

## Short Communication

# Fertilizer effect of composted sewage sludge and cattle manure on *Pelargonium* growth

Nesrine Dridi, Lilia Romdhane, Renata Ferreira and Noomene Sleimi

### ABSTRACT

Sewage sludge is considered as a main product obtained from urban liquid effluents that are discharged into sanitation systems of wastewater treatment plants. The aim of this work was to reuse it as compost, after the dehydration process, to replace the amendment applied in agriculture and also to reduce the environmental pollution caused by solid wastes. To justify our biotechnological approach, nutrient characterization of the composted dewatered sewage sludge was carried out and compared to cattle manure. The contents of N, P, K, and the organic matter are 3.67, 5.64, 6.60 g·kg<sup>-1</sup> dry matter (DM), and 70%, respectively, in compost and 3.1, 1.6, 3.0 g·kg<sup>-1</sup> DM, and 55%, respectively, in manure. Fertilization tests with composted dewatered sewage sludge and cattle manure were performed on *Pelargonium inquinans*. Monitoring the length of the first internodes showed an improvement of 4.2 mm in the length in compost plants with a development of 22.8 buds and 8.2 flower buds (19.4 buds and 4.4 flower buds developed in manure plants). It appears that the intake of composted dewatered sewage sludge ensures better growth for the studied plant due to its richness in nutrients, which confirms the beneficial effect of composting sewage sludge on plant cultivation.

**Key words** | cattle manure, compost, dewatered sewage sludge, nutrients, *Pelargonium inquinans*

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### HIGHLIGHTS

- Composted dewatered sewage sludge is rich in essential nutrients necessary for plant growth.
- The application of composted treated sewage sludge as a fertilizer improved the growth of *Pelargonium inquinans*.
- Composted dewatered sludge presents an appropriate alternative to chemical fertilizers application.
- Compost addition is more efficient than cattle manure to improve soil conditions.

### INTRODUCTION

The use of composted dewatered sewage sludge (CDSS) for the amendment of agricultural soils stabilizes organic matter (OM) (Houot *et al.* 2009) and increases nutrients, which improves crop growth and yield (Zraibi *et al.* 2015). Composts reduce several environmental damages posed by the application of chemical fertilizers and thus can be an

appropriate amendment alternative (Serpil 2012). By composting, it is possible to add value to sludge from urban wastewater treatment plants (WWTPs), a service that is particularly appreciated by local authorities and industrial establishments. Hence, the orientation towards a rational management of wastes (liquids and solids), based on the

valorization of treated discharges and the protection of the environment, becomes a major concern not only in Tunisia (Northern African country) but also in the whole world. In Tunisia, 113 new domestic and industrial WWTPs across the country were created, due to the application of the National Office of Sanitation Law N°73/74 (08-03-1974). However, sludge obtained from treated urban wastewater may contain undesirable agents such as bacteria and viruses (Romdhanaa *et al.* 2009) and heavy metals (HM) (Deniz *et al.* 2007) that could be reduced by composting.

Another form of compost that can be applied on agricultural lands as a biological fertilizer is the manure of mammals. It was demonstrated that the physical properties of soil have been improved by manure fertilization (Kuepper 2003). According to Chabaliier *et al.* (2006), cattle manure is rich in OM and it has a very low ammonia content, which prevents the burning of leaves. This type of manure is used as a fertilizer for some crops, if the compost is sufficiently hygienic.

The reuse of dewatered sludge taken from the WWTP of Ariana, located in northern Tunisia, for the cultivation of a decorative plant (*Pelargonium inquinans*) was studied. The geranium plant is known to tolerate and accumulate high concentrations of HM in its tissues and therefore is used in the field of phytoremediation to decontaminate metal polluted soils (Dan *et al.* 2001; Mahdih *et al.* 2013). The main goal of the present study was to validate the use of CDSS, in relation to the use of animal manure, as an alternative soil amendment for the growth of *P. inquinans*. In order to highlight the efficiency of CDSS compared to manure (as an organic matter fertilizer), nitrogen (N), phosphorus (P), potassium (K), pH, dry matter (DM), (OM), total organic carbon (TOC), and HM concentration (Hg, Cd, Cu, Pb, and Zn) were assessed. Moreover, the monitoring of plant behavior and composting process through the regular measurement of temperature were also studied.

## MATERIAL AND METHODS

### Composting

Following the described treatment process of wastewater mentioned in Sperling (2007), produced sewage sludge (SS)

from the WWTP was dehydrated using belt filters, then composted for four months using a mixture in equal proportions of dewatered sewage sludge (DSS), humus ( $A_{00}$ ), and sand (Landis *et al.* 2014). Sand was applied to increase porosity and improve aeration and the humus ( $A_{00}$ ) to improve biological activity to promote the decomposition of OM. The temperature was evaluated during the composting process (Tateda *et al.* 2002) whereas it was measured every 15 days.

### Plant culture

Young plants of *P. inquinans* were obtained by cutting propagation (Bankaji *et al.* 2016). Five plants were cultivated separately in CDSS substrate and in cattle manure substrate (control treatment/obtained from farmers). During the treatment (75 days), the length of internodes, the number of vegetative buds, and the flower buds were monitored every 15 days.

### Chemical characterization

All the samples were dried at  $70 \pm 2$  °C for 7 days (Sleimi *et al.* 2014; Bankaji *et al.* 2019). OM, TOC content, and pH were determined. To determine total P, N, K, and HM content, all samples were centrifuged at 3,000 rpm for 5 minutes. The concentration of the total P was determined after mineralization in the presence of phosphoric acid for 1 hour at 100 °C. To estimate the total N concentration, a transformation of OM in water into mineral matter was needed. Samples were heated at 105 °C for 30 minutes, in the presence of a nitrogen persulfate reagent. Concentrations were determined by spectrophotometry at 685 nm for P and 460 nm for N. HM and K were quantified by atomic absorption spectrometry after digestion with HCl at 130 °C for 2 hours using filtered supernatant of compost suspension (Alvarenga *et al.* 2015).

### Statistical analyses

The number of repetitions was three or five (flower and vegetative bud). Statistical analyses were carried out using one-way ANOVA. Tukey honest significant difference HSD test was used for post hoc comparison. *P*-value threshold for significance was assessed to 5%.

## RESULTS AND DISCUSSION

### Composting process and compost maturity

Results showed that compost temperature increased from 15.5 to 70 °C in 30 days, then it gradually decreased to 24 °C where it was stabilized during the last 15 days of composting (Figure 1). Moreover, no strange smell was noticed in the obtained compost which could be explained by the total decomposition of the OM.

According to a study by Pullicino *et al.* (2007), the evolution of the compost was based on the evaluation of temperature variation, which expresses the activity of the microorganisms related to the modifications of the medium. The stabilization of the compost temperature over time means that the composting process is complete, leading to mature compost. When it reaches ambient levels, it promotes the achievement of maximum rates of OM decomposition.

The maturity of compost could also be evaluated by controlling the smell, the germination test on plants, or by the determination of the chemical composition (N, OM, and TOC) (Pullicino *et al.* 2007).

### Physico-chemical properties of compost and cattle manure

Composition analysis of DSS, before and after the composting process, showed that it was very rich in minerals and OM and also contained various HM. The analysis of the essential and undesirable HM content suggested that the DSS could comply with the standard NT 106.20 of the

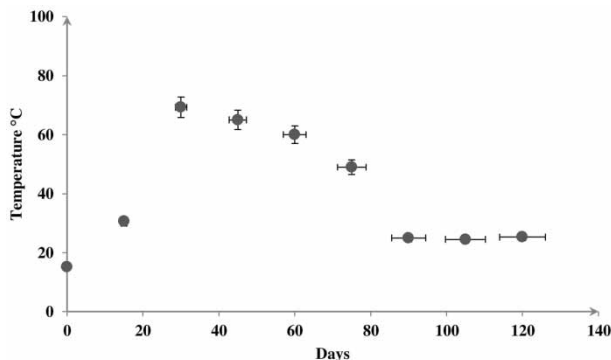


Figure 1 | Variation of sewage sludge temperature during the composting process.

application of SS as a fertilizer. Moreover, we noticed that the content of Cd, Zn, Hg, and Pb of sludge decreased after composting (Tables 1 and 2). A neutral pH was observed.

Regarding OM content, CDSS composition showed a low moisture percentage (2.2%) with a very high DM content (97.8%), which is composed of 70% of the OM and 30% of the mineral matter. In addition, compost had more than 20% DM, and 15% OM compared to manure. CDSS had a more significant C/N ratio than manure ( $C/N < 20$ ), and N, P, and K levels were higher in compost than in manure (Tables 1 and 2).

The nutrient enrichment of sludge conferred on the compost the fertilizing power to be used as fertilizers, as

Table 1 | Characteristics of dewatered sewage sludge and compost

Parameter	Dewatered sludge	Compost	NT 106.20
pH	7.40 ± 0.1	7.3 ± 0.02	–
Moisture (%) <sup>*</sup>	7.43 ± 1.16	2.2 ± 1.36	–
Dry matter (%) <sup>*</sup>	92.57 ± 1.16	97.8 ± 1.36	–
Organic matter (%) <sup>*</sup>	61.37 ± 0.52	70.0 ± 0.67	–
Cd (mg/kg DM) <sup>*</sup>	0.25 ± 0.003	0.15 ± 0.001	20
Cu (mg/kg DM) <sup>*</sup>	267 ± 0.61	176.0 ± 1.26	1,000
Pb (mg/kg DM) <sup>*</sup>	78.40 ± 0.46	53.1 ± 0.85	800
Zn (mg/kg DM) <sup>*</sup>	310.00 ± 0.64	225.0 ± 0.15	2,000
Hg (mg/kg DM) <sup>*</sup>	3.50 ± 0.01	1.2 ± 0.01	10

NT 106.20: Tunisian standard for the reuse of sludge in agriculture. Parameters marked by (\*) were significantly different at  $p < 0.05$ .

Table 2 | Characteristics of compost and cattle manure

Parameters	Compost	Cattle manure
pH	7.3 ± 0.02	7.5 ± 0.03
Moisture (%) <sup>*</sup>	2.2 ± 1.36	28.3 ± 0.25
Dry matter (%) <sup>*</sup>	97.8 ± 1.36	71.7 ± 0.25
Organic matter (%) <sup>*</sup>	70 ± 0.67	55.0 ± 0.51
Total nitrogen (g N/kg DM) <sup>*</sup>	3.6 ± 0.02	3.1 ± 0.04
Phosphorus (g P/kg DM) <sup>*</sup>	5.6 ± 0.01	1.6 ± 0.01
Potassium (g K/kg DM) <sup>*</sup>	6.6 ± 0.06	3.0 ± 0.06
Total organic carbon (g/kg DM) <sup>*</sup>	59.9 ± 0.12	33.5 ± 0.02
C/N	9.53	8.87

Parameters marked by (\*) were significantly different at  $p < 0.05$ .

soil conditioner in degraded farmland and soils lacking indispensable ions and also in gardens. However, DSS may contain compounds that have an undesirable effect on soil conservation or on the food quality of crops. They are dangerous for human and animal health if they rise above a certain standard, such as for HM, that could render some sludge unsuitable for spreading (Deniz *et al.* 2007). In fact, it is fairly well established that composting tends to reduce the availability of toxic metals present in organic waste in addition to those essential for cellular functions such as copper and zinc (Houot *et al.* 2009).

Neutral pH is suitable for the normal growth of most ornamental plants (Grigatti *et al.* 2007). On the other hand, lightly alkaline pH, such as the one obtained (7.3), makes the compost a safe product for soils and plants. According to the World Health Organization, a low pH value influences the mobility and the availability of HM in the soil. Also, when the pH value is more than 7, HM concentrations decrease with the increase of pH (Zeng *et al.* 2011).

Moreover, the compost presented a satisfactory ratio ( $C/N < 20$ ) which prevents N immobilization processes when applied to the soil (Alvarenga *et al.* 2015).

In general, when the sludge meets the standards and regulations for spreading, it is valued in agriculture as a fertilizer capable of providing plants with the necessary nutrients for their growth and development (Deniz *et al.* 2007).

### Behavior of *Pelargonium*

In order to validate the reuse of CDSS as an amendment for plants, we studied the behavior of *P. inquinans* grown in two types of substrate: compost and manure. The elongation of internodes and the enumeration of vegetative and flower buds were measured over time.

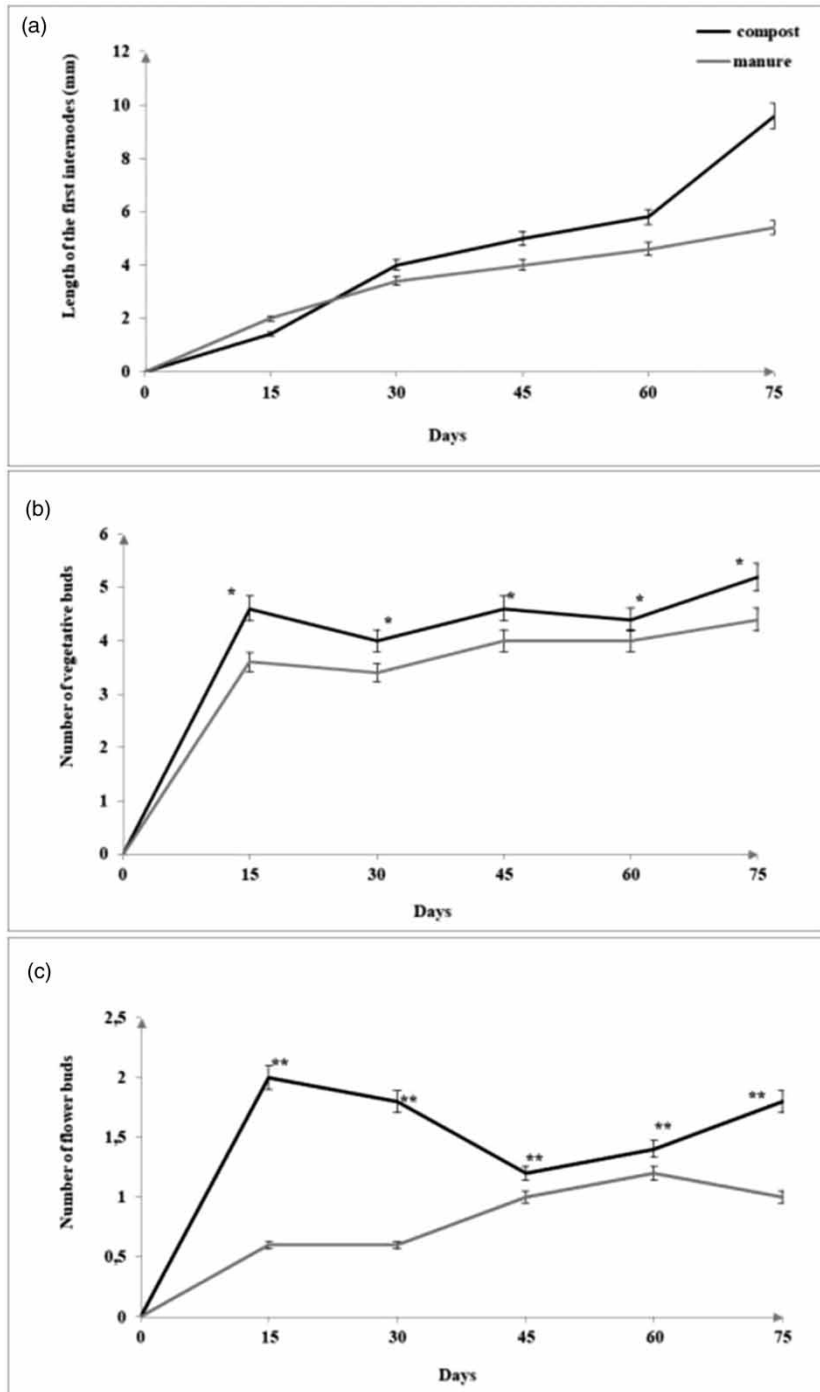
A non-significant difference in the elongation of the first internodes of the compost plant compared to that of the manure was observed. Plants that were treated with compost increased 9.6 mm during the growing season, while those treated with manure only increased 5.4 mm during the same period (Figure 2). Monitoring vegetative buds' number in *P. inquinans* shows that those compost-grown plants developed significantly ( $p < 0.05$ ) more buds. In fact, they reached 5.2 buds in total compared to the plants treated with manure (4.4 buds) over the treatment period (Figure 2).

A significant difference ( $p < 0.01$ ) was noticed between the number of flower buds developed in the compost pots, with 8.2 buds in total at the end of treatment and those developed in the manure pots (4.4 flower buds) (Figure 2).

The results of Grigatti *et al.* (2007) showed that the use of CDSS on potted plants has an important effect on growth. Ribeiro *et al.*'s (2000) study showed that *Pelargonium* plants grown in compost of urban origin developed an average number of 9.5 leaves compared to a control using the peat, which only developed on average 3.3 leaves. Another study, using zonal geraniums grown in hydroponics and without the addition of fertilizers demonstrated that plants developed eight flowers (Tayama & Carver 1990). Singh & Agrawal's (2007) results showed that the application of SS on *Beta vulgaris* plants promoted the development and increased the biomass production. Zraibi *et al.* (2015) showed that the incorporation of composted sludge in soils had a positive effect on the growth and yield of lettuce. The previously reported results demonstrated that the compost also promoted the development of flower buds more than manure.

When studying the influence of macronutrients in compost on plant growth and development, our results showed that the length of the first internodes, as well as the number of vegetative buds and flower buds of *P. inquinans* growing in the compost pots, are significantly ( $p < 0.05$ ) higher than those growing in the manure. This difference could be due to the high content of macronutrients contained in the compost. Indeed, total N, P, and K contents of the compost showed a significant difference ( $p < 0.05$ ) compared to the manure (Tables 1 and 2). This result could prove the importance of nutrient enrichment of compost compared to cattle manure (Dridi & Toumi 1997).

Nitrogen is a fundamental constituent of proteins and chlorophyll; it plays a major role in plant growth and microorganisms (Kaye & Hart 1997). The deficiency of N induces a decrease in stem growth and leaf area. In addition, the flowering and the fructification will be affected (Zhao *et al.* 2004). The excess of N also causes a delay in maturity and growth (Dos Santos *et al.* 2009). Moreover,  $NH_4^{4+}$  behaves like an antagonistic cation of  $K^+$ ,  $Ca^{2+}$ , or  $Mg^{2+}$  whereas an excess of  $NH_4^{4+}$  could provoke a deficiency in these elements, and then the appearance of chlorosis (Heller *et al.* 2006).



**Figure 2** | Evolution of elongation of the first internodes (a), variation of the vegetative buds (b) and variation of the flower buds (c) counted in *Pelargonium inquinans* after 75 days of treatment. Data for plants cultivated in compost substrate (black line) and plants cultivated in manure substrate (gray line) show mean values  $\pm$  SE,  $n = 5$ . Significant differences at  $p < 0.05$  are marked with asterisks (\*).

Phosphorus plays an important role in root growth, organogenesis, flowering, fruit ripening, photosynthesis, and respiration. The deficiency of this

macronutrient induces the delaying of growth and flowering. In excess, it causes a blockage of the absorption of several nutrients such as Cu, Ca, Zn, and Fe (Fageria 2006).



Potassium is involved in several functions in plants such as photosynthesis, enzymatic activation, protein synthesis, and osmotic potential (Perner et al. 2007). Its deficiency causes leaf browning, due to the inhibition of leaf photosynthesis (Gerardeaux et al. 2010).

Analysis of the morphology of the plants grown in the compost did not show any symptoms of deficiency or excess in all the fertilizers mentioned above. This allowed us to conclude that the compost nutrient contents are sufficient to fulfill the plants' needs. On the other hand, we noticed that the leaves of the plants cultivated in the manure pots are often light green and the development of the flower buds is reduced compared to the normal conditions. This result could be explained by a K ( $3 \text{ g}\cdot\text{kg}^{-1}$ ) or P ( $1.6 \text{ g}\cdot\text{kg}^{-1}$ ) deficiency in the manure in relation to plant needs.

Maintaining the growth and the development of geranium in the presence of low contents of HM in substrates demonstrates its ability to adapt to metals (Dan et al. 2001). Indeed, this plant has the ability to survive and accumulate more than one metal in a growth medium, including various metallic contaminants such as Cd, Ni, and Pb (Mahdieh et al. 2013).

## CONCLUSION

The present study demonstrated that the composting process could reduce the availability of Cd, Zn, Cu, Hg, and Pb in sewage sludge. Their low concentrations, which are in compliance with Tunisian standards, enabled the compost to be applied as a fertilizer on *Pelargonium* plants. Compared to manure, the compost contained higher concentrations of N, P, K, OM, and TOC, that could clearly explain the better performance of compost-treated plants, in terms of vegetative growth and flower buds biomass, than cattle manure. It may be concluded that the reuse of SS could be suitable as amendment for plants because of its richness in nutrients, which improve their growth when compared to manure.

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## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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