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Use of Several Organic Waste Materials as Growing Media for Conifer Plants

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Abstract

In this experiment the use of different organic waste materials - poplar tree bark, palm fibre and sewage sludge compost (Biosolid) - as substrates in the production of ornamental plants was studied, with a special interest in the suitability of palm fibre as growing substrate for conifer plants. The plant species tested were *Pinus densiflora*, *Cupressus arizonica* and *C. sempervirens* and the substrate mixtures were: (1) poplar tree bark, (2) poplar tree bark with 15% of sewage sludge compost, (3) poplar tree bark with 30% of sewage sludge compost, (4) palm fibre, (5) palm fibre with 15% of sewage sludge compost and (6) palm fibre with 30% of sewage sludge compost. The substrates were physically and chemically well characterized and 75-cm plants were grown on them for one year. For each species, the experimental design consisted of six random blocks with 60 plants per substrate grown in 7-l capacity pots. The plant and substrate status were periodically tested during the experiment. Since biosolid recycling is the main objective of the present work, mixtures with 30% of composted sewage sludge will be the most convenient substrate to use. Plant growth in palm fibre substrates mixed with biosolid showed similar results as those grown in poplar tree bark based substrates. For *C. sempervirens* and *C. arizonica*, a mixture of poplar tree bark or palm fibre and 30% biosolid compost in volume gave the best results. However, the lower cost of the poplar tree bark than the palm fibre substrate indicated the use of the PB+30% CSS. Also, the results showed that palm fibre substrate alone was not a good growing media for *Cupressus* plants.

Keywords: *Cupressus arizonica*, Growing Media, *Cupressus sempervirens*, Organic Waste Materials, *Pinus densiflora*.

استفاده از چند پس ماند آلی به‌عنوان بستر رشد برای گیاهان سوزنی برگ

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چکیده

در این آزمایش استفاده از پس ماندهای آلی مختلف شامل: پوست درخت صنوبر، الیاف خرما و کمپوست لجن فاضلاب (پس ماندهای آلی جامد) برای تولید گیاهان زینتی با توجه ویژه به الیاف خرما به‌عنوان یک بستر رشد برای گیاهان سوزنی برگ مورد مطالعه قرار گرفت. گونه‌های گیاهی مورد استفاده در این آزمایش شامل: کاج ژاپنی (*Pinus densiflora*)، سرو نقره‌ای (*Cupressus arizonica* L.) و سرو ناز (*C. sempervirens* L.) و مخلوط‌های بستر کشت شامل: (۱) پوست درخت صنوبر، (۲) پوست درخت صنوبر+ ۱۵ درصد کمپوست فاضلاب، (۳) پوست درخت صنوبر+۳۰ درصد کمپوست لجن فاضلاب، (۴) الیاف خرما، (۵) الیاف خرما+ ۱۵ درصد کمپوست فاضلاب و (۶) الیاف خرما+۳۰ درصد کمپوست لجن فاضلاب، بودند. قبل از شروع آزمایش خصوصیات فیزیکی و شیمیایی بسترهای مورد استفاده مشخص شد و گیاهانی با ارتفاع تقریبی ۷۵ سانتی‌متر، در یک دوره زمانی یک‌ساله در آنها کشت شدند. گونه‌های گیاهی در قالب طرح بلوک‌های تصادفی با شش تکرار در گلدان‌هایی با اندازه ۱-۷ کاشته شدند. هدف اصلی این آزمایش استفاده مجدد از پس ماندهای آلی جامد بود. نتایج نشان داد که بسترهای حاوی ۳۰ درصد کمپوست لجن فاضلاب مناسب‌ترین بسترها برای استفاده هستند. گیاهان رشد یافته در بسترهای الیاف خرما در مخلوط با کمپوست لجن فاضلاب، نتایج مشابه‌ای را نسبت به آنهایی که در بستر پوست درخت صنوبر، رشد یافته بودند، نشان دادند. در مورد گونه‌های سرو نقره‌ای *Cupressus arizonica* و سرو ناز *C. sempervirens* ترکیبی از پوست درخت صنوبر یا الیاف خرما با ۳۰ درصد پس ماندهای آلی جامد، بهترین نتایج را نشان داد، اما به دلیل کمتر بودن ارزش اقتصادی پوست درخت صنوبر نسبت به الیاف خرما، استفاده از بستر ترکیبی پوست درخت صنوبر+۳۰ درصد کمپوست لجن فاضلاب، توصیه می‌شود. همچنین نتایج نشان داد که بستر الیاف خرما به تنهایی بستر خوبی برای پرورش گونه‌های سرو مورد آزمایش نیست.

کلیدواژه‌ها: پسماندهای آلی، بسترهای رشد، کاج ژاپنی، سرو ناز و سرو شیراز.

Introduction

Materials such as peat and natural soils are commonly used in Iran for the production of substrates for ornamental plants (Padasht Dehkaei, 1998; Mahbob Khomami, 2005; Hatamzadeh and Karimi, 2005). However, for over 25 years, container production of ornamental trees, shrubs and perennial plants has depended almost entirely on quality soilless media derived from both organic and inorganic constituents. Waste products such as biosolids (Gouin, 1993; Ingelmo *et al*., 1998; Guerrero *et al*., 2002) and wood waste (Hicklenton *et al*., 2001; Chen *et al*., 2002) have frequently been used in nurseries, but the availability of other materials is attracting more attention. For example, coco fibres are increasingly used as substrate because they share many characteristics in common with peat (Lennartsson, 1997). This material has become commercially popular during the past few years, and it is now being successfully used in different parts of the world as peat substitute for container-grown ornamental plants (Handreck, 1993; Stamps and Evans, 1997; Offord *et al*., 1998; Noguera *et al*., 2000; Abad *et al*., 2002). To our knowledge, however, no experiments had been conducted to show the feasibility of this substrate for growing plants such as *Pinus densiflora*, *Cupressus sempervirens*or *Cupressus arizonica*.

Composted softwood bark and biosolid compost are both stable organic products containing essential plant nutrients, but for biosolids, changing economic, industrial and demographic conditions mean that both the physical and the chemical makeup of the compost shifts with time and source (Hicklenton *et al*., 2001). As the biosolid feedstock changes, so does the quality of the compost. While slight variations in texture, particle size and mineral composition are of less consequence when the material is used as landscape mulch, these factors may be of significant importance when combined with other constituents in the limited volume of a plant container. Since successful container culture depends on producing a consistent finished plant, variability in the growing substrate can pose significant problems if it affects the growth rate, nutrition or plant form and aesthetics.

The use of these materials provides environmental benefits since ecosystem damage caused by soil or peat extraction is avoided and the impact of residue accumulation is minimized (Raviv *et al*., 1986). There are also economic benefits, since the use of residues means lower costs than those of conventional materials (Ingelmo *et al*., 1998).

Guerrero *et al*., (2002) had shown the feasibility of poplar tree bark and sewage sludge mixtures as substitutes for peat in substrates formulation for growing *P. densiflora* and *C. arizonica* plants. *P. densiflora* dry weight showed no response to the addition of biosolids as a substrate component but, in contrast, *C. arizonica* dry weight increased significantly with the addition of the organic refuse. Differences in plant height were observed, but their commercial value was the same.

The objectives of this work were (1) to introduce palm fibre as an alternative substrate for *P. densiflora*, *C. arizonica* and *C. sempervirens* growth in containers and (2) to take a further step in the research on growing media for ornamental plants based on poplar tree bark–biosolid mixtures, with an increasing percentage of biosolid in the mixture.

Materials and Methods

This study was carried out in a commercial nursery devoted to producing conifer plants located near Talesh (-18 msl, longitude 48°, 52', latitude 38°, 25') in the North of Iran, which tested the alternative substrates in real production conditions. According to the data provided by the nearest pluviometric observatory, the annual average precipitation is 451 mm, the annual average temperature 13.8 °C and the average potential annual evapotranspiration is 768 mm. The irrigation water was classified as good quality water for irrigating pot plants by Waters *et al*., (1972).

The substrate mixtures used were: (1) poplar tree bark, (2) poplar tree bark with 15% of sewage sludge compost, (3) poplar tree bark with 30% of sewage sludge compost, (4) palm fibre, (5) palm fibre with 15% of sewage sludge compost and (6) palm fibre with 30% of sewage sludge compost. The substrates tested are shown in Table 1, as well as their relative costs. The most expensive component was the palm fibre, but it was introduced in this study as a request of the nursery, due to its similarities with peat and its increasing use as a plant growing medium in Iran. The commercially valuable composted sewage sludge (CSS) was produced from a mixture of sawdust and anaerobically digested sewage sludge (volume ratio of 0.2:1) by the aerated-pile method.

The hydrophysical characteristics of the substrates tested were determined using the method described by De Boodt and Verdonk (1972) and Bunt (1988) for measuring the water desorption curve of organic substrates. According to this method, $Porosity_0$ (%v/v) is the total pore space determined at 0-cm water suction, $Airspace_{10}$ (% v/v) is the difference in volume between porosity and the moisture content at 10-cm suction, and $Microporosity_{100}$ is the moisture content (% v/v) at 100-cm suction. Two intervals of available water (AW) commonly used for horticultural purposes (De Boodt *et al.*, 1974) were also determined. AW_{10-50} (% v/v) is the water released from the substrate when the suction increases from 10 to 50-cm, and AW_{50-100} (% v/v) is the water released from the substrate when the suction increase from 50 to 100-cm water tension.

The electrical conductivity (EC) and substrate pH were determined in the saturated paste extract using an Orion Conductivimeter and an Orion Research Ion Analyzer 920A pH-meter equipped with a pH-glass electrode, respectively, as well as the nutrient content by atomic absorption spectrometry (AA, Perkin Elmer 2800). The total concentration of heavy metals was determined after digestion with 3:1 (v/v) concentrated $HCl-HNO_3$ (aqua regia) by atomic absorption spectrometry. Total organic matter (TOM) was measured by the dry combustion method at 540 °C, oxidized organic matter (OMox) by the Walkley–Black method (1934) and N by Kjeldahl digestion (Bremmer and Mulvaney, 1982).

Three plant species were grown to evaluate the suitability of the substrates: *P. densiflora*, *C. arizonica* and *C. sempervirens*. For each species, the experimental design consisted of six random blocks with 60 plants per substrate grown in 7-l capacity pots. Plants were previously grown in 3-l pots, and transplanted to 7-l pots when they achieved around 75-cm height. All experimental pots were irrigated by aspersion. Two samples were taken in the course of the experiment: the first, six months after transplanting (September 2005) and the second 12 months later (April 2006). In each sampling, plant height was determined and three plants per treatment and species were collected. Shoots and roots were separated by cutting them off at the base of the root and rinsed with deionized water. Fresh weight was determined. Roots and shoots were oven-dried at 80 °C until a constant weight was obtained, and dry weight was determined. The Nitrogen content and nutrients and heavy metal concentrations in the shoots and roots were assessed.

The statistical significance of the results obtained was assessed by multiple ANOVA (F and Duncan's multiple range tests) with a probability level of 95%.

Table 1- Composition of the substrates tested and relative cost.

Substrate	Composition	Relative cost
PB+N	Poplar tree bark+1.5 $g\ l^{-1}$ slow release NPK fertilizer (16:8:12)	39
PB+15% SSC	Poplar tree bark+15% (v/v) sewage sludge compost	33
PB+30% SSC	Poplar tree bark+30% (v/v) sewage sludge compost	27
F	Palm fibre	100
F+15% SSC	Palm fibre+15% (v/v) sewage sludge compost	85
F+30% SSC	Palm fibre+30% (v/v) sewage sludge compost	70

Results and Discussion

In order to attain the first objective, several mixtures between poplar tree bark compost (PB), palm fibre (F) and increasing amounts of composted sewage sludge (CSS) were tested. The final substrates presented the physical characteristics shown in Table 2.

As found in previous studies (Ingelmo *et al.*, 1998; Chen *et al.*, 2002; Guerrero *et al.*, 2002), the particle and bulk densities increased with the addition of sludge and presented higher values for the poplar tree bark than for the palm fibre. When bulk density increases, the number of larger pores is reduced, and the root force necessary for deformation and displacement of substrate particles readily becomes limiting, and root elongation rates decrease (Taylor and Ratliff, 1969). There are also differences between plant species in root responses to compaction (Bennie, 1991; Materechera *et al.*, 1992) but inhibition of root elongation is not necessarily correlated with the inhibited uptake of mineral nutrients (Shierlaw and Alston, 1984). The porosity of the substrates decreased with the addition of sludge, and it was higher for the coco fibre media than for poplar tree bark substrates. A decrease in porosity with compost addition was also reported by several authors (Ingelmo *et al.*, 1998; Guerrero *et al.*, 2002) for peat- and poplar tree bark-sewage sludge substrates. Substrates using sludge showed higher microporosity than the poplar tree bark and palm fibre substrates. This fact is particularly interesting, since increases in microporosity improve rewettability of substrates due to both an increase in their water holding capacity and also a reduction in drainage (Beardsell and Nichols, 1982). Available water between 10 and 50 cm of water column suction (AW_{10-50}) was, in general, higher for palm fibre based substrates than for poplar tree bark substrates, but AW_{50-100} did not show any significant differences between them.

Although compost percentages affected some measured parameters, the physical properties of the substrates were generally within the recommended ranges for production of ornamental plants (Poole *et al.*, 1981; Bunt, 1988; Rynk *et al.*, 1992).

The soluble salt content of CSS-based media was very high immediately after potting (Table 3), and well above the 0.6–2.0 mS cm^{-1} recommended for healthy, vigorous growth (Wright, 1986). EC values above 3.5 mS cm^{-1} are often too high to support vigorous plant growth in containers (Lemaire *et al.*, 1985). Chong *et al.* (1991), however, have reported good growth of several woody species in media containing spent mushroom compost with initial EC values exceeding 8 mS cm^{-1}. The same fact was observed by Guerrero *et al.* (2002) for *P. densiflora* and *C. arizonica* grown using poplar tree bark and sewage sludge as container media. Bark compost typically contributes few soluble salts to growing media (Chong and Rinker, 1994) as does palm fibre, so the major contribution to the EC was related to the addition of sewage sludge compost.

Table 2- Main physical characteristics of substrates.

Substrate	Particle density (kg m^{-3})	Bulk density (kg m^{-3})	$Porosity_{0}$ (% v/v)	$Airspace_{10}$ (% v/v)	$Microporosity_{100}$ (% v/v)	AW_{10-50} (% v/v)	AW_{50-100} (% v/v)
PB+N	1980c	290b	85.4d	56a	18c	9.7b	3.3a
PB+15% SSC	2080b	410a	80.3e	44b	23b	9.9b	4.1a
PB+30% SSC	2120a	426a	79.9f	31c	25b	19.2a	4.7a
F	1580d	57e	96.4a	52a	21bc	16.6a	6.6a
F+15% SSC	1980c	115d	94.2b	45b	24b	19.5a	5.7a
F+30% SSC	2100ab	231c	89.0c	41b	32a	14.4ab	1.9a

Values followed by the same letter in the same column are not significantly different at the 95% level according to Duncan's test.

By the end of the experiment, EC decreased to the values recommended for plant growth for all the substrates and plant species (Table 3), but there were still significant differences between substrates with or without CSS, especially when it is added to the palm fibre. Substrate pHs were around 7.0 (Table 3), except for the palm fibre (pH 6.1), which is normal for this type of substrate (Abad *et al.*, 2002). At the end of the experiment, no significant differences between substrates were found due to the successive watering with the irrigation water (pH=7.3). A similar situation occurred with the electrical conductivity (EC irrigation WATER=490 μS cm^{-2}). The pH remained within the range considered suitable for woody plant container production (Whitcomb, 1988).

Oxidized organic matter (Table 4) decreased with the biosolid addition, as well as the total organic matter content. At the end of the experiment, total organic matter had increased in comparison with the initial conditions, but oxidized organic matter had decreased, and this must be due to the incorporation of plant residues to the media and the mineralization of the organic matter along the growing period. The addition of the sludge notably increased the nitrogen content of the substrates, as was expected, and the highest value corresponded to the F+30% CSS mixture.

Rosen *et al.*, (1993) have indicated that a C:N ratio of between 15:1 and 20:1 is ideal for ready-to-use municipal solid waste compost, Ozores-Hampton *et al.*, (1998) suggested a 25:1 ratio or less to consider a compost to be matured, and Ingelmo *et al.*, (1998) obtained optimal results for *C. sempervirens* growth using different substrates with biosolids as a component and with C:N ratios of around 25:1. In the present study, poplar tree bark and palm fibre initial conditions shown very high C:N ratios, but the biosolid addition significantly reduced this parameter, reaching optimal values as described in the references. The PB+15% CSS and F+15% CSS substrates were mature and stable according to Rosen *et al.*, (1993), but PB+30% CSS and F+30% CSS media have shown low values. By the end of the experiment, the poplar tree bark C:N ratio was reduced for the three plant species, but the opposite occurred with the palm fibre. Although, this might indicate that this medium is not suitable for long cultivation periods, the addition of the sludge minimized this problem, providing a most stable substrate. The rest of the substrates showed acceptable C:N values, except for the F+30% CSS media, which showed lower values than the ones for a mature substrate. However, Inbar *et al.* (1990) have cautioned that the C:N ratio of compost is only one technique by which maturity should be gauged and that plant bioassays and specific chemical analysis (to determine organic and inorganic chemical content and degree of decomposition) are equally important. Moreover, Guerrero *et al.*, (2002) described an optimal growth of *P. densiflora* and *C. arizonica* with C:N ratios much more higher than 25:1.

The heavy metal concentrations in all the substrates were lower than the limit values accepted in the European Union (1986). Table 5 shows the metal content in the initial materials.

All the plants in all the media appeared healthy throughout the growing season and did not shown signs of nutrient deficiency or toxicity at any time (data not shown). Figure 1 represents the increase in height during the experimental period. In general, *C. sempervirens* showed the greatest growth, except in the PB substrate. The best results for this plant species were obtained with the PB+30% CSS and F+30% CSS media, what suggests an interesting recycling solution for biosolids, and an economic benefit for nurseries. *C. sempervirens* root dry weight (Table 6) did not show any significant differences between the substrates tested.

Shoot dry weight decreased with the addition of sludge to the substrates with poplar tree bark and the highest values were obtained for those plants grown in palm fibre media. More consistent plants were developed in F+30% CSS container media than in PB+30% CSS, but they show a lower height increase. Substrates with 30% of composted sewage sludge

Table 3- Electrical conductivity EC (μS cm^{-1}) and pH of the substrates before and after the culture.

Substrate	Initial condition		Final characteristics					
			Pine		Arizonica		Cypress	
	pH	EC	pH	EC	pH	EC	pH	EC
PB+N	7.0c	1937c	7.4a	489b	7.2a	602a	7.3a	570b
PB+15% SSC	7.2b	6157b	7.0a	719b	7.1a	946a	7.1a	570b
PB+30% SSC	7.6a	8237a	7.5a	2180a	7.2a	883a	7.1a	1862a
F	6.1d	1343c	7.4a	350b	7.3a	349b	7.3a	469b
F+15% SSC	7.1cb	5313b	7.2a	2890a	7.4a	1090a	7.3a	2000a
F+30% SSC	7.0c	9350a	7.4a	2940a	7.4a	1109a	7.7a	2490a

Table 4- Total organic matter (TOM, %), oxidized organic matter (%), Kjeldahl nitrogen (%) and C/N ratio of the substrates before and after the culture.

Substrate	Initial condition				Final characteristics											
					Cypress				Arizonica				Pine			
	OM_{ox}	TOM	NKj	C/N	OM_{ox}	TOM	NKj	C/N	OM_{ox}	TOM	NKj	C/N	OM_{ox}	TOM	NKj	C/N
PB+N	39.3b	53.3b	0.43f	53.0	18.4ab	66.7c	0.22d	48.6	22.0a	65.4c	0.34c	37.6	22.0a	63.7c	0.31c	41.0
PB+15% SSC	32.6c	45.2c	0.89d	21.2	16.9b	57.3d	0.51b	19.2	18.7bcd	50.3c	0.56c	19.3	15.6b	62.6c	0.55b	16.4
PB+30% SSC	29.3c	42.5d	1.25c	13.6	17.6ab	67.5c	0.54b	18.9	17.7cd	50.0c	0.75b	13.7	14.7b	58.2d	0.49b	17.3
F	46.0a	85.6a	0.71c	37.6	19.9a	96.4a	0.16c	71.9	19.3bc	95.8a	0.16f	70	14.1b	95.2a	0.14d	58.6
F+15% SSC	42.1ab	53.9b	1.59b	15.3	18.1ab	79.6b	0.40c	26.3	16.6d	79.7b	0.48d	20	11.4c	82.2b	0.35c	18.8
F+30% SSC	34.3c	43.9cd	2.05a	9.7	17.0b	66.1c	0.69a	14.3	20.3ab	56.4d	0.94a	12.5	16.5b	64.5c	0.84a	11.3

Table 5- Heavy metals content (*Aqua regia* extraction, mg kg^{-1} dry matter).

Substrate	Cd	Cr	Cu	Zn	Pb	Ni
PB	3.1± 0.2	7.5± 0.6	12.4± 0.8	14.9± 1.0	0.5± 0.1	5.2± 0.1
F	-	-	0.008± 0.004	0.010± 0.004	-	-
CSS	2.6± 0.3	744± 2.1	460± 1.7	1420± 3.5	352± 1.9	87.3± 2.0

Table 6- Dry weight (g) of plants grown in the substrates tested.

Substrate	Cypress		Arizonica		Pine	
	Root	Shoot	Root	Shoot	Root	Shoot
PB+N	32.6a	81.58	46.55a	91.61a	71.18a	162.75a
PB+15% SSC	30.71a	60.87ab	52.77a	98.15a	64.45ab	124.14ab
PB+30% SSC	34.37a	73.02b	62.55a	116.89a	49.62b	113.08b
F	32.76a	68.21b	41.48a	63.18a	68.45a	129.33ab
F+15% SSC	40.26a	101.18ab	49.23a	130.2a	59.83ab	125.98ab
F+30% SSC	46.39a	113.57a	60.49a	127.42a	66.28ab	139.45ab

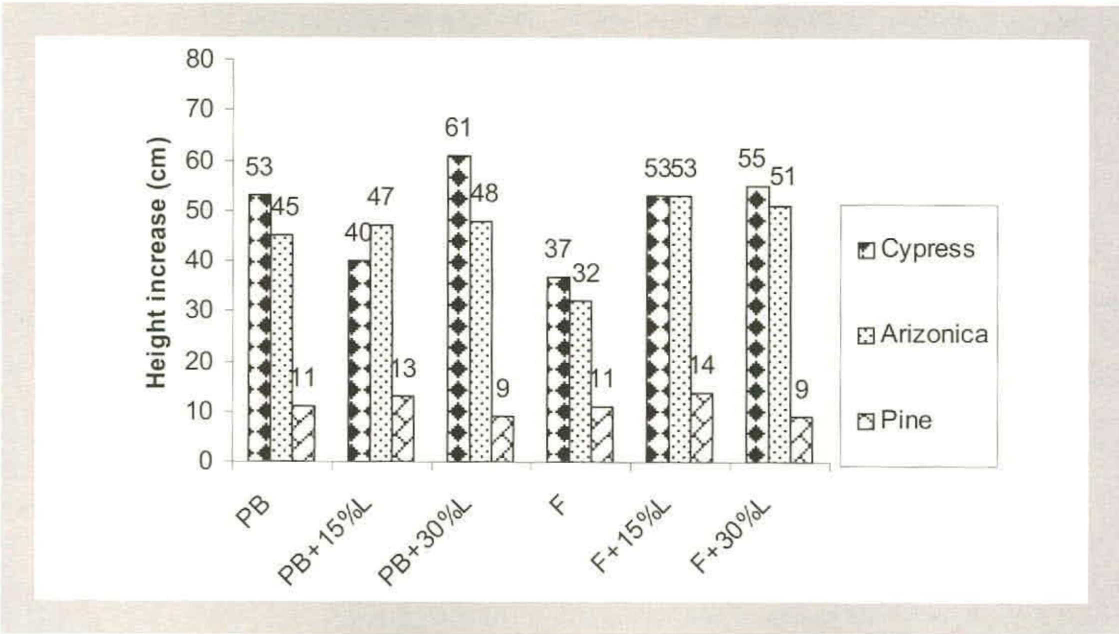

Figure 1- Height increase (cm) between the first and the last sampling of the three plant species used to test the substrates suitability.

showed the highest electrical conductivity values (Table 3) and, according to this work, gave the best growth parameters for cypress plants. High soluble salt concentrations immediately after planting are an important, but manageable consequence of biosolid compost incorporation in container media. Plant injury does not occur, as observed as well by several authors (Ingelmo *et al.*, 1998; Hicklenton *et al.*, 2001; Guerrero *et al.*, 2002) probably because: (1) the highly organic nature of the medium provides a high salt-buffering capacity and protection for the root system (Boodley, 1981) and (2) medium leaching under consistent irrigation quickly reduces soluble salts to acceptable levels (Hicklenton *et al.*, 2001; Guerrero *et al.*, 2002). Both types of substrate are recommended for growing this plant species under such experimental conditions, but the relative cost of the palm fibre substrate (Table 1) is more than twice that of the poplar tree bark based substrates.

P. densiflora did not show a relevant height increase during the growing period (Figure 1), and no variation was found in it because of the addition of sludge. It seems that these substrates are not the most appropriate for this plant species in comparison with the data obtained for *C. arizonica* and *C. sempervirens*. *P. densiflora* root and shoot dry weight indicated no significant differences between the substrates, but it is greater for plants growth in palm fibre than in poplar tree bark media. Guerrero *et al.* (2002) in a two year-long experiment observed a similar fact, namely that *P. densiflora* growth (height and dry weight) in poplar tree bark substrates with or without sewage sludge compost addition was lower than the growth observed for *C. arizonica*.

C. arizonica plants were higher when they were grown in the PB than in the F substrate, but when the sludge was included as a component of the container media, palm fibre gave better results than those substrates with poplar tree bark as the main component, giving similar results with increasing amounts of sewage sludge. In conclusion, and attending only to this parameter, a substrate with either 15% or 30% of composted sewage sludge and palm fibre is recommended for the nursery culture of *C.*

arizonica. *C. arizonica* plants did not show any significant differences in root or shoot dry weight, but this increase with the increasing addition of the sludge to both substrates. For that reason, the F+30% will be recommended for these plants, in order to reuse the greatest amount of this waste product. PB+30% CSS must be also considered appropriate for this plant species.

The accumulation of heavy metals is a much less serious problem in the container culture of ornamentals than where composts are used in field crops for human or animal consumption (Chaney, 1990). However, all plants produced in biosolid compost will inevitably undergo close scrutiny to assure human health is not compromised. Our data indicated that no significant amount of heavy metals was detected in shoot and root of the three plant species.

Conclusions

Plants grown in palm fibre substrates mixed with biosolids showed similar results to those ones growth in poplar tree bark based substrates. However, fibre substrate alone did not seem to be a good growing medium for *Cupressus* plants.

Since waste product recycling is the main objective of the present work, those mixtures with 30% composted sewage sludge will be the most convenient substrate to use, from an economical end environmental point of view. For *C. sempervirens* and *C. arizonica*, a mixture of poplar tree bark or palm fibre with 30% biosolid compost in volume gave the best results, but the lower cost of the poplar tree bark than the palm fibre substrate indicated the use of the PB+30% CSS. For *P. densiflora* the research of new mixtures between waste materials is recommended to attain better results.

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