



Fertilization value of municipal sewage sludge for *Eucalyptus camaldulensis* plants



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ABSTRACT

The wastewater treatment produces a large amount of sludge. The different uses of eliminations sludge such as landfills or incineration have consequences negative for the environment, the agricultural use has increased worldwide, especially in crops and few or no studies have been conducted with forest plantations in Algeria. The objective of this study is to assess fertilizing characteristics of the sludge from the wastewater treatment plant of Tiarret (Algeria). One-year-old saplings of *Eucalyptus camaldulensis* were transplanted into pots with sludge/soil mixtures where sludge content was 20%, 40% and 60%. Biometric measurements (height, base diameter, diameter at mid-height and the number of leaves) were performed during six months after planting. Results demonstrated the positive effect of sludge application. A significant difference in height increment and number of leaves was found between the control and sludge-treated plants. Biometric values for all sludge mixtures were higher than those for control plants (100% soil). The mixture, which contained 60% sludge, gives the best result, except for a diameter of stem. Plants grown on sludge/soil mixture had average height 49.4 ± 24.1 cm and average number of leaves 68.8 ± 6.2 while average height for plants grown on soil was 34.3 ± 12.8 cm and average number of leaves was 40 ± 3.8 . Sludge application provides soil amendment and additional nutrient supply for planted trees.

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1. Introduction

Sludge is the resulting waste of wastewater treatment from domestic or industrial origin. Sludge is composed of water and dry matter which ferments macronutrients (nitrogen, phosphorus) and organic matter. Sludge has a fertilizing interest in agriculture and other field [16,14].

Recovery of sludge is random and disposal is most always a significant operating expense. Economically the goal is to limit actually the costs of transportation. Due to their characteristics, several disposal routes are possible, depending on whether we want to highlight their character fertilizer or energy. Landfill (25%), incineration (15%) and the land farming (60%) [17].

Traditional solutions, such as landfill and incineration have several disadvantages: landfill can pose the risk of groundwater

contamination, same as burning which is the source of air pollution [3,7]. Land application is claimed to be one of the acceptable ways of utilization for the medium and long-term perspective in the European Union [12]. Indeed, the presence of toxic metals in sludge may limit its application because of the risk of soil contamination and the transfer of toxic substances into the food chain [23]. The risk of sewage sludge application has favored the use of this residue in forest land [15], mainly because most forest products do not directly enter the human food chain [9].

In Algeria, there are 165 operating treatment plants currently producing about 250,000 tons of sludge annually, expected to increase to 400,000 tons by 2020, according to the data of the Ministry of Water Resources Algeria [8].

Disposal of sewage sludge from the wastewater treatment plant of Tiarret is a serious issue for the National Sanitation Office (ONA). Plant produces about 10,000 tons annually of dry matter. We hypothesize that urban sludge, whatever its type, it can be used in forest plantation to improve the organic matter in the soil increasing the plants growth and reduce the volume of sludge

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produced by the sewage station [18,4]. However, the diverse chemical composition of sludge in the space and time can result in different degrees of plants responses. Due to it the scarce studies about sludge as soil amendment under méditerranéen condition.

The present study aims to investigate the effect of application of the urban sludge from Tiaret wastewater treatment plant for growing of *Eucalyptus camaldulensis*.

2. Material and methods

Agricultural soil, collected in few meters from Karman university campus, as this area is considered not to be contaminated by pollutants from exhaust-spewing cars, has been used in this experiment. The sludge for the experiment was taken on April 2015, from WWTP, located in the territory of the municipality of Bouchekif (Tiaret, Algérie), and the official launch of wastewater treatment in May 2008. The sludge was collected from a randomly on drying beds (on both ends of the beds at the center) where the mixed sludge subjected to dehydration. The principle is based on filtration and evaporation natural mud on a drying area in order to minimize the water content of the sludge. This sludge is regarded as stable, dry, solid state of particle an average size of about 6 mm. Main characteristic for both medias were evaluated in accordance with generally accepted soil testing methods.

Texture evaluation was performed as described by Robinson Khon [27].

The pH was measured as described by Callot-Dupuis [6].

The water content was expressed by weight as the ratio of the mass between wet and dry samples. The criterion for a dry sample was a constant weight of sample after drying in oven at temperature between 100 and 110 °C.

Organic carbon content was determined using dichromate oxidation, when treated with few drops of diphenylamine remaining dichromate was back titrated with FeSO₄ solution, according to the procedure described by Anne [2].

Active lime was determined according to the Drouineau method; the procedure involved reaction of the soil with ammonium oxalate, followed by the determination of unreacted oxalate by back-titration with potassium permanganate [6].

Total amount of nitrogen was determined by the micro-Kjedhal method [26].

Determination of phosphates was performed by standard method of coloring with ascorbic acid combined reagent and measuring for absorbance in a spectrophotometer.

Potassium was determined by atomic absorption spectrometry by direct aspiration of the filtered or digested and filtered sample into an air-acetylene flame [25].

Trace metallic elements (Cu, Zn, Pb, and Cd) and mineral elements (Cr, Mn, and Fe), were determined directly from solid sample by using of Inductively Coupled Plasma Mass Spectrometry (ICP-MS) [25].

Eucalyptus camaldulensis was selected as the test object in this study because of its good growth characteristics, high plasticity and economic value [22]. Plants were grown in the nursery for one year. Primary cleaned from nursery soil, plants were transplanted into pots (with a diameter of 8.5 cm and a depth of 14 cm) containing a mixture of sludge and soil with three different proportions of sludge in mixture (20%, 40% and 60%) and into control (100% soil).

During the experimental period pots with plants were placed in the open area, from May to October 2015. Climatic conditions during experimental period were typical for the Mediterranean climate – hot and dry summer (average temperature was around 30 °C). The plants was watered out manually with tap water.

During six months of the experiment, the effects of application of sludge in different concentrations for growing of *Eucalyptus*

camaldulensis were evaluated by measuring of the following biometric parameters: height growth, growth in diameter at the base, mid-height diameter and number of leaves. Measurement of these parameters was carried out twice per month.

Repeated measures analysis of variances (ANOVA) was used to study the effect of time and sludge concentrations on biometric parameters. The Statistica software (version 10) was used for all data analysis.

3. Results and discussion

Both medias characteristics had typical for their origin. The Soil sample a had sandy loam texture, alkaline pH and low organic matter content. Sewage sludge had pH close to neutral and significantly higher content of organic material and main nutrients. Heavy metals concentrations in average were higher for the sludge sample (Table 1).

The determination of total content of major elements revealed high values for P and low values for K, which may be explained by high rates of potassium retain in water during treatment process because of its high solubility. Nogueira et al. [23] have also determined that the values for P is very important than the values for K in their sludge. High organic matter content in the sludge indicated its urban origin, same as nitrogen, certainly contributing into fertilizing value of the sludge, which is also identified in the study of Ona and Osorio [24]. C/N ratio, close to 10, indicated that the mineralization processes already took place along with nitrogen release [11].

Generally, sludge is considered to be a toxic substrate for the environment and agricultural production due to high content of heavy metals, which limits its application as fertilizer (Gulvaeva et al., 2012; Nefedov et al., 2007 in Maksimova et al. [20]). However, in the sludge from Tiaret wastewater treatment plant heavy metals were present in low concentrations, not exceeding permitted levels according to the AFNOR standard [1]. Similar results were obtained by Maksimova et al. [20].

After six months of growing, the survival rate of *Eucalyptus camaldulensis* plants was around 80%. In general, biometric measurements had increased with increasing proportion of sludge

Table 1
Characteristics of soil and sewage sludge used in the experiment (mean \pm SD).

Physicochemical parameters	Sludge (N=20)	Soil (N=5)
pH	7.1 \pm 0.3	8.1 \pm 0.11
Electrical conductivity EC (mS/cm)	4.7 \pm 0.1	1 \pm 0
Cation exchange capacity CEC cmol/kg)	30.6 \pm 0.2	26.5 \pm 1.3
Total limestone CaT(%)	18.5 \pm 2.7	26.1 \pm 0.03
Active lime Ca act (%)	13.9 \pm 0.9	20 \pm 0.02
Water content (WW) (%)	3.9 \pm 1.7	12.3 \pm 0.17
Organic matter OM (%)	44.8 \pm 16.4	1.4 \pm 0.01
Carbon C (%)	19.1 \pm 4.1	0.6 \pm 0.04
Clay (%)	11.3 \pm 0.3	2 \pm 0.01
Coarse silt (%)	17.6 \pm 0.2	59.3 \pm 0.16
Fine silt (%)	40.5 \pm 0.1	6 \pm 0
Coarse sand (%)	10.5 \pm 0.1	25.9 \pm 0.12
Fine sand (%)	19.3 \pm 0.4	6.4 \pm 0.13
N (%)	2 \pm 0.2	0.9 \pm 0.01
P (mg/kg)	44.8 \pm 3.5	26.2 \pm 7.60
K (mg/kg)	1.2 \pm 0.1	59.4 \pm 4.6
C/N	9.5 \pm 2.7	0.6 \pm 0.3
Cr (μ g/kg)	341.9 \pm 86.9	189.3 \pm 18.11
Mn (μ g/kg)	156.64 \pm 38.48	804.8 \pm 59.72
Fe (μ g/kg)	136.9 \pm 30.06	559.8 \pm 538.7
Cu (μ g/kg)	59.6 \pm 15.7	44.9 \pm 4.05
Zn (μ g/kg)	2786 \pm 724.2	62.7 \pm 4.75
Cd (μ g/kg)	4.6 \pm 1.3	0.06 \pm 0.01
Pb (μ g/kg)	72.07 \pm	5.7 \pm 0.67



Fig. 1. Size of *Eucalyptus camaldulensis* after six months growth period for the different concentrations of sludge in substrate (Photos taken in October 2015).

in mixtures. Largest plants to be recorded were grown on the mixture with 60% sludge (Fig. 1).

Plants grown on mixture with 60% of sludge had an average final height of 49.4 ± 24.1 cm (Fig. 2A) and average leaf number 68.81 ± 6.2 (Fig. 2D). For plants grown on soil much lower average results were recorded 34.3 ± 12.80 cm for height and 40 ± 3.8 for the number of leaves. Usually, a large number of leaves is a good indicator of a good water and nutrients supply for the plant [13].

Diameter measurements also demonstrated some difference in plant development during the experimental growth period. The mid-height diameter values for plants on sludge mixtures with share of sludge 20%, 40% and 60% were 2.2 ± 1.3 , 1.8 ± 1.2 and 1.9 ± 1.2 mm respectively (Fig. 2C). For plants grown on soil mid-height diameter average value was 1.3 ± 0.7 mm. Base diameter average values were 3.2 ± 2.0 , 3.2 ± 1.8 and 3.2 ± 1.9 mm (Fig. 2B) for plants on sludge containing mixtures respectively, and 2.4 ± 1.0 mm for plants grown on pure soil.

Analysis of repeated measures for height and leaves number for *Eucalyptus* plants ($P < 0.001$ ***) demonstrated lowest values for the control plants grown in soil (0% sludge) and highest values for plants grown on mixture with highest proportion sludge in it (60% of sludge) (Fig. 3). The differences were most evident during the last two months (September and October)/these results prove good fertilizing and soil improvement qualities of sludge for Tiaret wastewater treatment plant.

Such results can be explained by presence of additional nutrients and organic matter in mixtures with the sludge, which complies with those obtained by Bouriou et al. [5]. The strong growth of *E. camaldulensis* was induced by fast nutrient consumption [22]. Michel et al. [21], which indicates that sludge could be used as fertilizer or amendment for forest soils.

On the other hand, the application of sludge increased the concentration of trace elements in the substrate. However particular trace elements in the substrate used here for example

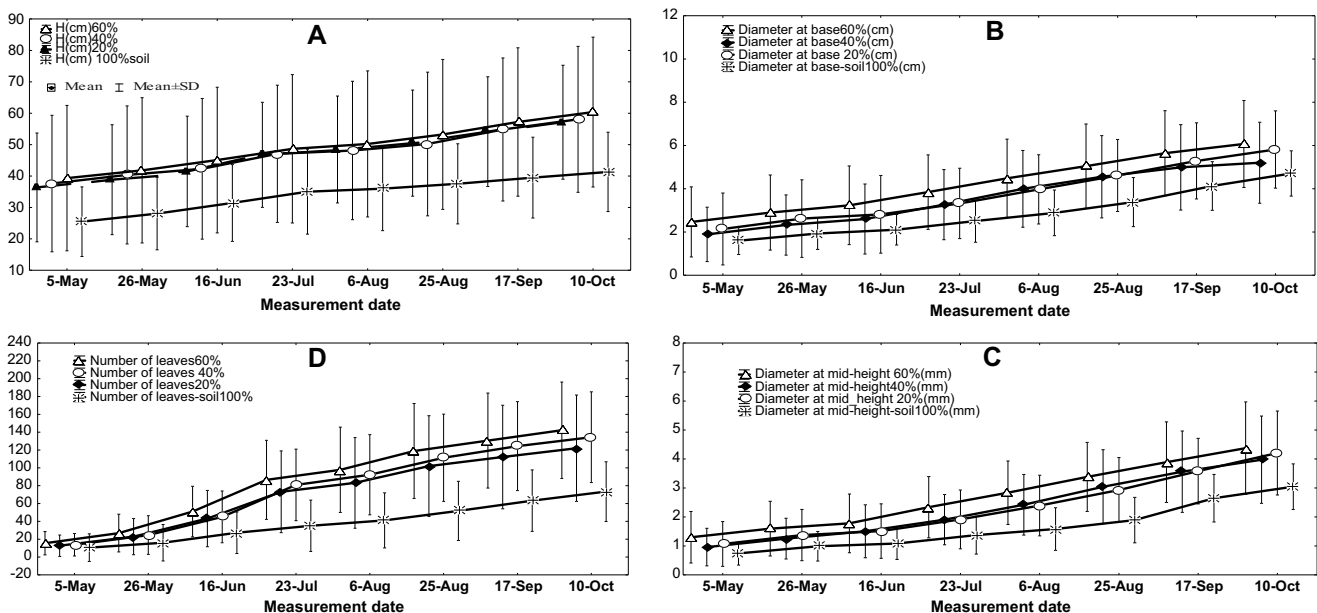


Fig. 2. Biometric parameters of *Eucalyptus camaldulensis* grown in forest soil and in forest soil with different proportion of sludge added (20%, 40% and 60%). (A: Height B: Diameter at base; C: Diameter at mid-height; D: Number of leaves).

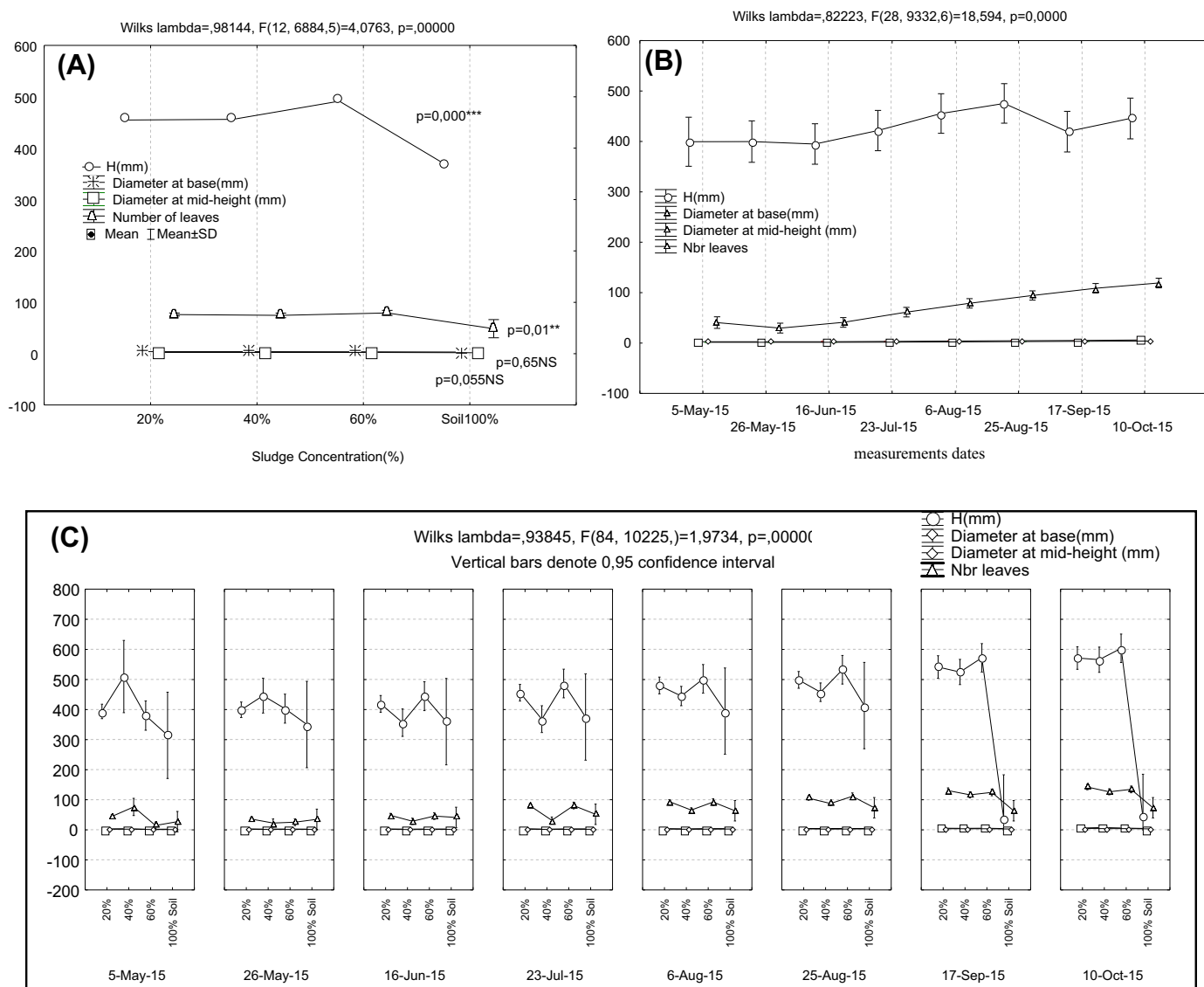


Fig. 3. Dynamic of biometric parameters for plants during growth period for different sludge/soil mixtures. (A: Effect of sludge concentrations; B: Effect of measurement date; C: Effect interaction measurement date and sludge concentrations).

lead, zinc, and copper, can also be found in high concentration in natural soil. Bouriou et al. [5] had demonstrated good growth of larch (*Larix decidua*) on forest soil fertilized with municipal sludge, considered as a source of fertilizer due to its high contents of organic matter and available nitrogen and phosphorus, he also had found limited absorption of the heavy metals.

In the present study we found a positive effect of sludge amendment for wastewater treatment plant. Therefore, in the similar climatic condition, effects of sludge application to forest soil are expected to be even higher due to an improvement of both physical and chemical soil properties [19].

4. Conclusion

Spreading of sewage sludge is a widely used practice in agriculture that serves for several purposes, as sludge utilization, soil improvement and reintroduction of nutrients into natural cycles. However, land application of sludge always poses the risk of soil pollution, in addition, the fate of toxic compounds in the environment cannot be fully predicted, and toxicants from sludge can migrate into groundwater or contaminate food products.

At the same time sewage sludge can be successfully used for fertilization of forest lands and urban landscapes. Application of sludge in forestry appears to be a good utilization option for this type of waste along with its ability to improve the structure and fertility of forest soils.

The results of our experiment had demonstrated good fertilizing properties of soil/sludge mixture that contained 60% of sludge. Plants of *E. camaldulensis* fertilized with sludge had 20% better growth and 40% high leaf numbers. While sludge adding improved plants development, no negative effects on trees' health were observed.

The study also demonstrated the possibility of sludge application as a soil fertilizer in urban areas. In most of cases city landscapes are covered with poor soils, sludge application provides soil amendment and additional nutrient supply for planted trees, as it had been shown in our study.

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