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Assessment of metal and mineral contents in soils amended by sludge in cork oak seedlings

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ABSTRACT The cork oak (*Quercus suber* L.) is a tree species that has a high economic and naturalistic value. It was chosen for this job since we explore the possibility to improve the choice of sludge-based growing media in order to enhance the nutrition quality for plants by minerals and trace elements and to assess the level of contamination by heavy metals (lead, copper, etc.). The biometric parameters of the meristem growth, aerial and underground biomass are the main criteria for the standardization of plants. Seven types of substrates were tested for raising seedlings. The dosing of heavy metals was carried out on the various substrates before sowing and after 18 months. The results showed morphogenetic differences for the seven substrates, particularly for the pine bark and olive pomace mix sludge and also high levels of nitrogen, phosphor, potash (NPK) and heavy metals mainly for substrates amended by sludge. The high levels of heavy metals induce high soil pollution that may be used as bio-indicator of toxicity, reflecting the sensitivity of the species. The obtained results showed high levels of NPK for four substrates, but according to the standards these levels do not exhibit harmful effects on the growth. The plants cultured with sludge-based substrates, namely substrates S1 and S2 (<25% sludge), showed levels of heavy metals according with the standard Osol (1986). These substrates can be recommended, however; substrates S3 (45% sludge) and S4 (65% sludge) have high levels especially of lead and copper thereby affecting the growth parameters. Therefore, these latter are unfavorable substrates for growth and the species is sensitive for their high concentrations in the sludge. Finally sewage sludge have qualities and ideal characteristics for a recovery in forest areas but requires a good study for the future of these heavy metals in plant tissues and in the ecosystem.

KEY WORDS Cork oak; growing media; metal toxicity; sludge.

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INTRODUCTION

The current industry requires the search for new substrates and a better recovery of waste from human activity. In order to search for substrates that can offer better growing conditions to the plants in the tree nursery, we chose a remarkable forest species which is the cork oak (*Quercus suber* L.) for its great naturalistic and economic value and its specific physiological features that distinguish it from other woody trees.

We can list more than 100 locally available materials that could be used in mixtures with other materials for the manufacture of growing substrates at local level, such as cork pellets, olive oil cake, sawdust, grape marc, manure, bark composts, urban composts and sludge from urban sewage treatment plants, etc.

According to Kahia et al. (2004), a dozen peats from the north-eastern region of Algeria have been tested for the production of cork oak and maritime pine plants.

In this context we have sought to improve the quality of cork oak plants in tree nurseries by optimizing their production techniques, in particular by adding waste sludge mixed by aerators and water retention elements as a substrate for soilless culture. In general, for mixtures, we seek from a physicochemical and economic point of view to create an optimal substrate for the cultivated plant, as chemical fertilizers are very expensive, it would be interesting to be able to replace them.

Through this trial, we aim to make a physicochemical characterization of the sludge and to see the effects of its use on the plants of Cork oak in soilless culture nursery.

MATERIAL AND METHODS

Seedlings are raised in plastic pots with a capacity of 0.5 kg. The tested substrates consist of a mixture of topsoil, olive pomace, sawdust and sludge. Two control substrates, the first based on peat and topsoil and the second consisting of topsoil and the most used olive pomace in Algerian nurseries, were compared to other treatments. The seedlings are distributed according to the 7 following modalities:

Substrate 1: 60% topsoil +25% olive pomace + 15% sawdust.

Substrate 2: 60% topsoil +25% pine bark + 15% sawdust.

Substrate 3: 25% sludge + 50% olive pomace + 25% sawdust.

Substrate 4: 45% sludge + 45% olive pomace + 10% sawdust.

Substrate 5: 25% sludge + 50% pine bark + 25% sawdust.

Substrate 6: 45% sludge +45% pine bark + 10% sawdust.

Substrate 7: 30% topsoil +50% peat + 20% sand

In order to evaluate the performance of the elaborated substrates, measurements of morphological characteristics such as the height and dry weight of the plants are determined on seedlings of 9 months (1st measurement) and 18 months (2nd measurement). The determination of heavy metals is carried out on the different substrates before sowing and after 18 months.

The Extraction of total heavy metals "Pb-Cr-Zn-Mg" (regal water) was carried out according to (Hoening et al., 1979) and the determination of total heavy metals using a flame atomic absorption spectrometer (SAAF-100AA).

RESULTS AND DISCUSSION

For the characterization of the different physicochemical parameters, all substrates have presented

	pH	Organic matter %	CaCO3%	CEC cmol+ kg-1
S1	7.6	33	0.6	23.18
S2	7.8	29.5	0.45	28.5
S3	5.92	53	2.03	28.2
S4	5.88	57	3.4	23.5
S5	6.3	43	1.52	18.5
S6	6.10	45	3.2	17.6
S7	6.8	64.7	0.45	28.5

Table 1. Physicochemical characteristics of culture substrates.

a slightly acidic to neutral pH that ranges between 5.88 and 7.8. These values are moderately desirable for soilless cultivation (Andre, 1987). All substrates were rich in organic matter which varies between 24.5% and 64.7% (Table 1).

The active limestone levels of the substrates showed a minimum rate of 0.45% recorded for substrates 2 and 7 and the maximum rate (3.4%) was recorded in substrate 4 and 6. However, we can consider our substrates as little calcareous (Coppenet & Juste, 1979).

For the "CEC", which corresponds to the amount of cations that a soil can retain on its adsorbent complex at a given pH, the values ranged from 17.6 Cmol+ kg^{-1} (substrate 6) to 28.5 Cmol+ kg^{-1} (substrates 2, 3 and 7) and that have high CECs according to Baize (2000). Table 1 illustrates the results of the chemical analyses of the different tested substrates. For nutrients, substrate 3–5 and 4–6 are very rich in N.P.K and their concentrations are within the cited standards by Lacée (1985).

The results from the 9–month seedlings revealed that height growth was higher at substrates 4, 6, 3 and 5 with the following contents 69.35, 68.01-56.7, 55.9 cm respectively (Fig. 1). The morphological characteristics of the plants pruned by the sludge are very close to similar to those offered by substrate 7 (European Reference Control), which explains the effect of residual sludges on radial and height growth due to their richness of mineral and organic substances. While the obtained results from the 18-month seedlings inverted the order of height growth that was higher at substrates 3 and 5 compared to substrates 4 and 6 with the contents of 61.4, 56.9, 30.8, 35.2 respectively (Fig. 1). Substrates formulated with residual sludge of 45% with olive pomace or pine bark, showed a regression in growth towards the substrates formulated with residual sludge of 25%. The emission of the leaves or apparent plastochron and meristem elongation were more significant in substrates 3, 4, 5, 6 compared to other substrates which shows us that sludge has an important role in growth at well-studied doses. We can also observe that there is a significant correlation between stem elongation and leaf emission, which is more active when meristem elongation is more intense and is decreased when meristem growth tends to slow (Lowry et al., 1951; Osol, 1986; Maillard, 1987; Alatou, 1990).

By a simple comparison between the two mixtures based on residual sludge with olive pomace and with pine bark, it appears that the retaining effect of the sludge in association with olive pomace promotes better growth in height (S3). Our results are in contrast with those reported by Laala et al. (2016) who found that the sludge-based mixture (30%) combined with pine bark gives better aerial growth than that combined with olive pomace.

For metal contents, compared to the standards, our results showed that total levels of Mg and Cr in the different substrates were below the threshold of 150 mg/kg for Mg and 83 mg/kg for Cr (Kabata-Pendias & Pendias, 2001). For Mg the levels varied between 282.93 ppm in S2, and 842.32 ppm in S6, while the Cr levels were between 22.33 ppm in S2 and 68.33 ppm in S6.

On the other hand, lead ranged from 17.34 ppm in S1 to 315.88 ppm in S6 and zinc levels varied from 75.12 ppm in S1 to 601.49 ppm in S5. All were above the indicative values and were so supe-

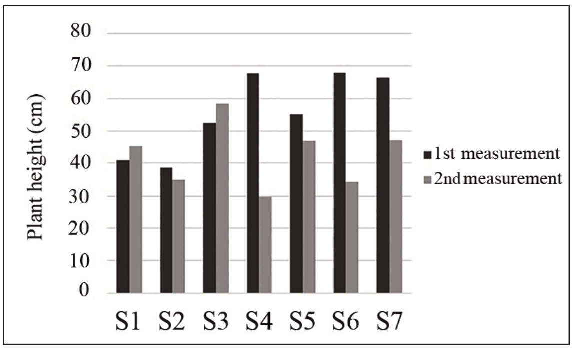

Figure 1. Shoot height variation in during 1st and the 2nd measurement.

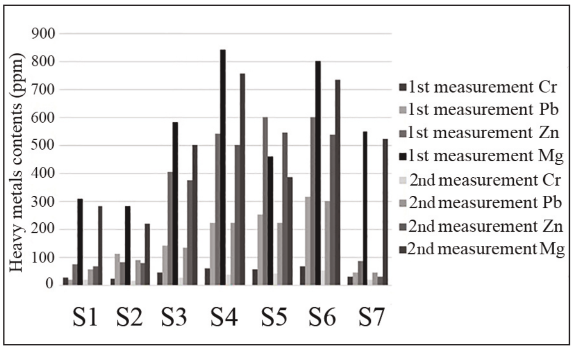

Figure 2. Heavy metals content in different substrates during the 1st and the 2nd measurement.

rior to the range of variation in concentrations reported by Kabata-Pendias & Pendias (2001) which follows the order of 44 mg/kg and 100 mg/kg for Pb and the Zn respectively, and allowed us to classify our soils as very polluted for these two heavy metals (Fig. 2).

According to Baize (1997), high concentrations of certain heavy metals such as Pb and Cd are assimilated by plants that can cause a decrease in height growth. The appearance of a mosaic at the leaf and even yellowing and falling leaves supported our results for substrates 4 and 6.

Although Pb is a very soluble element in the soil, it can accumulate in the roots especially in cell membranes but its translocation to the epigeous parts of a plant is a very limited phenomenon. Therefore, Pb is not a systematic toxic element. It does not diffuse into the vascular system of the plant (Kabata-Pendias & Pendias, 1992). Cd is strongly absorbed by clay, organic substances, sludge and humic acids with which it forms complexes. Its retention by the solid phase increases exponentially with the increasing pH (Halen, 1993). Absorption of Cd is generally controlled by pH and organic matter (Bourg & Loch, 1995). These results showed also that diameter increase follows the same pattern as height and biomass growth. The mixture of the sludge with the olive pomace (aerator and water retaining element) improves the porosity of the substrate and promotes the development and elongation of the roots with a very dense hair. Hence, our results are consistent with those of Chouial et al. (2001).

CONCLUSIONS

We have demonstrated in this work that the use of substrates based on 25% sludge and olive pomace has shown very advantageous use and it allows to produce cork oak plants with satisfactory morphological performance.

However, we must be careful because plenty of sludge leads to the accumulation of some heavy metals which will induce toxicity. This will disrupt the growth of the plants, that appears only after 9 months and is manifested by a fall and yellowing of the leaves and even a stiffness of the stem. These sludges are rich with nutrients elements, which have fostered significant growth in height and mass; excess Pb and Zn will pose less risk of toxicity because this sludge will be used in silviculture. Nevertheless, it is necessary to take into account the heavy metal content in the sludge, because at high doses, these metals can cause enormous risks of phytotoxicity and will subsequently lead to a high rate of plant mortality.

These plants are perfectly shaped, especially at the root system, and they have excellent growth after transplantation in the forest.

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