber (1:1).

Potting medium	**Shoot height (H) (cm)**	**Root collar Diameter (D) (mm)**	**H/D (cm/mm)**	**Shoot dry weight (S) (g)**	**Root dry weight (R) (g)**	**(R/S)**
peat:perlite (3:1)	28.2^{a}	3.5^{ns}	8.0^{a}	1.2^{b}	0.2^{b}	0.13^{b}
peat:coconut fiber (1:1)	19.4^{b}	3.8^{ns}	5.1^{b}	1.8^{a}	1.7^{a}	0.58^{a}

Values are the means ± St. error of the mean in parenthesis. Within the same column the means followed by different letters are statistically different (P<0.05, Duncan test). (ns): non-significant differences (P>0.05).

Table 8. *Quercus macrolepis* seedlings growth and biomass accumulation at the end of the nursery phase, raised in peat:perlite (3:1) and peat:coconut fiber (1:1).

Potting medium	Shoot height (H) (cm)	Root collar diameter (D) (mm)	H/D (cm/mm)	Shoot dry weight (S) (g)	Root dry weight (R) (g)	(R/S)
peat:perlite (3:1)	29.1^{a}	3.9^{b}	7.4^{a}	2.5^{ns}	3.2^{b}	1.3^{b}
peat:coconut fiber (1:1)	17.7^{b}	5.0^{a}	3.6^{b}	2.0^{ns}	5.4^{a}	3.0^{a}

Values are the means ± St. error of the mean in parenthesis. Within the same column the means followed by different letters are statistically different (P<0.05, Duncan test). (ns): non-significant differences (P>0.05).

3.3 The effect of potting media on plant species field performance

3.3.1 *Pinus halepensis*

Five months after outplanting the field survival of *P. halepensis* seedlings was very high for all treatments (91.1 to 100%) (Fig. 1). However, after twelve months, the survival was affected by the dry-hot period, but this effect was not similar for all treatments. The seedlings raised in peat-perlite (3:1) and peat:rice hulls (3:1) media were slightly affected and survived in high percentage (approximately 97%). In contrast, the survival of seedlings raised in the other three media was significantly reduced, ranging from 75% (in kenaf 100%) to 85.7% (in peat:rice hulls 1:1). Twenty four months after outplanting, after the second summer, the survival slightly decreased. The lower survival rate of seedlings raised in the kenaf media could be explained both by the limited volume of the growth medium available for the roots due to shrinkage and the fact that seedlings were not hardened enough for their roots to tolerate field stresses. The high values of the nitrogen concentration in the shoots and roots possibly lead to the reduction of the seedlings' drought resistance and field survival (Landis 1985).

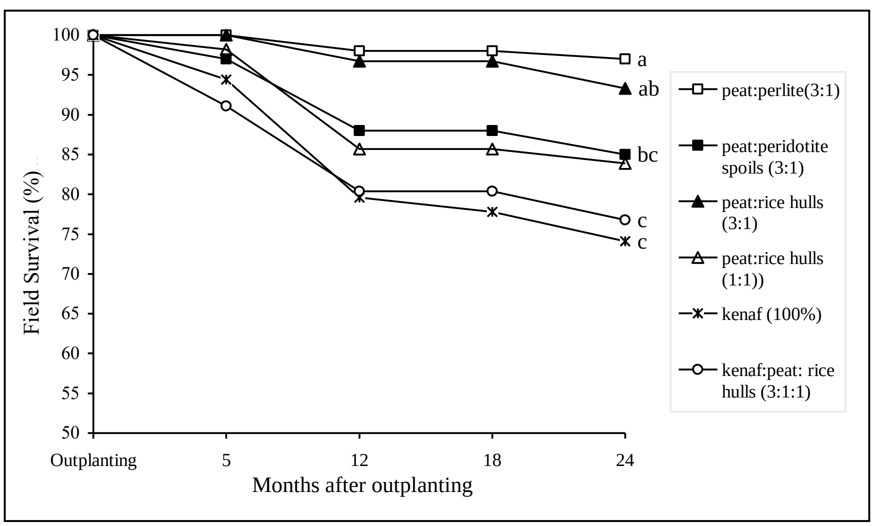
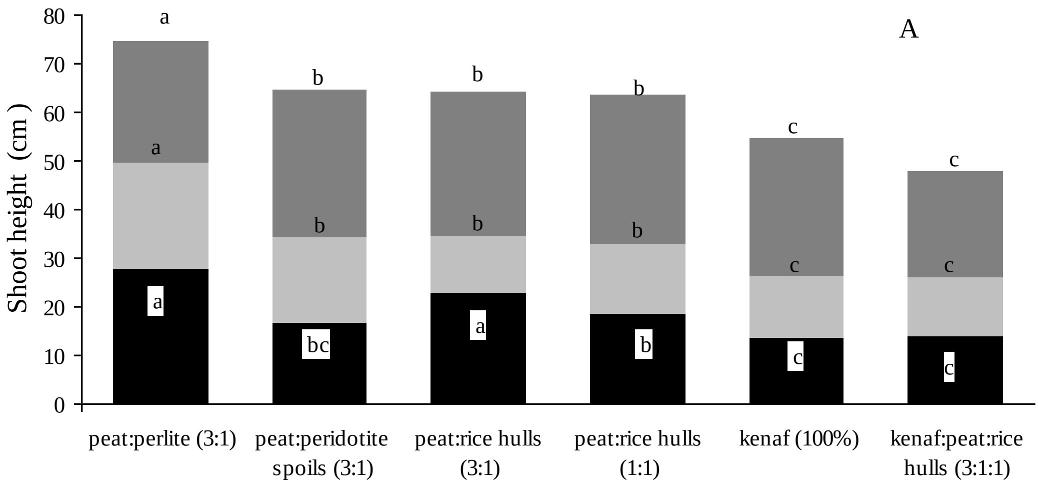


Figure 1. Field survival of *P. halepensis* container seedlings raised in the six potting media during 24 months. The means followed by different lower case letters, are significantly different (*P*<0.05, Duncan test).

The studied potting media also had a significant effect on field growth. The seedlings raised in peat:perlite (3:1) had a greater height than the seedlings raised in all other potting media the first, as well as the second, year after outplanting (Fig. 2A), while the seedlings grown in pure kenaf and in kenaf:peat:rice hulls presented the lowest heights. The higher diameter values were also observed in the seedlings grown in peat:perlite (3:1), followed by those grown in peat:rice hulls (3:1), while the seedlings grown in kenaf:peat:rice hulls presented the lowest diameter (Fig. 2B). The lower field growth of seedlings raised in the two kenaf media can be attributed to their lower initial quality, hence seedling morphological and physiological characteristics before planting highly affect the seedling growth during the first years after outplanting (Sutton 1980; Burdett et al. 1983; Mattsson 1996; Tsakaldimi 2001). However, the overall evaluation of seedling field performance shows that apart from control medium (peat:perlite, 3:1), the medium peat:rice hulls (3:1) should be also considered as the most appropriate for the production of *P. halepensis*, a Mediterranean drought resistant pine species.



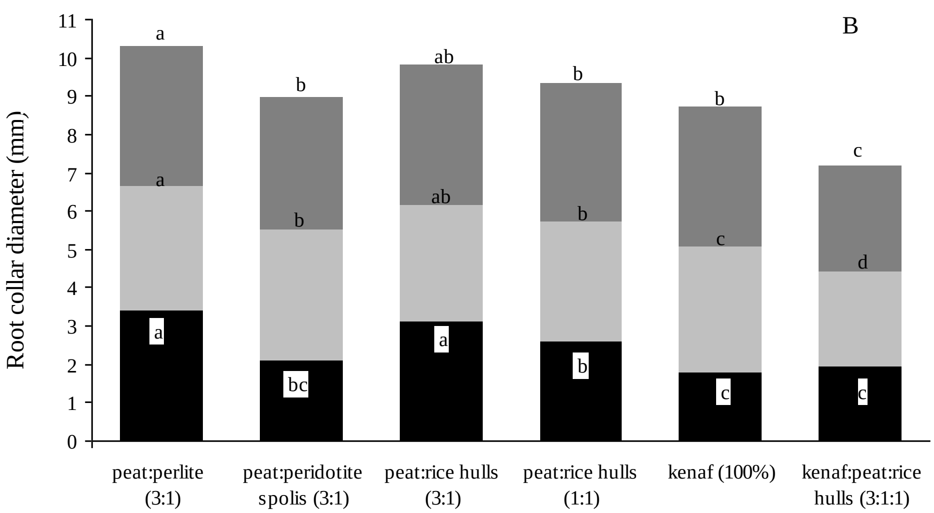


Figure 2. Height (A) and root collar diameter growth (B) of *P. halepensis* container seedlings raised in six potting media during 24 months. Black bars: initial growth, light grey bars: growth after 12 months and dark grey bars: growth after 24 months. Different lower case letters between treatments show significant differences for the final height in each growth period (*P*< 0.05, Duncan test).

3.3.2 *Ceratonia siliqua*

C. siliqua seedlings' field survival was high (91 to 97.8%) the first five months after outplanting (Fig. 3). The dry summer period of the first outplanting year sharply decreased the seedlings survival of both treatments (36.7% for peat:perlite and 27.3% for peat:peridotite spoils), while during the second outplanting year, the survival only slightly decreased (30% and 23.4%). The statistical analysis showed that replacing perlite by peridotite spoils, in the peat based medium had no significant effect on the *C. siliqua* seedlings' field survival. The low survival of seedlings of both media may be explained by the planting site; *C. siliqua* seedlings were planted in a site belonging to the *Oleo-lentiscetum* floristic zone, while the species natural distribution is within the *Oleo-ceratonietum* floristic zone.

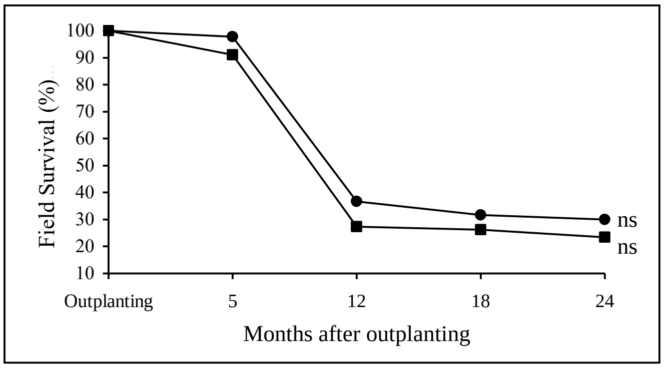


Figure 3. Field survival of *C. siliqua* container seedlings raised in peat:perlite (3:1) -●- and peat:peridotite spoils (3:1) -■- during 24 months. The means followed by ns = non-significant differences (*P*>0.05).

In contrast, seedlings' field growth significantly affected by the type of potting medium. At the end of the first as well as of the second year after outplanting, the seedlings raised in control medium had significantly greater height and root collar diameter than those seedlings raised in peat: peridotite spoils (Fig. 5). The reduction of shoot height and biomass observed in the nursery for seedlings raised in peridotite spoils seems to be crucial for seedling field performance.

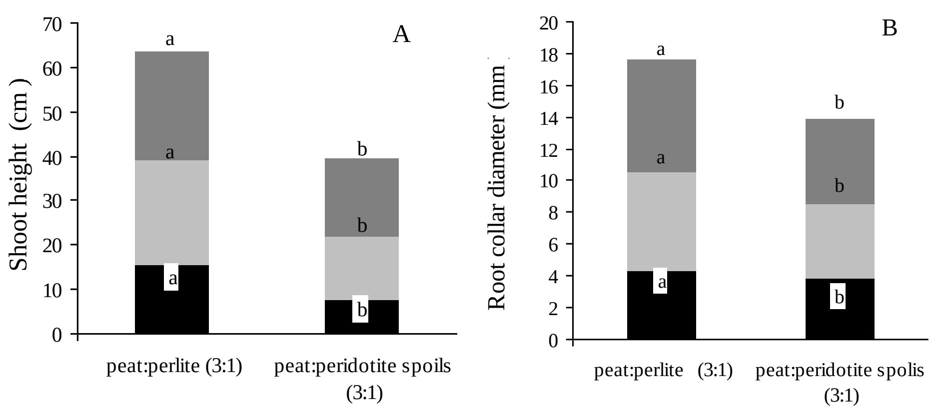


Figure 4. Height (A) and root collar diameter growth (B) of *C. siliqua* container seedlings raised in peat:perlite (3:1) and peat:peridotite spoils (3:1) during 24 months. Black bars: initial growth, light grey bars: growth after 12 months and dark grey bars: growth after 24 months. Different lower case letters between treatments show significant differences for the final height in each growth period (*P*< 0.05, Duncan test).

3.3.3 *Q.ilex* and *Q. macrolepis*

Six months after outplanting (in June) *Q. ilex* and *Q. macrolepis* seedlings raised in peat:coconut fiber presented significantly higher field survival (52% and 41%, respectively) than that in peat:perlite (33% and 26%, respectively) (Fig. 5). The better survival of seedlings grown in coconut fiber can be attributed to their below ground characteristics at the nursery; they had a greater root collar diameter, higher below ground growth and a more rich root system than the control seedlings (Tsakaldimi et al. 2013). However, the 6-month survival of both oak species should be considered very low, taking into account that it only concerns the effect of transplanting shock and not the effect of summer drought, which is the crucial factor determining seedling survival in the Mediterranean region (Tsakaldimi et al. 2013).

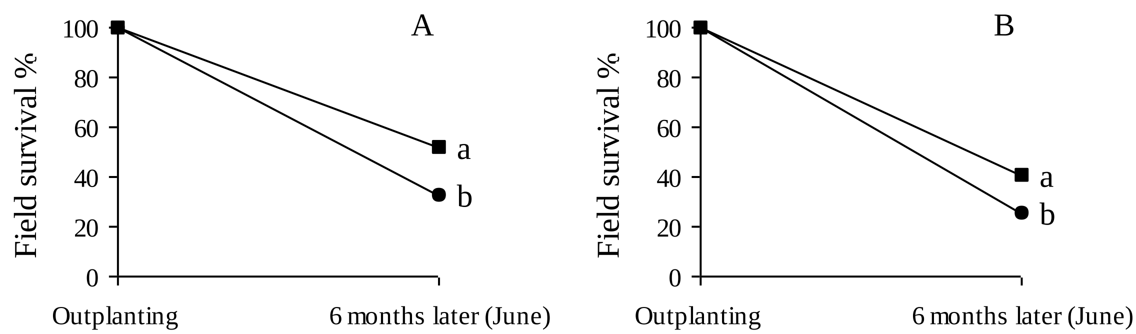


Figure 5. Field survival of *Q. ilex* (A) and *Q. macrolepis* (B) container seedlings raised in peat:perlite (3:1)-●- and peat:coconut fiber (1:1) -■- six (6) months after field outplanting. The means followed by different lower case letters, are significantly different (*P*<0.05, Duncan test).

Even though further data on field performance of oaks is missing, it seems that coconut amendment to peat can be positively examined, since it positively influences oaks nursery growth. The use of coconut as a suitable growth substrate has been reported for many plants, mainly for vegetables, aromatic herbs or floriferous.

4 Conclusions

Summarizing the results of the experiments conducted on wastes as potting media substitutes, the following conclusions can be extracted:

Organic waste materials

Rice hulls - This waste material can successfully be used instead of perlite at a ratio (3:1 v/v) with peat for production of *P. halepenis* container seedlings (or other Mediterranean pines), since, based on the overall seedling nursery and field performance, it produces seedlings similar to that of control medium.

Kenaf - This organic waste material increases the total porosity and plant available water in the potting medium but at the end of the nursery growth period, its volume greatly decreases from 20-50%. Thus, further research for kenaf is needed in order to be suggested as a successful replacement of peat or perlite for the forest species production. *P. halepensis* seedlings raised in the two studied kenaf media grew less than the control seedlings at the nursery, and this negatively affected seedlings field performance. Nevertheless the obtained results are not very disappointing; however, to ensure the volume stability of the kenaf-based potting medium seems to be essential for the production of high quality seedlings. Possibly kenaf has to be composted before use in order to achieve its volume stability.

Coconut fiber - Even though scarce data on seedling performance is available, it seems that coconut amendment to peat in a ratio 1:1 (v:v) can be positively examined, since it positively influenced seedlings' below ground growth in the nursery that contributed to the significantly higher field survival of Mediterranean oaks *Q. ilex* and *Q. macrolepis*. However, coconut coir should be put to further tests before its full operational use, studying both different mix ratios with peat and its effectiveness in production of other forest plant species.

Inorganic waste materials

The spoils of peridotite - This natural inorganic waste material can be used with caution as an alternative of perlite in a ratio 3:1 v/v with peat. Although it increases the total porosity of the peat-based medium, it greatly reduces plant available water and presents an unbalanced Ca/Mg ratio. In case of *P. halepensis* container seedlings, the addition of peridotite spoils to peat contributed to a significant reduction of seedlings dimensions and biomass compared to the control. However, these seedlings presented high survival rates (approximately 85%, two years after outplanting), and satisfactory growth in the field. Given that the outplanting was carried out in dry sites, without any post-planting care, the peridotite spoils suggested to be mixed in a small proportion with peat for the production of containerized Mediterranean pine seedlings. In the case of *C. siliqua* container seedlings, the addition of this waste material resulted in a significant reduction of seedlings size and biomass, which seems to be crucial for seedling field performance. Thus, peridotite spoils are not suggested as potting media substitute for *C. siliqua* seedling production. However, future research adjusting nutrient and irrigation regime tailored to peridotite spoils' physical and chemical attributes could be undertaken.

5 References

Abad M, Noguera P, Bures S (2001) National inventory of organic wastes for use as growing media for ornamental potted plant production: a case study in Spain. Bioresource Technology 77: 197–200.

Alifragis D, Papamichos N (1995) Description-Sampling-Laboratory Analysis of Forest Soils and Plant Tissues. Dedousi Publishers, Thessaloniki, Greece.

Alifragis D, Grigoriou A, Passialis C, Voulgaridis E (1997) Kenaf as a secondary crop in sandy soils under Mediterranean climate conditions. In: Proc. 3rd International Conference on Development of Forestry and Wood Science/Technology. Serbia/Yugoslavia, Belgrade, 29th September–3rd October, pp 1–8.

Bragg N, Brocklehurst TF, Smith AC, Bhat M, Waldron KW (2006) The development of sustainable growing media components from composted specific bio-waste streams. International Plant Propagators' Society Combined Proceedings 55: 256-258.

Burdett AN, Simpson DG, Thompson CF (1983) Root development and plantation establishment success. Plant Soil 71: 103–110.

Di Benedetto A, Petracchi JC, Marcella G, Montaron P, Chavez W (2006) Evaluation of alternative substrates for bedding plants. International Journal of Agricultural Research 1(6): 545-554.

Dueitt S, Newman SE (1994) Physical analysis of fresh and aged rice hulls used as a peat moss substitute in greenhouse media. In: Proceedings of SNA Research Conference, vol. 39, pp 81–85.

Dueitt S, Howell J, Newman SE (1993) Rice hulls as a vermiculite substitute in peat-based media for growing greenhouse bedding plants. In: Proceedings of SNA Research Conference, vol. 38, Section 2: container grown plant production, pp 62–64.

Gounaris N, Ganatsas P, Tsakaldimi M, Zagas T, Tsitsoni T, Hatzistathis A (2000) Effect of the production technique on the survival and growth of seedlings of two oak species. Scientific Annals of the Dept. of Forestry and Natural Environment, A.U.Th, vol. 40/1, pp 193-205 (in Greek).

Guerin V, Lemaire F, Marfa O, Caceres R, Giuffrida F (2001) Growth of *Vivurnum tinus* in peat-based and peat-substitute growing media. Scientia Horticulturae 89: 129-142.

Hartmann HT, Kester DE, Davies FT (1997) Plant Propagation, Principles and Practices. Prentice-Hall International, Inc., Englewood Cliffs, New Jersey.

Heiskanen J (1993) Favourable water and aeration conditions for growth media used in containerized tree seedling production: a review. Scand. J. Forest. Res. 8: 337–358.

Heiskanen J (1995a) Compaction of growth media based on *Sphagnum* peat during one-year culturing of container seedlings. Suosera 46 (3): 63–68.

Heiskanen, J (1995b) Physical properties of two-component growth media based on *Sphagnum* peat and their implications for plant available water and aeration. Plant Soil 172: 45–54.

Handreck KA (1993) Properties of coir dust, and its use in the formulation of soilless potting media. Commun. Soil Sci. Plant Anal. 24: 349–363.

Handreck K, Black N (2002) Growing Media for Ornamental Plants and Turf. 3rd edn. University of New South Wales Press Ltd. Sydney, Australia. ISBN 0 86840 7968.

Jacobs DF, Landis TD, Luna T (2009) Growing media. In*:* Dumroese RK, Luna T, Landis TD, (eds), Nursery manual for native plants: A guide for tribal nurseries - Volume 1: Nursery management. Agriculture Handbook 730. Washington, D.C.: U.S. Department of Agriculture, Forest Service.

Kuczmarski D (1994) Amending the cost of media. Amer. Nurseryman 179 (10): 47–52.

Landis TD (1985) Mineral nutrition as an index of seedling quality. In: Duryea ML (ed), Evaluating Seedling Quality: Principles, Procedures and Predictive Abilities of Major Tests. Forest Research Laboratory, Oregon State University, Corvallis (Chapter 4).

Landis TD, Tinus RW, McDonald SE, Barnett JP (1990) Containers and growing media.The Container Tree Nursery Manual Agriculture Handbook 674 (vol. 2). USDA Forest Service, Washington, DC.

Landis TD, Tinus RW, McDonald SE, Barnett JP (1995) Nursery planning, development and management. The Container Tree Nursery Manual Agriculture Handbook 674 (vol. 1). USDA Forest Service, Washington, DC (Chapter 1).

Landis TD, Morgan N (2009) Growing media alternatives for forest and native plant nurseries. In: Dumroese RK, Riley LE (eds) National Proceedings: Forest and Conservation Nursery Associations—2008. Proc. RMRS-P-58. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 26–31. Online: http://www.fs.fed.us/rm/pubs/rmrs_p058.html.

Lennox TL, Lumis GP (1987) Evaluation of physical properties of several growing media for use in aerial seedling containers. Can. J. For. Res. 17: 165-173.

Linderman RG, Davis EA (2003) Arbuscular mycorrhiza and growth responses of several ornamental plants grown in soilless peat-based medium amended with coconut dust (coir). HortTechnology 13(3): 482-487.

Lopez-Galarza S, Maroto JV, Cano E, San Bautista A, Pascual B (2002) Enhancing root systems of waiting-bed strawberry plants grown on substrates. J. Hort.Sci. Biotech. 77:58-61.

Martinez H (1995) Coir could quickly gain share in growing media market. Greenhouse Management and Production 14: 69-73.

Mattsson A (1996) Predicting Weld performance using seedling quality assessment. New Forests 13: 227–252.

Meerow AW (1994) Growth of two subtropical ornamentals using coir (coconut mesocarp pith) as a peat substitute. HortScience 29: 1484-1486.

Noguera P, Abad M, Pucahdes R, Noguera V, Macquieira A, Martinez J (1997) Physical and chemical properties of coir waste and their relation to plant growth. Acta Horticulturae 450: 365–369.

Offord CA, Muir S, Tyler JL (1998) Growth of selected Australian plants in soilliess media using coir as a substitute for peat. Australian Journal of Experimental Agriculture 38: 879–887.

Reinikainen O (1993) Choice of growing media for pot plants. Acta Horticulturae 342: 357–360.

Ritchie GA (1984) Assessing seedling quality. In: Duryea ML and Landis TD (eds) Forest Nursery Manual: Production of Bareroot Seedlings. Martinus Nijhoff/ Dr. W. Junk Publishers, The Hague/Boston/Lancaster, for Forest Research laboratory, Oregon State University, Corvallis, pp 243-259.

Rose R, Carlson WC, Morgan P (1990) The target seedling concept. In: Proceedings of Combined Meeting of the Western Forest Nursery Associations, Roseburg, 13–17 August, Oregon. USDA Forest Service, Gen. Tech. Rep. RM-200, Rocky Mountain Forest and Range Experiment Station, Colorado, pp 1–8.

Rose R, Haase DL (2000) The use of coir as a containerized growing medium for Douglas-fir seedlings. Native Plants Journal 1:107-111.

Snedecor GW, Cochran WG (1988) Statistical Methods. The Iowa State University Press.

Spectrum Analytic Inc. (2015) Magnesium Basics. Online: http://www.spectrumanalytic.com/support/library/ff/Mg_Basics.htm.

Stamps RH, Evans MR (1999) Growth of *Dracaena marginata* and *Spathiphyllum* 'Petite' in Sphagnum Peat- and Coconut Coir Dust-based Growing Media. J. Environ. Hort. 17(1): 49-52.

Sutton RF (1980) Planting stock quality, root growth capacity and Weld performance of three boreal conifers. New Zeal. J. For. Sci. 10: 54–71.

Tsakaldimi M (2001) Research on the production and quality assessment of the container-planting stock used in the afforestations. Dissertation, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki.

Tsakaldimi M (2004) Use of inorganic and organic solid wastes for container-seedlings production. Proceedings of the International Conference 'Protection and Restoration of the Environment VII', 28 June-1 July 2004, Mykonos, Greece.

Tsakaldimi M (2006) Kenaf (*Hibiscus cannabinus* L.) core and rice hulls as components of container media for growing *Pinus halepensis* M. seedlings. Bioresource Technology 97: 1631-1639.

Tsakaldimi M, Ganatsas P, Jacobs DF (2013) Prediction of planted seedling survival of five Mediterranean species based on initial seedling morphology. New Forests 44: 327-339.

Wang YT (1994) Using ground kenaf stem core as a major component of container media. J. Amer. Soc. Hortic. Sci. 119 (5): 931–935.

Webber CL, Whitworth J, Dole J (1999) Kenaf (*Hibiscus cannabinus* L.) core as a containerized growth medium component. Ind. Crops Prod. 10: 97-105.