USE OF INORGANIC AND ORGANIC SOLID WASTES FOR CONTAINER- SEEDLINGS PRODUCTION

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ABSTRACT

This study examines the effect of peridotite spoils and rice hulls as components in peat-based growth media on biomass accumulation and nutrient concentrations of containerized *Pinus halepensis* seedlings. The results showed that the spoils of peridotite limited the shoot and root dry weight of the seedlings while the rice hulls did not significantly affect it. Shoot and root concentrations of K slightly decreased whereas those of Mg, P, Ca increased in seedlings produced in peat: spoils of peridotite medium. The addition of the rice hulls to peat slightly affected nutrient concentrations of seedlings.

ΧΡΗΣΙΜΟΠΟΙΗΣΗ ΑΝΟΡΓΑΝΩΝ ΚΑΙ ΟΡΓΑΝΙΚΩΝ ΣΤΕΡΕΩΝ ΥΠΟΛΕΙΜΜΑΤΩΝ ΓΙΑ ΤΗΝ ΑΝΑΠΤΥΞΗ ΒΩΛΟΦΥΤΩΝ ΦΥΤΑΡΙΩΝ

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ΠΕΡΙΛΗΨΗ

Η εργασία εξετάζει κατά πόσο η μίξη στείρων υλικών περιδοτίτη και ριζοφλοιού με τύρφη επηρεάζει τη βιομάζα και τη συγκέντρωση θρεπτικών στοιχείων στους φυτικούς ιστούς των παραγόμενων φυταρίων χαλεπίου πεύκης. Τα αποτελέσματα έδειξαν ότι τα στείρα υλικά περιδοτίτη μείωσαν το ξηρό βάρος βλαστού και ρίζας των φυταρίων, ενώ ο ριζοφλοιός δεν επηρέασε σημαντικά τη βιομάζα των φυταρίων σε σχέση με το μάρτυρα. Η μίξη τύρφης με στείρα υλικά περιδοτίτη μείωσε σημαντικά τη συγκέντρωση καλίου στο βλαστό και στη ρίζα των φυταρίων ενώ οι συγκεντρώσεις μαγνησίου, φωσφόρου και ασβεστίου αυξήθηκαν. Η μίξη τύρφης με ριζοφλοιό επηρέασε ελαφρά τη συγκέντρωση θρεπτικών στοιχείων στους φυτικούς ιστούς των φυταρίων.

1. INTRODUCTION

A potting medium for growing plants, rarely contains a single ingredient, often being composed of two or more materials such as soil, peat, pine bark, sand, perlite, vermiculite. However, the high price and the limited availability of some materials on one hand and the demand for recycle and reclaim solid wastes generated form by agriculture, livestock, forestry, mining etc on the other hand, resulted in the investigation of various residues as components of a container growth medium [1], [2], [3].

Although there is not an ideal growth medium suitable for all production techniques, this should incorporate physical, chemical and biological requirements for good plant growth together with those requirements of practical plant production [1], [4], [5], [6]. Thus, the aim of this study was a) to investigate the feasibility of replacing perlite (commonly used in seedling production) with an inorganic and an organic residue in peat—based growth media by examining the physical and the chemical properties of the media and b) to assess their effect on biomass accumulation and nutrient concentrations of containerized *Pinus halepensis* seedlings.

2. MATERIALS AND METHODS

Two experiments were conducted at an open-air nursery of State Forest Service (N. Chalkidona, North Greece). The seeds of *Pinus halepensis* were sown during March.
Experiment 1: it was consisted of two media treatments: peat:perlite (3:1, v/v) as a control and peat: spoils of peridotite (3:1, v/v). Spoils of peridotite (particle size 2-4 mm) were derived from the mining area of the Grecian Magnesites Company. Three types of containers: paper-pots FS615 (482 cm^3 cell volume), quick pots T18 (650 cm^3 c.v.) and planteK-35 F (270 cm^3 c.v.) were used for each growing medium. The experimental design was a randomized complete block with 3 replications. There were 24 seedlings per treatment, per replication (total 432 seedlings).

Experiment 2: it was also consisted of two media treatments: peat:perlite (3:1, v/v) as a control and peat:rice hulls (3:1, v/v). The rice hulls were fresh and they were obtained directly from the mill. The quick pots T14 (330 cm^3 cell volume) were used for each growing medium. The two treatments were arranged in a randomized complete block design with 3 replications. There were 24 seedlings per treatment, per replication (total 144 seedlings).

All potting media used in the two experiments, were fertilized with mixed fertilizer (N:P:K 15:30:15 + micronutrients) at 1.3 kgr/m^3. potassium sulfate at 0.6 kgr/m^3, super-phosphate (0-20-0) at 1.0 kgr/m^3, magnesium sulfate at 0.4 kgr/m^3 and lime at 2 kgr/m^3. All seedlings were irrigated with an overhead irrigation system, as needed. During the growth period, seedlings were watered with ammonium nitrate solution (250 g/ 100 lit water) every 15 days. In early September, seedlings were preconditioned to water stress (predawn leaf water potential - 1.5 MPa) in order to promote their resistance to field water deficits. After the drought, the seedlings were well watered and then were fertilized with 150 g potassium sulfate, 200 g super-phosphate and 15 g ammonium nitrate per 100 lit water, every 20 days.

2.1 Growth media sampling

At the beginning of the experiments three random samples of each growth medium were taken for the estimation of 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 [7]. The bulk density was determined as the ratio of dry mass to volume at - 0.1 KPa matric potential [8]. The particle density was measured using pycnometers with water bath. The total porosity was estimated as (particle density- bulk density)/ particle density [9].

At the end of the growth period, three random samples of each growth medium were taken for the determination of N, K, Na, Ca, Mg total concentrations, soluble P, exchangeable cations, pH and percentage of organic matter. Total N was determined by Kjeldahl method. Total concentrations of K, Na, Ca, Mg and Cu were determined after dry ashing at 500 °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, Mg and Cu using an atomic absorption spectrophotometer (PERKIN ELMER A Analyst 300). Soluble P was measured by Olsen method, using NaHCO3 as an extracted solution and then P was determined by visible spectrophotometry and molybdenum blue method. The pH was determined electrometric in a 1 soil: 10 water suspension. The exchangeable cations K^+, Na+, Mg ++, Ca were determined by atomic absorption spectrophotometry. The estimation of the organic matter was made by the loss on ignition (L.O.I.) method [7].

2.2 Biomass estimations and plant tissue analysis

At the end of the nursery growth period (November), twelve randomly selected seedlings per treatment, from both experiments, were collected for destructive sampling and they were transferred to the laboratory for biomass estimations as well as for tissue 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 °C for 48 hours and then they were weighed. The root to shoot ratio was calculated by the root and shoot dry weights [10].

After biomass estimations, 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 [11], [12]. All samples were pooled at a mill with a sieve 40 mesh and were collected in plastic bottles. Total N was determined by Kjeldahl method. Total concentrations of P, K, Ca, Mg and Cu were determined after dry ashing at 500 °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), [7].

2.3 Statistical analysis

All statistics were calculated with SPSS software (v. 9.0 for windows). 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 [13].

3. RESULTS

3.1 Physical and chemical properties of the growing media

The physical properties of the three formulations of the growing media, used in the two experiments, are shown in the Table 1. Water retention characteristics presented great differences between the growing media. The retained water at field capacity (-1/3 atm), at permanent wilting point (-15 atm) as well as the available water were greater in the medium peat:perlite (246.56%, 196.05%, 50.51% respectively) and were much lower in the medium peat: peridotite spoils (54.19%, 26.60%, 27.59% respectively). The bulk density of the medium peat:perlite was relatively similar to bulk density of the medium peat: rice hulls and ranged from 0.096 to 0.099 g/cm^3. On the contrary, the addition of peridotite spoils to peat much increased the bulk density to 0.449 g/cm^3. No differences were detected in the total porosity between the three growing media which ranged from 71.17 to 80.08%.

TABLE 1. Physical properties of the three growing media formulations

Physical properties	peat:perlite (3:1)	peat:peridotite spoils (3:1)	peat:rice hulls (3:1)
Field capacity (%)	246.56	54.19	149.81
Permanent wilting point (%)	196.05	26.60	128.08
Plant available water (%)	50.51	27.59	21.73
Bulk density (g/cm^3)	0.096	0.449	0.099
Particle density (g/ cm^3)	0.33	2.00	0.50
Total porosity (%)	71.17	77.55	80.08

Generally adequate amounts of nutrients were retained in the studied growing media (Tables 2 and 3). The addition of peridotite spoils to peat much decreased the N total concentration and the percentage of organic matter, increased the Mg total concentration in extremely high value (25.85 mg/g) and as a consequence increased the ratio Mg/Ca, while did not affect the pH value in relation to control (7.1 to 7.5) (Table 2). On the contrary, the addition of rice hulls to peat increased the N, K, Na total concentrations, the percentage of the organic matter and decreased the pH value to 6.1.

TABLE 2: Chemical properties of the growing media used in the two experiments. The amounts of the nutrients are the total concentrations.

Growing media	N %	K mg/g	Na mg/g	Ca mg/g	Mg mg/g	pH	Organic matter %
Peat:perlite (3:1)	0.54	0.17	0.35	11.65	1.40	7.1	58.65
Peat:peridotite spoils (3:1)	0.21	0.20	0.20	11.08	25.85	7.5	25.07
Peat: rice hulls (3:1)	0.62	0.49	0.44	11.90	1.70	6.1	65.21

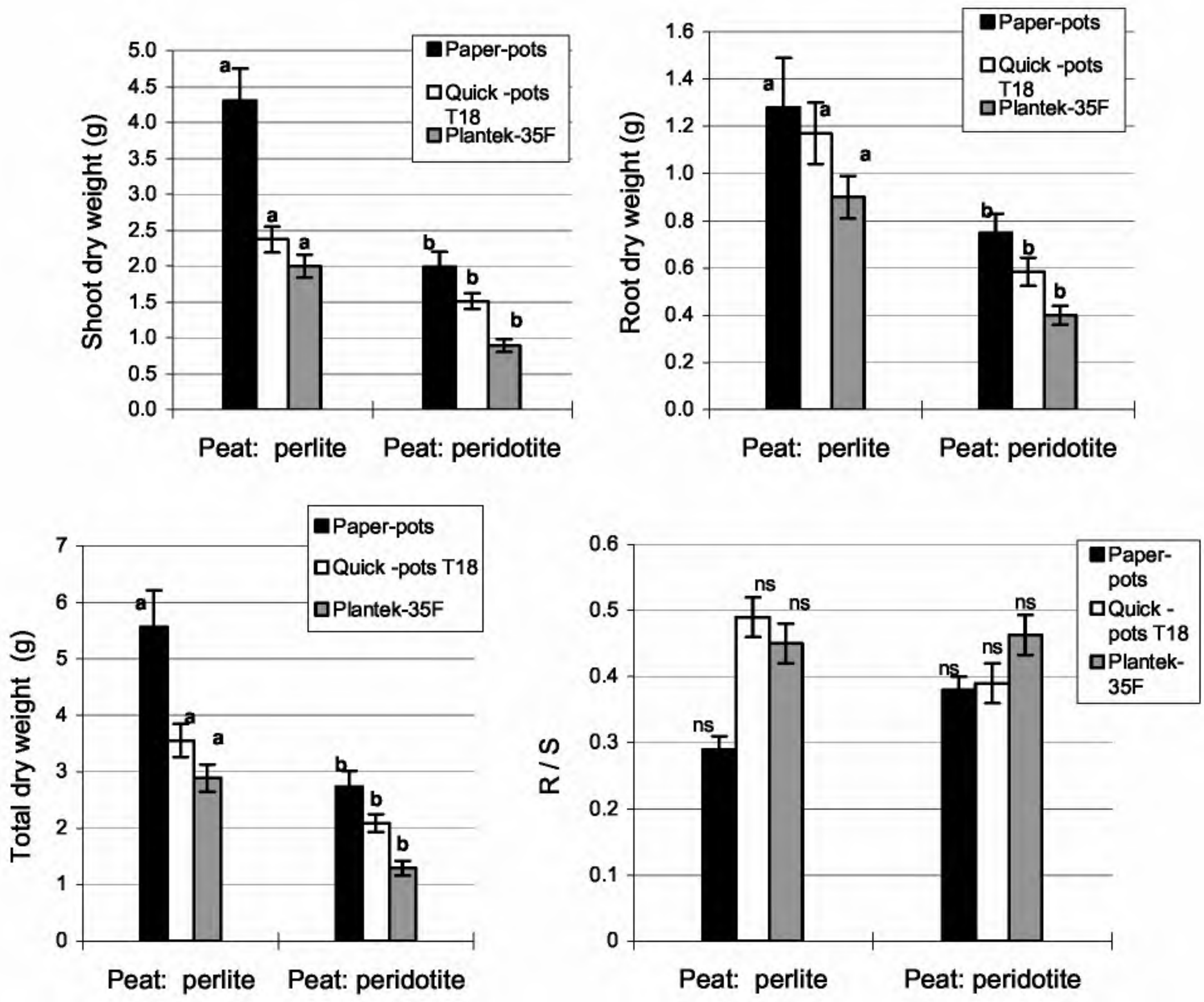
As it is shown in Table 3, the medium peat: perlite (3:1) presented the higher concentration of soluble P (10 mg/100g) than the other two growing media. The addition of peridotite spoils to peat significantly reduced the concentrations of K^+ and Ca^{++}. There were no other remarkable differences in the concentrations of exchangeable cations between the three growing media.

TABLE 3: Exchangeable cations and the soluble P of the growing media used in the two experiments.

Growing media	P (mg/100 g)	K^+ (meq/100 g)	Na^+ (meq/ 100 g)	Ca^{++} (meq/100g)	Mg^{++} (meq/100 g)
peat:perlite (3:1)	10.0	0.36	0.65	14.12	3.17
peat:peridotite spoils (3:1)	5.0	0.06	0.43	4.87	4.03
peat: rice hulls (3:1)	5.0	0.16	0.86	11.06	2.97

3.2 Biomass accumulation of seedlings

The results from the first experiment revealed that the addition of peridotite spoils to peat significantly reduced the shoot dry weight, root dry weight and total dry weight of seedlings, in all container types used. However, the R/S ratio remained unaffected by the growth medium treatment (Figures 1- 4). At the second experiment, the addition of raw rice hulls to peat did not significantly affect the dry weights of the seedlings (Figure 5). The total dry weight of the seedling ranged from 3.38 to 4.15 g.



Figures 1- 4 : Effect of replacing perlite with spoils of peridotite on seedling biomass. Values are means ± standard error. For the same container type, the means followed by different letters, are significantly different ($P < 0.05$, n=12, Duncan test). ns = non significant differences ($P>0.05$).

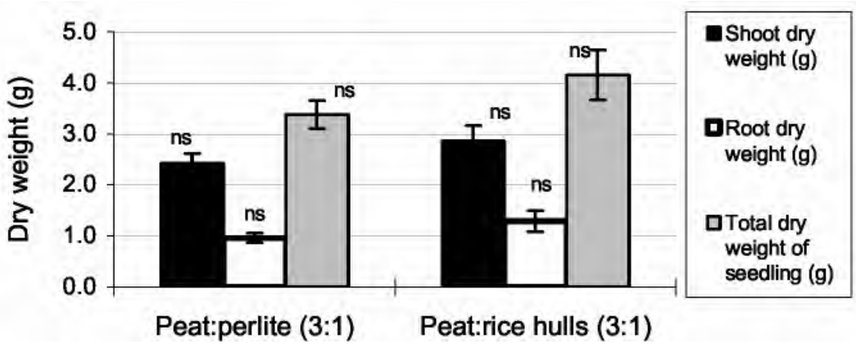


Figure 5: Effect of replacing perlite with rice hulls on seedling biomass. Values are means ± standard error, ns: non significant differences ($P>0.05$).

3.3 Nutrient concentrations in the seedlings

As it is shown in the Table 4, seedlings grown in peat: peridotite spoils presented significantly greater P and Mg concentrations in their shoots and N, P, Mg and Ca concentrations in their roots than seedlings grown in peat: perlite medium. However, no significant differences were found in nutrient concentrations between the seedlings grown in peat:rice hulls and seedlings grown in peat: perlite, with the following exception; P concentration of roots was significantly greater in seedlings grown in peat:perlite (Table 5).

TABLE 4: Nutrient concentrations in shoots and roots of one-year old *Pinus halepensis* seedlings grown in peat:perlite (3:1) and peat:peridotite spoils (3:1) medium

Shoots						
Growing media	Container type	N %	P mg/g	Mg mg/g	K mg/g	Ca mg/g
peat:perlite	Paper-pots	0.99	1.00	1.85 b	7.52	5.50
peat:peridotite spoils	-//-	1.05	1.43	3.63 a	6.25	8.46
peat:perlite	Quick -pots T18	0.91	1.12 b	2.63	6.53	11.20
peat:peridotite spolis	-//-	1.38	2.07 a	3.21	6.15	15.04
peat:perlite	Plantek-35F	0.88	1.60	2.62	7.05	5.02
peat:peridotite spoils	-//-	1.36	1.10	3.58	5.52	10.06
Roots						
Growing media	Container type	N %	P mg/g	Mg mg/g	K mg/g	Ca mg/g
peat:perlite	Paper-pots	0.64	0.80	1.28 b	3.33	4.27 b
peat:peridotite spoils	-//-	0.79	0.95	3.21 a	2.84	9.99 a
peat:perlite	Quick -pots T18	0.71 b	0.80 b	1.78	3.16	7.64 b
peat:peridotite spoils	-//-	1.06 a	1.45 a	3.27	3.52	10.4 a
peat:perlite	Plantek-35F	0.71 b	0.85	2.06 b	3.22	8.37 b
peat:peridotite spolis	-//-	1.01 a	1.05	3.71 a	2.75	16.93 a

TABLE 5: Nutrient concentrations in shoots and roots of 1+0 *Pinus halepensis* seedlings grown in peat: Derlite (3:1) and in peat: rice hulls (3:1) medium

Shoots					
Growing media	N %	P mg/g	Mg mg/g	K mg/g	Ca mg/g
peat: perlite	0.82	1.58	2.03	5.86	5.55
peat: rice hulls	0.95	1.63	1.74	5.93	4.29
Roots					
Growing media	N %	P mg/g	Mg mg/g	K mg/g	Ca mg/g
peat:perlite	0.63	0.97 a	1.46	3.56	6.48
peat:rice hulls	0.67	0.70 b	1.22	2.79	4.99

4. DISCUSSION-CONCLUSIONS

The findings of this study show that the studied alternative materials (inorganic and organic) modified the physical and chemical properties of the growing medium, which in turn, influenced seedlings biomass and nutrient status. This effect was more obvious in the case of peridotite spoils which greatly reduced water retention characteristics of the growing medium. The field capacity, the permanent wilting point and the plant available water of the growing medium were reduced by the replacement of perlite with peridotite spoils. On the contrary, bulk and particle density were increased approximately four times compared to the control medium. These alternations are considered to be negative for seedlings development [1], [5]. However, the increase of bulk density was lower than that recorded by the addition of sand (0.6^3 g/cm³) [14]. The only evident change in chemical properties, caused by the addition of peridotite spoils, was the extreme high concentration of magnesium and the high Mg/Ca ratio, which exceed the common values recorded for several growing media. Furthermore the high Mg/Ca ratio in the substrate causes anomalies in the plant physiology and reduces the growth [15]. This change consequently contributed to a higher Mg uptake by seedlings that resulted in higher Mg concentration in plant tissues, especially in roots. Regarding the concentrations of other tissue nutrients, peridotite addition increased Ca of plant tissues and slightly affected N and P concentrations, especially in roots. As a result of all the above-mentioned changes, the pine seedlings raised in the growing medium with peridotite spoils exhibited significantly lower biomass accumulation. This can be attributed to either water limitation for the plant or to higher bulk density that restrict the root development, even though the total porosity was within the proposed range for plant production [1].

The addition of rice-hulls to peat also modified the physical and chemical properties of the growing medium. The water retention characteristics were largely affected; the plant available water was reduced to less than half of the control, while the total porosity increased. Similar effects were reported by Kuczmarski [16] and Dueitt and Newman [17]. However, the rice hulls increased the percentage of the organic matter and improved medium acidity for *Pinus halepensis* seedlings [18]. Rice hulls increased also the N, K, Na total concentrations of the growth medium in relation to control, even though no significant differences were found in nutrient concentrations between seedlings grown in rice hulls and perlite, respectively. Seedlings of both treatments exhibited similar shoot and root biomass accumulation. This shows that rice-hulls can substitute perlite in a growth medium containing 3 parts peat and 1 part rice hulls without causing any problem in biomass allocation and nutrients content of pine seedlings. On the contrary, earlier studies report that the increase of the rice hulls proportion (peat-rice hulls 1:1) significantly reduced the seedling quality of *Pinus halepensis* [19]. Also, other scientists [20] reported that the dry weights of begonia and impatiens decreased in media containing 40-50% rice hulls. However, Kuczmarski [16] suggests the use of composted rice hulls than raw one because the raw rice hulls compete the plants for the available nitrogen.

As a conclusion it could be asserted that the addition of peridotite spoils to peat caused unfavorable physical and chemical properties of the growth medium, limited the shoot and root dry weights of the seedlings and much Mg concentrations increased in shoot and root and resulted in high Mg/Ca ratios. While, the addition of rice-hulls to peat gave seedling dry weights similar to control and slightly affected the nutrients concentration of seedlings. Finally, it seems that the physical and chemical properties of a medium can prescribe the seedlings' growth. The medium peat: rice hulls (3:1) can successfully substitute the medium peat: perlite (^{3}:1), while the medium peat: spoils of peridotite (3:1) needs more research in order to be used for plant production in Forestry.

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