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Agricultural valorization of sludge from the Jerada sewage treatment plant

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ABSTRACT

The reinforcement of the infrastructure in Morocco is accompanied by the setting up of several wastewater treatment plants which produce on the one hand purified water, but on the other hand, large quantities of sludge, are considered waste. Our work focused first on the physicochemical and bacteriological characterization of the sludge from the Jerada wastewater treatment plant (WWTP), which showed that all the parameters analyzed are more significant than those of other sludge studied, whether Moroccan or foreign. The richness of the residual sludge of the Jerada WWTP in fertilizing elements encourages its use as a soil amendment, germination tests of lentils and watercress were carried out for different percentages of sludge, for lentils, these tests showed that the sludge can be considered as a fertilizer at a concentration of 25%. In comparison with the results of the germination of lentils by olive pomace, the germination rate of the seeds decreases when the concentration of olive pomace increases. Then, a trial of sludge valorization in bean culture was carried out in the laboratory in order to study the impact of sludge amendment on plant growth (Bean), the monitoring of the parameters: Stem size, number of leaves, and leaf area showed that the sowing of bean in different concentrations of sludge and soil leads to a positive effect on bean yield on the three parameters, for concentrations of 5% and 10% sludge.

1. Introduction

The rapid growth of the population produces more and more wastewater discharges (Le et al., 2010), and the purification of the latter generates, with the purified water, a significant amount of wastewater sludge without any plan for its management, as well as their final destination, is a direct nuisance to human health and the environment, without forgetting that the sludge is a source of organic matter and nutrients (Williams, 2005).

These indications lead us to consider an agroecological solution, the reuse of waste sludge in agriculture (Kacprzak et al., 2017). For this purpose, our work is to carry out a spreading test in order to highlight the impact of the application of waste sludge on the response of a plant, in this case, the bean.

The sewage treatment plant of the city of Jerada presents an example of this problem of waste sludge, since it generates a considerable quantity, then the main objective of our work is to proceed to the Sludge's valorization of the Jerada's wastewater treatment plant (WWTP) by cultivating the bean over a period of 3 months (from January to April).

2. Materials and methods

2.1. Study area

The WWTP which is the subject of this study is located in the city of Jerada 60 km far from the southwest of Oujda (Cantoni and Rignall, 2019). It belongs to the province of Jerada which, administratively, belongs to the oriental, a region consisting of a prefecture (Oujda-Angad) and six other provinces (Taourit, Nador, Driouch, Jerada, Figuig, and Berkane) (Fig. 1).

Spread over an area of 18.34 km^2, the urban commune of Jerada suffers from unfavorable physical and natural conditions. For it is wedged between the massive Horsts in the north and the high plateaus in the south, the city of Jerada is

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strewn on altitudes varying between 1000 and 1400 m (Rankou et al., 2015).

Due to its geographical position, Jerada has a distinctly Mediterranean climate, characterized by very cold winters and dry, usually hot summers. The climate in the city of Jerada varies from arid in the highlands to semi-arid in its central part (Rankou et al., 2015).

The drinking water supply of the city of Jerada is ensured by 4 boreholes with a total flow of 240 l/s, in 2020 the number of drinking water subscribers of the city is 11,683; while the number of sanitation subscribers of the same year is about 11,335 subscribers, which gives a sanitation connection rate of 84.58% (Mounia et al., 2013).

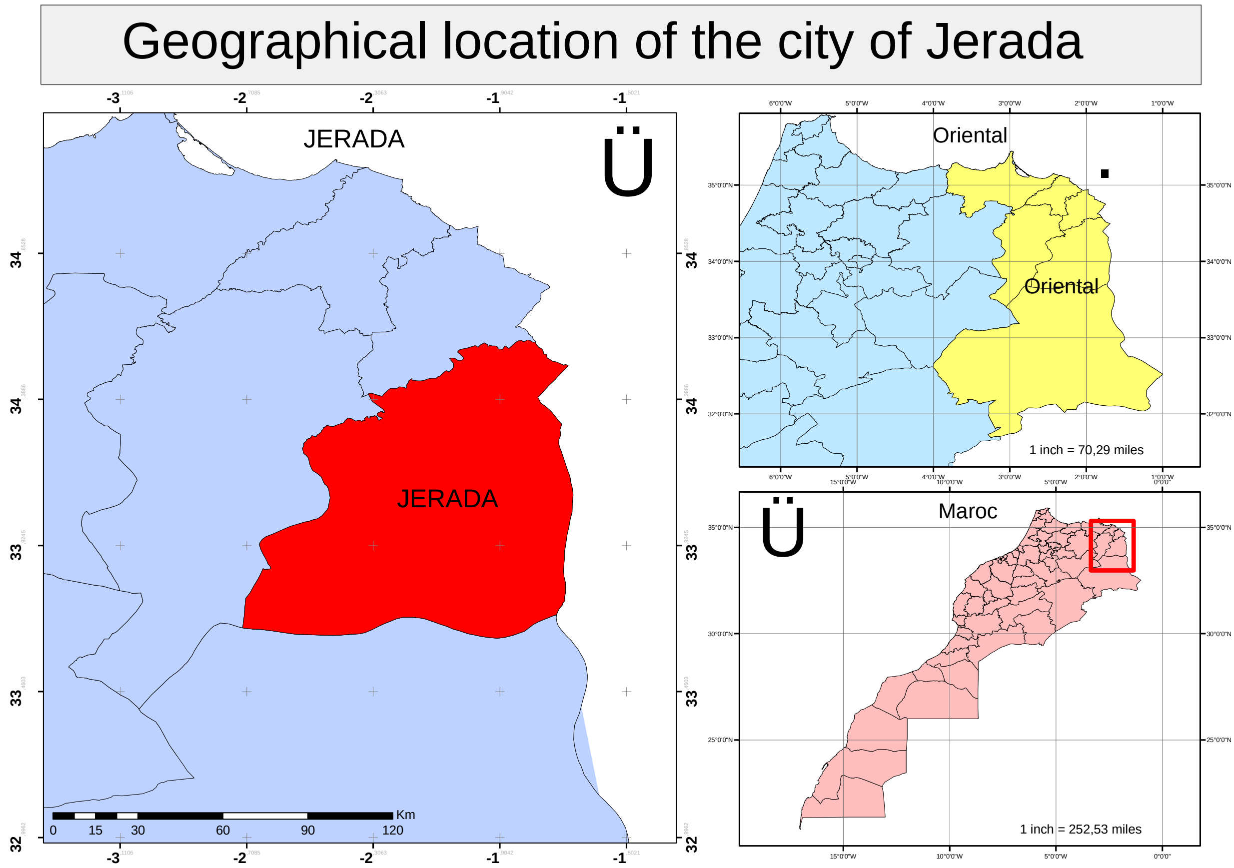

Fig. 1: Geographical location of the city of Jerada (Khnaijer et al., 2020a; 2020b)

2.2. Jerada WWTP

The wastewater treatment plant of the city of Jerada commissioned in 2016 of aerated lagoon type, is characterized by a treatment capacity of 2500 m^3/d equivalent to 51250 *E.H*, and an area of 10 hectares (Mounia et al., 2013).

The plant has two processes, first, the water process which contains a pumping station at the entrance that delivers the raw water to the pretreatment works, then the pretreated water arrives at the primary treatment (anaerobic tanks) then the secondary treatment (aerated tanks) and finally the polishing tanks. Then the sludge line where there are six drying beds (Mounia et al., 2013).

2.3. Germination test

Generally, the germination test allows us to know the germination capacity of a seed lot and in our case, it allows us to deduce the impact of the sludge of the sewage treatment plant on the plant before using it as a fertilizer for agriculture. Thus, the germination test was carried out on two types of seeds most used in the region (lentils and cress).

The germination index (GI) gives a narrow estimate of phytotoxicity as written by Zucconi et al. (1985). To determine the value of this index, 10 g of powdered sludge is mixed with distilled water and the solution is then shaken and left to stand, then diluted with distilled water in three different concentrations (25%, 50%, and 100%). The control concentration (0%) consisted of distilled water only. 5ml of each sludge solution was added to a Petri dish containing cotton wool on which 25 cress/lentil seeds were uniformly placed and then incubated for 48 h at 25°C (Zucconi et al., 1985).

$$\text{IG} = \left(\frac{GB}{GT}\right) * 100 \qquad (1)$$

where, *GB* is the number of germinated seeds in the mud and *GT* is the number of germinated seeds in the control. And with the following conditions:

- If *GI<50%:* High phototoxicity

- If 50%<*GI*<60% apply 90 days before germination
- If *GI*>60% the sludge can be used as fertilizer

2.4. Protocol for the valorization of waste sludge in agriculture

Considering the sludge of the WWTP of Jerada shows its richness from the point of view of fertilizing elements and physicochemical point of view as the dryness, the organic carbon, and the pH are susceptible to be valorized in agriculture (Table 1). And to discover the effect of the reuse of waste sludge on the bean plant, a follow-up of this culture was carried out using different concentrations of sludge and soil, for that purpose:

- The bean was used as a plant, which is a winter species, belonging to the legume family, whose fruits form a pod, and can be grown as a green vegetable or dry after the pods have matured (Vymazal, 2013).
- The soil used in this study is sandy type taken from "Sale." It was sampled from the topsoil (0-20 cm depth); with physicochemical properties summarized in Table 2 (Ameziane et al., 2020).
- The irrigation water used in the present study for the irrigation of fava beans comes from the well of the high school of technology Sale; its characteristics remain in conformity with the standards of water intended for irrigation (Table 3) (Vymazal, 2013).
- The residual sludge from the Jerada WWTP was dried and crushed to remove the unground residue before being used as fertilizer (Table 1).

Table 1: Physicochemical parameters of sludge

Physicochemical parameters	Characteristic of the sludge
pH	7.56
Conductivity (µs/cm)	1691
Dryness (%)	23.58
Organic carbon (%)	46
Organic matter (%)	23.73
Mineral matter (%)	21.17
Phosphorus (%)	6.819
HN4 (ppm)	212.8
NO3 (ppm)	14.62
Potassium	1.04

Table 2: Physicochemical parameters of soil

Physicochemical parameters	Soil characteristics
pH	7.61
Humidity (%)	4.51
Organic carbon (%)	4.88
Organic matter (%)	6.88
Phosphorus (%)	0.0103
Total nitrogen (%)	0.134
Potassium	0.0445

Table 3: Physicochemical parameters of well water

Parameter	Well water	Water standards for irrigation
pH	7.29	6.5-8.51
T(°C)	17.9	35
TSS (mg/l)	0.232	2000
MO (mg/l)	7.2	-
Conductivity (µs/cm)	1178	8700
Turbidity (NTU)	1	-
Nitrates (mg/l)	10	50

The trials consisted of using five different percentage pots of sludge and soil (from which 5 gausses of beans were sown in each). The plants were irrigated three times per week (Table 4).

Table 4: Composition of sludge/soil pots

	Pot 1	Pot 2	Pot 3	Pot 4	Pot 5
Soil	100%	95%	90%	85%	80%
Sludge	0%	5%	10%	15%	20%

2.5. Measured parameters

Regular monitoring of the bean plant is carried out through three parameters (length of aerial parts (stems), number of leaves, and leaf area). The latter is calculated by multiplying the length (L) by the width (l) of each leaf (*L*l*) (Boughou et al., 2018).

3. Results and discussion

3.1. Germination test

The germination index (*GI*) of lentil seeds is more important than that of cress. This index decreases when the concentration of sludge increases. Thus, the *GI* varies between 1% and 51% for cress seeds and between 25% and 77% for lentil seeds. The maximum *GI* is observed for the 25% concentration (Table 5).

It can be concluded that plants respond differently to sludge as fertilizer depending on the concentration. Thus, for 25% of sludge, only lentils have *GI* which is higher than 60% (Table 5). The comparison between the two seeds shows that watercress is very sensitive to the concentration of sludge compared to lentils. In comparison with the results obtained from the germination test of lentils by olive pomace, the germination rate of seeds decreases when the concentration of olive pomace increases (slowing down the germination process according to the increase of the dose of pomace) (Ameziane et al., 2020).

Table 5: Germination test result

Percentage of sludge	GI of cress seeds	GI of lentil grains
25%	51%	77%
50%	36%	51%
100%	1%	25%

3.2. Recovery of waste sludge from bean cultivation

The growth of the bean stem was monitored during the study period (almost 3 months) (Fig. 2).

During this period, maximum stem lengths varied between 53.8 cm (10% sludge concentration) and

64.60 cm (15% sludge concentration) with an average length of 50.65 cm (Fig. 3).

These values remain more significant at the stem lengths (47 cm and 58.9 cm) of plants fertilized with sludge from the Sidi-Ali Lebhar urban wastewater treatment plant of the city of Bejaia-Algeria (Zucconi et al., 1985).

Similarly, in comparison with the stems irrigated by well water and in the absence of fertilizing elements in the study of the assessment of wastewater in the city of the sale in bean agriculture, it is found that the maximum length of the stem is about 50 cm which shows that the contribution of fertilizing elements existing in the sludge are positively influenced on the growth of the length of the stem. Generally, the growth of stem lengths over time follows a linear relationship for all sludge/soil concentrations (Chaoua et al., 2019; Cucci et al., 2019).

Fig. 2: 3-month-old beans

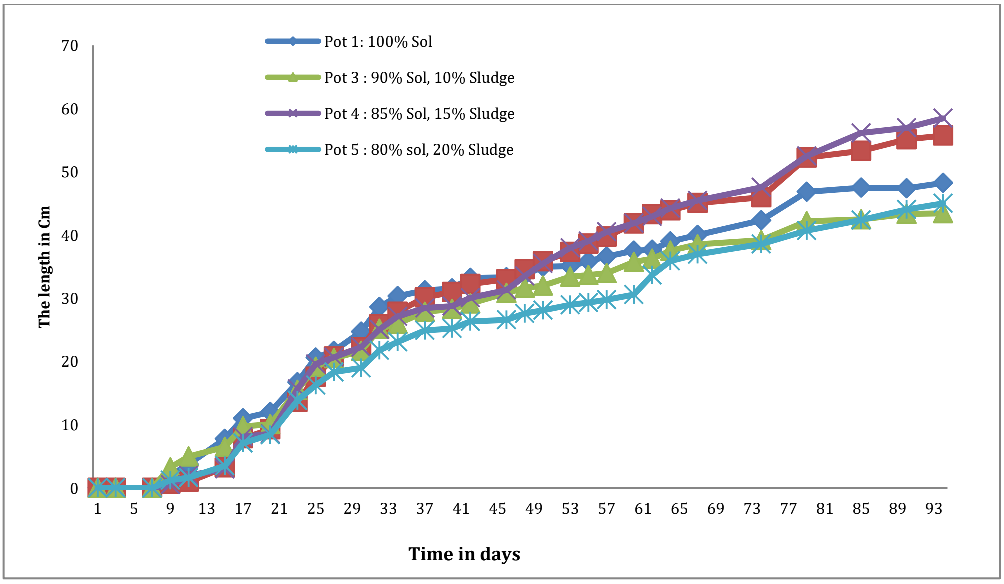

Fig. 3: Temporal evolution of the average stem length in the 5 pots

The number of leaves in the first days increases in a convergent way, the difference appears after two months of the semi. The final number of leaves for each concentration varied between 49 leaves (15% sludge) and 201 leaves (10% sludge and 90% soil) with an average number of 110 leaves. The highest number of leaves was observed for 10% sludge and 90% soil. The decrease in the number of leaves observed can be explained by the fall of some leaves (Fig. 4).The average number of leaves of the plants fertilized by sludge remains on average higher than the number of leaves of the plants amended by pomace (44 leaves) (Ameziane et al., 2020).

Leaf space increases differently in the five concentrations. The largest leaf area (24.72 cm^2) is observed for the sludge concentration (5% sludge and 95% soil); while the smallest leaf space (15 cm^2) is recorded for the 20% sludge concentration (Fig. 5).

This explains that the contribution of the fertilizing elements of the sludge on the plant-soil system had an influence on the growth of the bean. This confirms the contribution of fertilizing elements by the waste sludge.

In comparison with the results found in the pomace valorization study, the yield of the three parameters is much higher (Leaves max 201, stem: 64 cm and leaf space: 25 cm^2) than the yield found in the pomace valorization study (Leaves: 42, stem: 45 cm and leaf space: 11 cm^2) (Ameziane et al., 2020).

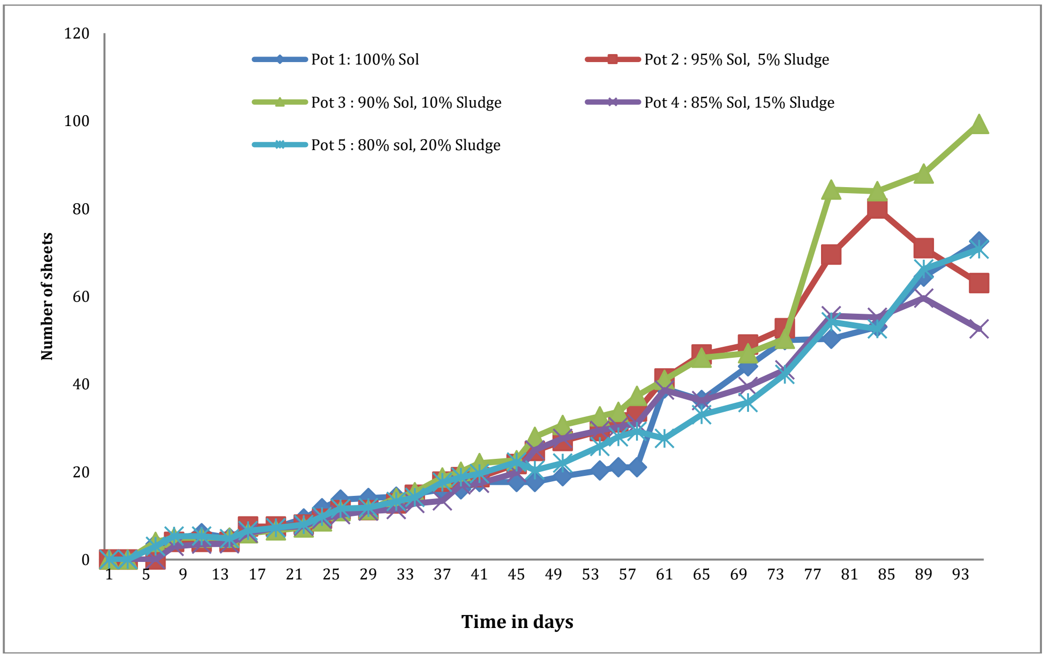

Fig. 4: Temporal evolution of the average number of leaves in the 5 pots

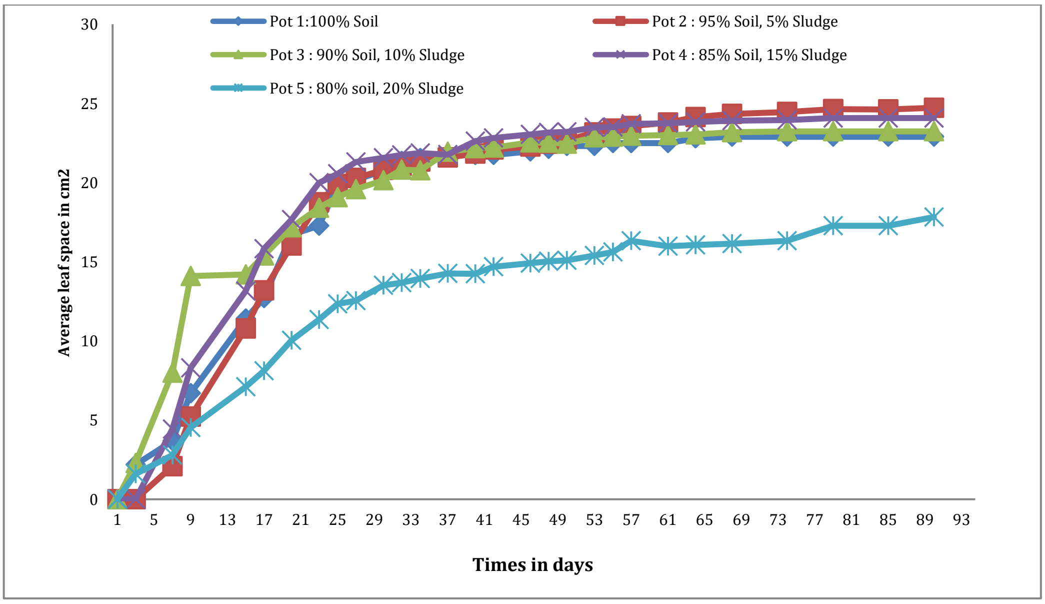

Fig. 5. Temporal evolution of the average leaf space in the 5 pots

The yield of bean growth exceeds 93% for both parameters (stem length and number of leaves). The highest yield of the average number of leaves (95.96%) is observed for 10% sludge. And, stem length (99%) is marked at the concentration of 5% sludge (Fig. 6).

To know the impact of different concentrations of sludge (0%, 5%, 10%, 15%, and 20%) on the growth of the bean, and as evidenced by the number of leaves and length of the stem, we calculated the correlation coefficient (σ) between these two parameters (stems and leaves) for each concentration is very close to 1 (it is between 0.92 and 0.97). For all the different concentrations, there is a positive correlation higher than 0.92, which explains that the number of leaves is closely proportional to the size of the stem. It can be seen that there is a stabilization of the stem length for all concentrations at the end (Fig. 7).

4. Conclusion

Morocco's WWTPs generate a fairly large amount of waste sludge on a daily basis (275t/d in 2018), however, these significant quantities remain without any management, recovery or treatment plan, or strategy.

The Jerada WWTP's sludge shows its richness from a fertilizing element point and from a physicochemical point such as dryness, organic carbon, and PH. Therefore, this allows us to use this sludge as a soil fertilizer for the cultivation of beans which remains the most appropriate technique for sustainable management of the sludge of the WWTP.

The valorization of the Jerada WWTP's residual sludge by making the test of germination made it possible to determine the limit concentration tolerated by the seeds.

Similarly, monitoring the growth of the bean through the three parameters, stem length, number of leaves, and leaf space to determine the concentration of sludge giving the best yield.

Plant yields generally exceeded 93% for all different sludge concentrations for both parameters (stem length and number of leaves). While the optimum yield in terms of stem length and leaf space can be assured for 5% to 10% sludge concentrations.

In comparison with the results found in the pomace valorization study, the yield of the three parameters is much higher. Similarly, for the germination index of sludge, the latter can be considered as a fertilizer at a specific concentration, unlike olive pomace.

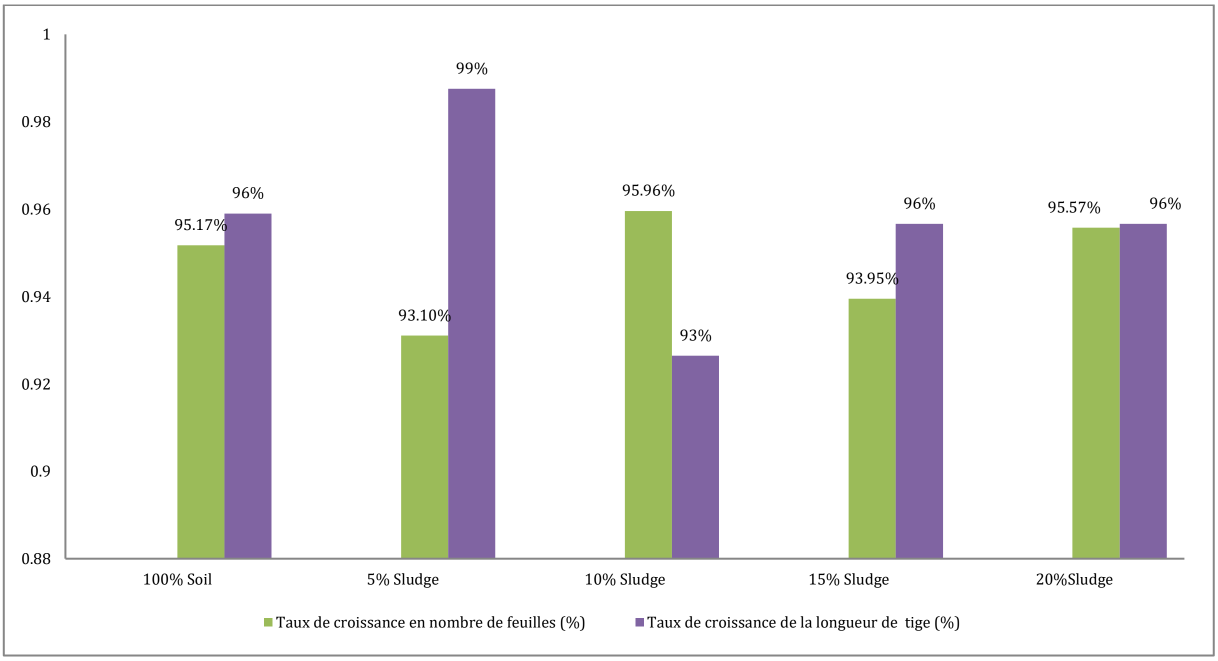

Fig. 6: Growth rates of average leaf number and stem size of beans for different sludge concentrations

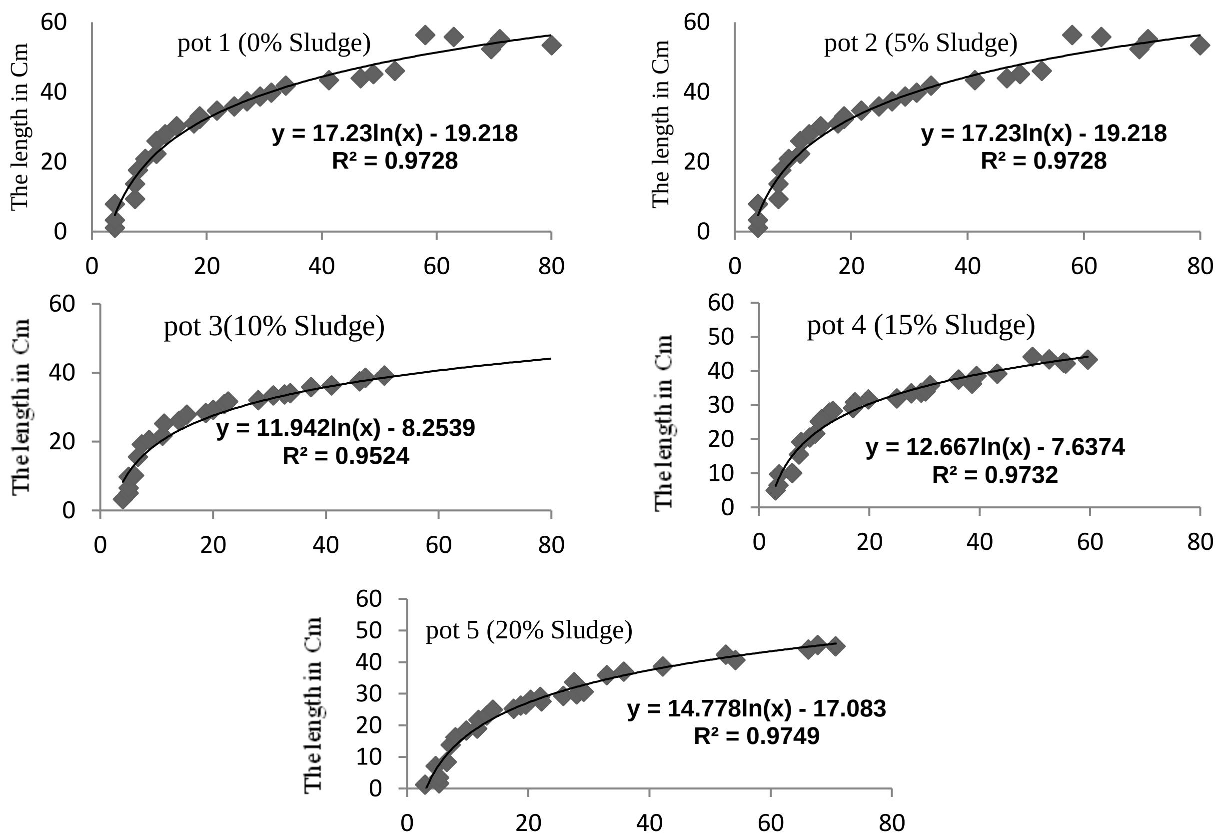

Fig. 7: Correlation curves between stem length and number of leaves as a function of sludge concentration

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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