



Effect of application sludge from Ain Defla wastewater treatment plant on the biomass and tomato production. Efeito da aplicação de lodo da estação de tratamento de águas residuais de Ain Defla na biomassa e na produção de tomate.

Naima Douaer^{1*}, [Madjid Mehaiguen](#)¹, [Mohamed Zouidi](#)², [Abdelkader Douaoui](#)³

^{1*}- Department of Ecology and Environnement, Faculty of Nature and Life Sciences and Earth sciences, University of Khemis Miliana, Algeria. E-mail: n.douaer@univ-dbk.m.dz

²- Centre de Recherche en Aménagement du Territoire (CRAT), Campus Zouaghi Slimane, Route de Ain el Bey, 25000 Constantine, Algérie.

³- University Center of Tipaza, Laboratory Management and Valorization of Agriculture and Aquatic Ecosystems (LMVAAE), Algeria.

Abstract

The objective of this study is to evaluate the effect of sewage sludge on the yield and biomass of tomatoes. The complete randomization block device consists of three treatments with nine repetitions in a plastic greenhouse intended for the cultivation of tomatoes: C: the control soil; S+S: soil spread with sludge; S+F: soil with mineral fertilization. The results obtained show a very significant correlation between the level of organic amendment and productivity: the best performances are obtained with the treatment of soil and sewage sludge. The evaluation of the hygienic quality revealed the absence of pathogenic germs and bacterial in the tomatoes harvested from the soil treated with sewage sludge.

Keywords: Sewage sludge. Soil. Agriculture. Fertilization. Vegetable production.

Resumo

O objetivo deste estudo é avaliar o efeito do lodo de esgoto no rendimento e biomassa dos tomates. O dispositivo de blocos de randomização completo consiste em três tratamentos com nove repetições em uma estufa de plástico destinada ao cultivo de tomates: C: solo de controle; S+S: solo espalhado com lodo; S+F: solo com fertilização mineral. Os resultados obtidos mostram uma correlação muito significativa entre o nível de emenda orgânica e a produtividade: os melhores desempenhos são obtidos com o tratamento de solo e lodo de esgoto. A avaliação da qualidade higiênica revelou a ausência de germes patogênicos e bacterianos nos tomates colhidos do solo tratado com lodo de esgoto.

Palavras-chave: Lodo de esgoto. Solo. Agricultura. Fertilização. Produção de vegetais.

Introduction

Wastewater generated from various urban activities cannot be directly discharged into the environment as they contain various organic and mineral pollutants. Therefore, before being released into the natural environment, they must undergo purification treatment, which results in the production of residual sludge. Sewage sludge contains fertilizing elements and can serve as an energy source. Over the past few decades, this sludge has transitioned from being considered waste to valuable products (ITICESCU et al., 2022). Before being discharged into the natural environment, they must undergo purification treatment, leading to the production of residual sludge. In Algeria, the current production of sludge is approximately 350 tons per year (SIEE POLUTEC, 2019).

The production of sludge increases with the development of wastewater treatment plants. A major challenge is to find a solution for the economical disposal of these residues while complying with environmental protection and public health constraints (BAUMONT et al., 2004; RAMDANI et al., 2015). Sludge from wastewater treatment plants has potential fertilizing properties and can be used to enrich agricultural soils due to its nitrogen, phosphorus, and organic matter content (DOUAER et al., 2021; MARIN; RUSĂNESCU, 2023). Agricultural valorization of residual sludge can be considered the most suitable recycling method for rebalancing biogeochemical cycles, environmental protection, and significant economic benefits. It aims to conserve natural resources and prevent any waste of organic matter through incineration or land filling (SINGH; SHARMA, 2016).

Recycling or agricultural valorization represents a more rational management approach and contributes to the reintegration of mineral and organic elements into the soil, thus moving closer to natural cycles (ALVARENGA et al., 2015). Residual sludge can replace or reduce the excessive use of costly fertilizers. This study was conducted to test the effectiveness of utilizing residual sludge in agriculture compared to mineral fertilizers. Within this context, greenhouse experiments and laboratory analyses were undertaken to: Characterize the sludge in terms of its fertilizing elements; evaluate the effectiveness of applying sewage sludge on the hygienic quality of tomatoes through microbiological analyses and assess the impact of sludge application on tomato biomass, yield, and morphological parameters.

Materials and methods

1. Sludge preparation

Activated sludge comes from the wastewater treatment plant in Ain Defla (Algeria), with 90% of its origin being domestic. The wastewater treatment plant in the city of Ain Defla is located near the Chelif River. Bounded to the north by a wilaya road, to the southwest and east by agricultural land, it has been operational since March 2007 and was constructed by the hydraulic department of the Ain Defla wilaya. Samples of the sludge were collected on 31/12/2017 from the wastewater treatment plant located in the municipality of Ain Defla. The sludge was randomly collected from drying beds (at both ends and the center) where mixed sludge was subjected to dehydration.

The wastewater sludge had a neutral pH; electrical conductivity of 3.81 ms/cm and higher levels of organic matter and carbon. The average concentrations of heavy metals were present in low concentrations, in accordance with the AFNOR NA 17671 standard according to LADJEL and ABOU (2014). The different elements are organized in the following order: Zn > Cu > Pb > Cr > Ni >

Cd> Hg. The physicochemical analysis of the sludge from the Ain Defla wastewater treatment plant allowed us, first of all, to ensure that it is not toxic to vegetable plants and soil as it contains very minimal amounts of heavy metals, which are well below the AFNOR standards. Secondly, the sludge is rich in organic matter and fertilizing elements (Table 1).

Table 1 - Characterization of residual sludge from the Ain Defla wastewater treatment plant.

Physico-chemical parameters	Residual sludge
pH	7.21
Electric Conductivity EC(ms/cm)	3.81
Humidity (H)%	56.1
Loss on ignition (LOI) %	39.91
Organic matter (O.M) %	76.54
Carbon (C) %	15.17
Nitrogen (N) (g/kg)	38
Chromium (Cr) (mg/kg)	48
Nickel (Ni) (mg/kg)	9
Copper (Cu) (mg/kg)	105
Cadmium (Cd) (mg/kg)	1
Zinc (Zn) (mg/kg)	474
Lead (Pb) (mg/kg)	75
Mercury (Hg) (mg/kg)	0.1

2. Soil preparation

Our experimentation was carried out at the experimental station of the Technical Institute of Vegetable and Industrial Crops (ITCMI) in Staoueli, located on the Algerian coast, during the dominant season characterized by a dry and humid climate. The shelter used is an Algerian-made tunnel greenhouse called Casdep, with a surface area of 240 m², oriented North-South, and its characteristics are summarized as follows: size (256 m² × 3 m) and surface area: 213,5 m². It is covered with a locally-made polyethylene (PE) plastic film. The soil has the following characteristics: sandy loam texture, acidic pH (6.8), electrical conductivity (EC) averaging 0.128 ms/cm. The average organic carbon is 1.83 and of organic matter content is 3.42, which indicates that the soil is rich in organic matter.

3. Field experiment

The experimental protocol consists of three treatments with 9 plants each (Figure 1): C - the control soil without sludge and without mineral fertilization; S+S - soil spread with active sludge; S+F - soil with mineral fertilization. The complete randomization block device consists of nine plants per treatment in a plastic greenhouse intended for the cultivation of industrial tomato. Before putting plants in the greenhouse for treatment S+S are equal to 3 kg/m² (SOULIGNAC, 2000), with total doses applied to each plot being homogeneous to fix the sludge application factor. The mineral fertilization for treatment S+F is 130 kg/ha N, 120 kg/ha P₂O₅, and 150 kg/ha K₂O.



Figure 1 - Experimental site for application of sludge in industrial tomato crop production at the experimental station of the Technical Institute of Vegetable and Industrial Crops in Staoueli (ITCMI).

4. Cultivation

The industrial tomato crop of the "Panekra" F1 Hybrid variety was used for the analysis. This tomato hybrid has excellent adaptation to all growth conditions, and disease resistance, and it produces consistently sized fruits for fresh consumption. Its fruits are harvested in the spring and summer (RANDY, 2023). It belongs to the category of indeterminate tomatoes, meaning they do not independently stop their growth. For this reason, the yield of the Panekra F1 tomato is very high (VOLKOVA; DIMITRIEV, 2018), and tomatoes are very vigorous. They have a developed root system, allowing plants to grow on all soils, even the poorest, by feeding on the lower layers of the soil (SIEVIDOV, 2022).

Before germination, tomato seeds were planted in seedling trays for one month until they reached a vegetative stage with 2 to 3 leaves. Subsequently, they were transplanted into pots (27 pots distributed across three treatments with 9 plants each). Throughout the experimental period, the plants were placed in a greenhouse from January to May 2018. During the experimental period, the average temperature was 30 °C with a relative humidity ranging between 70% and 80%. The plants were irrigated with tap water by a drip irrigation system. In order to evaluate the effects of the different treatments C, S+S, and S+F, on tomato growth, morphological and physiological measurements were carried out.

5. Morphological parameters of tomatoes

For each treatment, three individual plants were evaluated for growth in diameter at the base, number of leaves, number of fruits, and fresh weight (g) for four months of the experiment, and these parameters were measured twice a month. Repeated measures analysis using Origin Pro 8.5 was used to study the effect of sludge concentrations on the analyzed parameters.

6. Microbiological analysis of tomatoes

In this study, three samples of tomatoes from each treatment were selected, crushed, and then blended using a mixer. Subsequently, 25 grams of each sample were placed in a sterile plastic bag

with 225 ml of 0.1% buffered peptone water. The analysis of the tomatoes was carried out according to the microbiological standard B-ON°52/4/P727/2004 (SOBRATEE; WORKNEH, 2015). The microorganisms counted or sought were mainly: Aerobic mesophilic bacteria (AMB), Total coliforms (TC), Fecal coliforms (FC), Clostridium, Vibron, salmonella, and Helminthe.

Results and discussion

1. Effect of sludge on morphological parameters of tomato

Stem height: Stem height differs among treatments. After approximately five months of growth, the maximum length of the stem is recorded in cultures grown on soils treated with sludge (97 cm), followed by cultures grown on soil treated with chemical fertilizer (95 cm). For cultures on the control soil, stem growth does not exceed an average of 88 cm (Figure 2). The work conducted by Velli et al. (2021) showed that the addition of biochar derived from sewage sludge improved soil characteristics and plant growth, notably increasing the dry weight of both aboveground (stems and leaves) and belowground (roots) plant tissues. Vegetative biomass is considered a key criterion for assessing plant growth (EYHERAGUIBEL, 2004). We observed that plants treated with the soil + sludge mixture reached a maximum length of 97 cm in terms of stem height and diameter. This indicates that the plant grows under favorable conditions, primarily due to the presence of nitrogen and organic matter. Similar results were reported in terms of plant height (BAKSHI et al. 2019; CRISTINA et al., 2020).

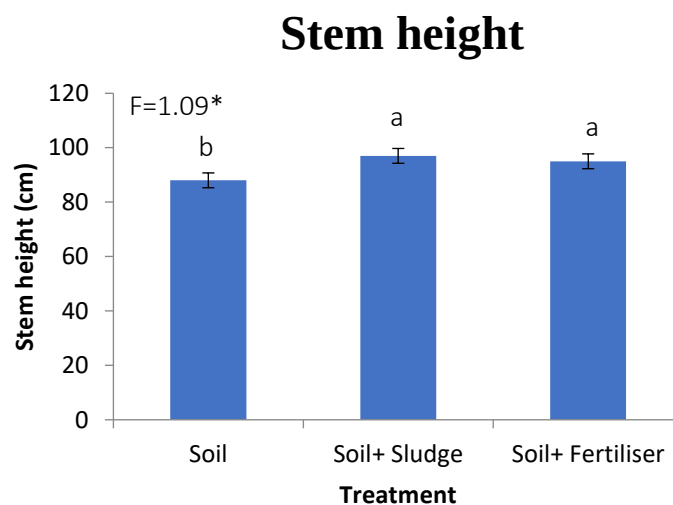


Figure 2 - Variation in the tomato plants stem height according to the different treatments.

Stem diameter: Sewage sludge can influence the radial growth of plants, as demonstrated and shown in Figure 3, which indicates that radial growth is more pronounced with the sludge treatment, with a value of 1.8 cm.

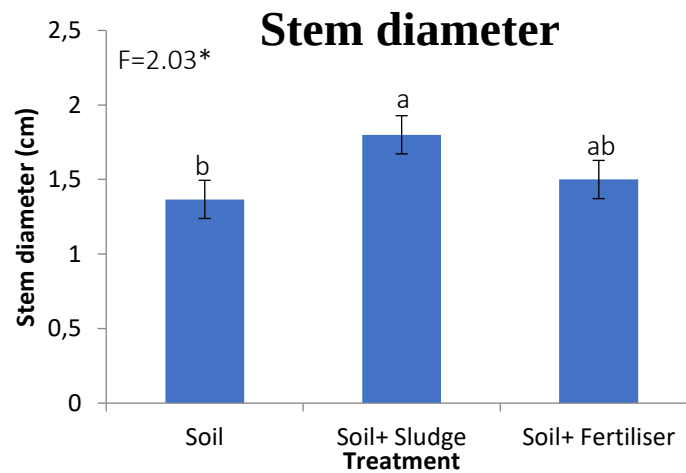


Figure 3 - The average diameter variation of the stem according to the treatment applied.

Leaf number: The number of leaves is a good indicator of proper watering and mineral nutrition and biomass production by the plant. Figure 4 and Figure 5 represent the number of leaves on tomato plants for the different treatments. According to Figure 4, the highest number of leaves is recorded for plants in the soil + sludge treatment, with an average of 20 leaf levels per plant. For plants in the control soil treatment, a lower number of leaves is recorded. Similar studies have shown that adding municipal sewage sludge during an outdoor experiment promoted the growth of tomato plants, especially in terms of the volume of the above-ground part, compared to tomatoes grown in untreated soils (GIANNAKIS et al., 2021).

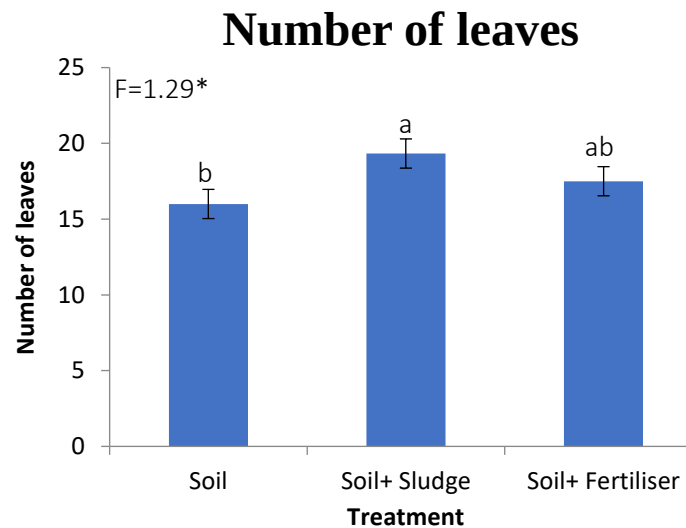


Figure 4 - The averages variation in the number of leaves according to the different treatments.



Figure 5 - Photos of tomato leaves from different treatments (Photos taken on 19.02.2018).

Fruit numbers: The fruit refers to the final result of a vegetative development that lasts several months in order to meet needs, provide a significant yield, and enable species regeneration in the case of vegetable crops, according to our experimentation. According to our results (Figure 6), tomatoes treated with sludge produced the highest quantity of tomatoes (12 fruits), while plants in the control soil recorded approximately 9 fruits per plant. In previous studies, the application of sewage sludge can enhance soil fertility and productivity (HUSSEIN et al., 2010; DOUAER et al., 2021). Conversely, an experiment conducted by some researchers demonstrated that all yield components of wheat, white cabbage, and tomato significantly increased with higher sewage sludge rates compared to the control (ÖZYAZICI, 2013).

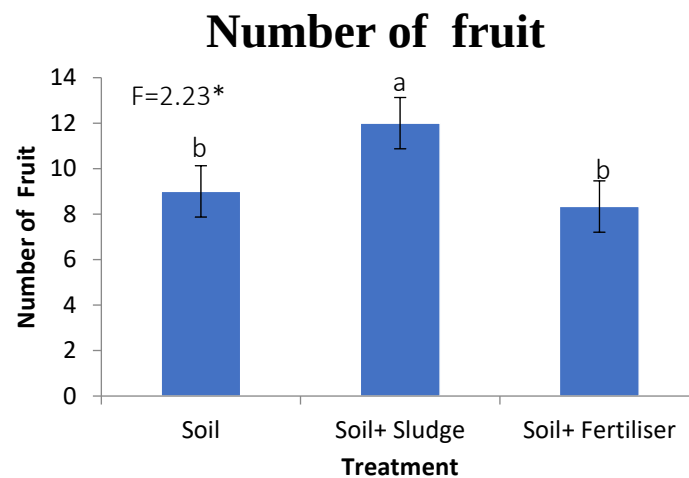


Figure 6 - Variation in the number of tomato fruits of the different treatments.

Plant biomass can be influenced by various factors such as soil moisture, soil and air temperature, photoperiod, solar radiation, precipitation, and genotype. One of the most significant factors affecting biomass is the availability of soil nutrients. Sewage sludge spread in agricultural fields represents one of the most important contributions to the environment because spreading sewage sludge in agricultural fields can have several environmental benefits, including nutrient enrichment, soil quality improvement, and waste reduction. However, it is important to note that the use of sewage sludge must be regulated and closely monitored to prevent any potential risks associated with the presence of contaminants. Strict standards are typically in place to ensure a safe and sustainable use of these residues in agriculture (MARIN; RUSĂNESCU, 2023). To date, there is

no standardized protocol for their extraction and the modifications in vegetative growth and fruit maturation in plants induced by sludge application (HERNÁNDEZ-ARENAS et al., 2021).

Weight: The fruits harvested at the end of the experiment have different weights (Figure 7). We observe an average of 240 g/fruit for the treatment with sludge, 212 g/fruit for the treatment with fertilizer, and 167 g/fruit for the control treatment with soil. Thus, the sludge treatment records the maximum value, indicating that it is the best treatment compared to the other two treatments in all the studied morphological parameters for the plant.

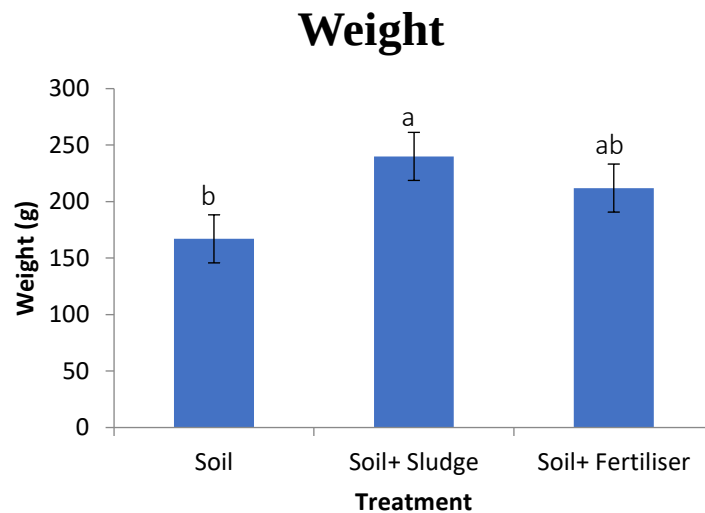


Figure 7 - Variation in tomato fruit weight of the different treatments.

2. Microbiological analysis of tomatoes

Microbiological testing was conducted on the tomatoes to determine if they were contaminated with pathogenic bacteria originating from the spread sludge. The results are presented in Table 2.

Table 2 - Microbiological analysis of tomato fruits treated with sludge and fertiliser.

Treatment	Total coliform	Faecal coliform	Clostridium	Aerobic mesophilic bacteria	Salmonella	Vibron	Helminthe
Control soil tomato	absence	absence	Absence	absence	absence	absence	absence
Tomato from (S+F)	absence	absence	Absence	absence	absence	absence	absence
Tomato from (S+S)	absence	absence	Absence	absence	absence	absence	absence

The assessment of the hygienic quality of tomatoes revealed the absence of pathogenic bacteria: total mesophilic aerobic flora, total coliforms, faecal coliforms, salmonella, and sulfite-reducing clostridia.

The level of bacterial contamination in tomatoes harvested from soil treated with sludge is zero. For example, salmonella and faecal coliforms can survive for 20 to 70 days, vibrios for 10 to 20 days, and helminth eggs for 30 to 60 days.

The results of Raïs et al. (2016) show that the contamination by fecal indicators varies considerably for the same treatment in the case of all radish, lettuce, and cucumber. They have noticed

that for lettuce, the outer leaves, often in contact with the soil, are significantly more contaminated with coliforms and fecal streptococci than the inner leaves.

Research on the valorization of sludge in agriculture by Rejeb (2011), also supports these findings. According to the initial results obtained, agricultural products produced in the Borj Touil area have satisfactory bacteriological quality. According to Carrington (2001) sludges treated according to the suggested standards for advanced treatment will not contribute to the pathogenic burden of the environment and pose no risk to human, animal, or plant health.

Conclusion

This study highlights the significant benefits of using sewage sludge for cultivation of tomato. The application of this sludge has indeed increased the production of the experimental crop. The addition of sludge improves all the studied growth parameters, including stem length and diameter, number of leaves, and number of fruit. The evaluation of the hygienic quality of tomatoes revealed the absence of pathogenic bacteria: Aerobic mesophilic bacteria (AMB), Total coliforms (TC), Fecal coliforms (FC), Clostridium, Vibrion, salmonella, and Helminthe.

The level of bacterial contamination in tomatoes harvested from soil treated with sludge is nonexistent. This is a definite positive outcome regarding its use in agricultural soils. Furthermore, these residual sludges contain only a small proportion of heavy metals, which are well below the AFNOR standards. Therefore, they do not pose any risk of toxicity.

Conflicts of interest

The authors declare no conflicts of interest regarding the work presented here. All authors read and approved the final manuscript.

Authors' contribution

Naima Douaer and Madjid Mehaiguen - execution of the experiment and also wrote the manuscript; Mohamed Zouidi - performed the statistical analysis; Mohamed Zouidi and Abdelkader Douaoui - reviewed the manuscript.

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