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# Effect of Compost Made with Sludge and Organic Residues on Soil and Sugar Beet Crop in Morocco

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ABSTRACT

The objective of this study was to determine the effects of the application of different doses of compost made with sludge and organic residues from plants on some soil characteristics, growth and yield of sugar beet (*Beta vulgaris* L.) grown in Moroccan soil having low organic matter. A field experiment was conducted and complete randomized block with four replicates was designed. Treatments consisted of control without any organic amendment and three concentrations of compost (2.5, 5.0 and 7.5 t ha$^{-1}$). Results showed that, in general, application of at least 5 t ha$^{-1}$ of compost increased soil organic matter along with C rates and other mineral nutrients such as N, P and K. Application of 5 t ha$^{-1}$ of compost significantly increased sugar beet biomass and recoverable sugar yield. This beneficial effect was reversed with the highest dose of 7.5 t ha$^{-1}$.

**Key words:** Sugar beet, compost, biomass, mineral nutrient, recoverable sugar

## INTRODUCTION

Moroccan soils are suffering from an imbalance in their structure, their organic matters and their nutrients resulting therefore in the decrease in agricultural production. Significant declines in soil organic matter lead to the deterioration of its physical properties and imbalances in its mineral content (Mustin, 1987; Mrabet *et al*., 2001). In addition, application of conventional agricultural practices such as deep soil tillage, can lead to a progressive deterioration of soil fertility, especially in Mediterranean areas characterized by scarce rains and elevated temperatures (Biederbeck *et al*., 1994; Bulluck *et al*., 2002; Moussadek *et al*., 2014). Moreover, modern agriculture reduced crop rotations and the use of high mineral fertilizers without organic cropping systems refunds is characteristic of such imbalance. The soils have become very infertile and dependent on mineral fertilization. In addition, misuse of nitrogen fertilizers had a bad effect on the water quality.

As a consequence, to maintain elevation of crop productivity and to improve some soil properties, a reduction of agricultural inputs and a greater supply of organic material are highly needed. Hence, the return to organic fertilization was a necessity both agronomically and environmentally (Ouatmane *et al*., 2000).

Compost is a stable humus-like product, which results from the biological decomposition of organic materials under controlled conditions. Nowadays, application of compost in farms is mostly adopted and it is considered as the best environmental solution. Several authors have detailed the benefits of organic matter on the soil. It improves physical properties of the soil (Allison, 1973; Chen and Avnimelech, 1986; Mustin, 1987; Pedra *et al*., 2007; Hargreaves *et al*., 2008). Compost causes an increase in the proportion of soil aggregates (Clapp *et al*., 1986) and enhances air spaces; facilitating therefore, drainage and soil aeration to resist thus compaction. It also improves macroporosity and microporosity of the soil (Pagliai and Antisari, 1993). Compost increases the capacity of soil water retention. A 5% increase in Soil Organic Matter (SOM), treated as compost, quadruples the soil's ability to retain and store water. This good water retention by humus is a considerable asset for soil during drought (Mustin, 1987). Compost also increases Cation Exchange Capacity (CEC) of the soil therefore increases its ability to retain nutrients. Indeed, adding 4% of urban compost to a sandy soil from the center of Saudi Arabia has improved its CEC of 4.9-8.7 meq/100 g soil (Mustin, 1987). The fraction of the SOM in the soil contributes to create favourable physical conditions, especially the ability of air and water, which promotes the development of root systems. It participates in the mineral nutrition of the plant being a reservoir of nutrients released into the liquid phase as the mineralization events operating in the soil. Thus, the richness of SOM is of vital importance in sustainable agriculture. The problem of the management of organic matter in the soil of the farms is also needed to preserve the physical and chemical fertility.

Compost improves mineral nutrition of plants, particularly nitrogen, phosphate and potassium nutrition (Nuntagij *et al*., 1989; Yuksel, 2004; Hasyim *et al*., 2014; Abdel-Fattah and Merwad, 2015). The compost contains about 1-4% nitrogen. Also, it stimulates the activity of terrestrial microorganisms that use atmospheric nitrogen for their growth. When these organisms die the nitrogen in these microorganisms is available in the soil for plants (Nuntagij *et al*., 1989).

The effects of organic matter in the soil for improving crop production also can be assessed qualitatively and quantitatively. Abedi *et al*. (2010) reported that the increase of yield in wheat was the result of application of municipal solid waste compost. Several other studies find that the contribution of organic amendments increases the yield of crop plants such as lettuce (Shiralipour *et al*., 1992), rice (Kavitha and Subramanian, 2007), vine (Korboulewsky *et al*., 2004) and water leaf (Uko *et al*., 2013).

The production of organic waste (sewage sludge, biodegradable organic waste) during the last decade increased dramatically in Morocco and mainly around the region of El Jadida. Their removal becomes a problematic and thus their valorization in agriculture by composting is highly needed.

This study aimed to study the effect of the supply of compost sewage sludge systems of the city of El Jadida on physical and chemical characteristics of the soil and on sugar beet growth parameters, sugar yield and some qualitative parameters.

## MATERIALS AND METHODS

**Description of the experimental site, soil and compost:** The field study was conducted during 2008 at the experimental station of the Regional Office for Agricultural Development of Doukkala at Zemamra, Morocco. It is located in the Western central zone of Morocco (32º37'30" N, 8º42' W) with mean annual rainfall of 300 mm and mean annual temperature of 24ºC. Sown parcel of 1365 $m^2$ was divided into 16 micro-plots corresponding to 4 treatments and 4 repetitions. Treatments consisted of adding 0, 2.5, 5 and 7.5 t $ha^{-1}$ of raw compost, corresponding to 0, 7.5, 15, 22.5 kg, to each elementary plot. Each micro- plot has a size of 6 m long and 5 m wide and is separated by a neutral zone of 3 m wide. The soil has a clay-loam texture, low organic matter and has a slightly alkaline pH. Some relevant characteristic of this soil are summarized in Table 1.

Composting was carried out within the framework of the project MOROCOMP, using a horizontal cylindrical bioreactor with a total volume of 4 $m^3$. The bioreactor is equipped with a programmable control system which allows the turning of the compost and the regulation of the air flow and water. The stirring system consists of a steel axis which passes through the centre of the bioreactor. Steel blades are distributed along this axis enable the reversal of the formed aggregates. The obtained compost is a mixture of sewerage sludge from the city of El Jadida, cattle manure, straw, leaves and sugar beet tops. The physico-chemical analyses of this compost are shown in Table 2.

The amendment is made by hand and then buried using rototillers to distribute the compost homogeneously. The soil was taken for analysis at 120 days after sowing using an auger

Table 1: Physical and chemical characteristics of representative soil sample before sowing (0-20 cm depth)

| Parameters | Values |
|---|---|
| **Grain size** | |
| Clay (%) | 35-37 |
| Silt (%) | 13.5-14 |
| Sand (%) | 49-50 |
| Organic matter (%) | 1.25 |
| pH | 7.85 |
| Total $CaCO_3$ (%) | 0.09 |
| Electrical conductivity (mS $cm^{-1}$) | 0.27 |
| Bulk density | 1.40-1.46 |
| Assimilable $P_2O_5$ (ppm) | 10.5 |
| Exchangeable $K_2O$ (ppm) | 150.4 |

Table 2: Physical and chemical analyses of the used compost

| Physical parameter | | Macronutrients (% DW) | | Heavy metals (ppm) | |
|---|---|---|---|---|---|
| pH | 8.1 | N | 1.12 | Cd | nd |
| EC (mS $cm^{-1}$) | 2.5 | $P_2O_5$ | 1.34 | Pb | nd |
| Dry weight (%) | 58 | $K_2O$ | 0.96 | Ni | nd |
| Org. matter (%) | 36.3 | Fe | 0.48 | Cr | 28 |
| Org C (%) | 22.5 | Ca | 0.79 | Cu | 45 |
| C/N | 17.9 | Mg | 0.94 | Zn | 12 |
| | | Na | 1.11 | Mn | 100 |
| | | | | Ba | 12 |

DW: Dry weight, nd: Non detected, Org.: Organic to a depth of 0-20 cm in each micro-plot. Several samples were carried mixed to collect a composite sample of 1 kg and recovered in white plastic bags well referenced. The samples were dried in the open air, except for a portion that was analysed for its fresh mineral nitrogen content.

**Plant material, growth parameters and yield:** Our experiments were performed on a root crop sugar beet Olga variety. The study focused on the growth and development of the plant through the production of biomass (weight of leaves and roots), taken directly from the field. All samples were collected to obtain more homogeneous groups (random sampling in space), as appropriate samples, either directly analysed or stored for later use. Some of this material was used to determine the fresh weight and dry matter after drying in an oven. Seeding was performed after spreading compost in the test plots by planting holes separated every 20 cm. The distance between rows was 50 cm.

Sampling was performed randomly at different stages of growth of the plant (50, 83, 120 and 160 days after sowing). The samples were placed in white plastic bags properly referenced. These samples were transferred to the laboratory on the same day, washed, cut and drained before measuring their fresh weight. The dry weight was determined after drying in an oven at 80°C. Other samples were used to measure leaf area using an automatic area meter. Population density was determined at 50 days after "Thinning" by counting the number of seedlings per meter linear. Root yield, Recoverable Sugar Yield (RSY) and Quality Index (QI) were performed at harvest (das). Sucrose was estimated in fresh samples of sugar beet root by using Saccharometer. Sugar loss was calculated using the following formula:

$$\text{Sugar loss (\%)} = 0.29+0.343\ (\text{K+Na})+0.094\ \alpha\text{-amino N}$$

$$\text{Sugar recovery (\%)} = \text{Sucrose (\%)-sugar loss (\%)}$$

Recoverable Sugar Yield (RSY) (t ha$^{-1}$) was calculated as root yield (t ha$^{-1}$)×sugar recovery. Quality index (QI) was calculated as, sugar recovery (%)×100/Sucrose (%).

$$\text{Gross sugar yield (t ha}^{-1}\text{)} = \text{Root yield (t ha}^{-1}\text{)×sucrose (\%)}$$

Sugar loss yield was computed as: root yield (t ha$^{-1}$)× sugar loss.

**Analytical methods:** The pH was measured on the liquid portion of an aqueous solution with a ratio of 10/25 (w/v) as described by Mathieu and Pieltain (2003). The electrical conductivity was determined using a conductivity meter glass electrode at a temperature of 25°C on a 1/5 ratio (Mathieu and Pieltain, 2003). The relative humidity of fresh soil was determined after drying soil samples in an oven at 105°C.

Organic carbon assay was performed by the modified method of Walkley and Black (1934). The total nitrogen of soil and compost was determined by the Kjeldahl method (Mathieu and Pieltain, 2003). The presence of phosphorus in soils and compost was determined by the Olsen method (Iatrou *et al.*, 2014). Exchangeable potassium was determined by flame photometer (Mathieu and Pieltain, 2003). Other macronutrients and trace elements were determined using atomic absorption spectrophotometer and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES).

**Statistical analysis:** The data was analysed by ANOVA and the differences among treatments were compared using Tukey's test.

## RESULTS

**Effect of compost application on physical and chemical characteristics of the soil:** Physical and chemical analyses of soil were performed at 120 days after sowing sugar beet. They are presented in Table 3. Present data showed that the application of compost to soils had no significant effect on soil pH, or on electrical conductivity whatever the dose of compost applied to the soil. However, we found that there is an increase in organic matter in dose dependent-manner although, a significant increase was observed only when the treatment T3 (7.5 t ha$^{-1}$) was applied allowing a gain of 0.5%. Compost increased significantly the Relative Humidity (RH) of the only in T3 (7.5 t ha$^{-1}$) when compared to the control. The results showed that compost increased the nitrogen content in a dose dependent-manner. However, significant differences were observed only for 5 and 7.5 t ha$^{-1}$ (T2 and T3) when compared to the control. This is particularly true for the total nitrogen concentration and mineral forms of nitrogen assimilated by plants ($NO_3^-$ and $NH_4^+$). The compost used in this study also enhanced the soil exchangeable cations, particularly potassium and assimilated phosphorus. This enrichment is proportional to the applied doses of the compost and was significantly different from the control at the three applied doses.

Table 3: Physical and chemical analyses of the soil amended with different concentrations of composts 120 days after sowing

| Parameters | Control | T1 | T2 | T3 |
|---|---|---|---|---|
| pH (water) | 8.2±0.08$^a$ | 8.3±0.08$^a$ | 8.2±0.15$^a$ | 8.2±0.17$^a$ |
| EC (µS cm$^{-1}$) | 300±100$^a$ | 276±29$^a$ | 288±30$^a$ | 287±66$^a$ |
| RH (%) | 20.5±2.44$^b$ | 22.5±2.33$^b$ | 22.5±2.33$^b$ | 32.3±2.94$^a$ |
| Total organic C (%) | 0.74±0.08$^b$ | 0.78±0.08$^b$ | 0.99±0.08$^a$ | 1.01±0.08$^a$ |
| Total organic matter (%) | 1.27±0.108$^b$ | 1.35±0.21$^b$ | 1.43±0.27$^b$ | 1.74±0.21$^a$ |
| Total $N_2$ (%) | 0.079±0.003$^b$ | 0.091±0.006$^{ab}$ | 0.097±0.004$^a$ | 0.104±0.006$^a$ |
| $NH_4^+$ (mg kg$^{-1}$) | 56±1.7$^b$ | 78.5±30.5$^b$ | 169±62$^a$ | 169±62$^a$ |
| $NO_3^-$ (mg kg$^{-1}$) | 54±0.8$^b$ | 72±31$^b$ | 138±16$^a$ | 183±29$^a$ |
| C/N | 9.5 | 8.6 | 10.2 | 9.71 |
| $P_2O_5$ (ppm) | 16±1$^d$ | 25±0.2$^c$ | 30±0.6$^b$ | 39±1.5$^a$ |
| $K_2O$ (ppm) | 148±8$^d$ | 170±7$^c$ | 201±7$^b$ | 248±8$^a$ |

Values are means standard errors (5%). Values followed by the same letter are not significantly different (p<0.05), EC: Electrical conductivity, RH: Relative humidity

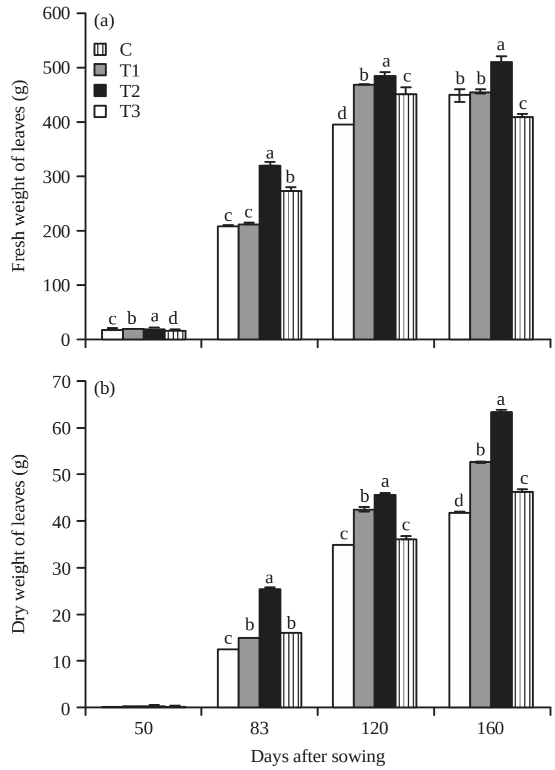


Fig. 1(a-b): Time course analysis of (a) Fresh weight and (b) Dry weight of the leaves after sowing sugar beet on the soil without treatment (C) Amended with different concentration of compost: 2.5 t $ha^{-1}$ (T1), 5 t $ha^{-1}$ (T2) or 7.5 t $ha^{-1}$ (T3). Values are mean and standard errors (5%) of 4 replicates. Data followed with the same letters is not significantly different from the control (p<0.05)

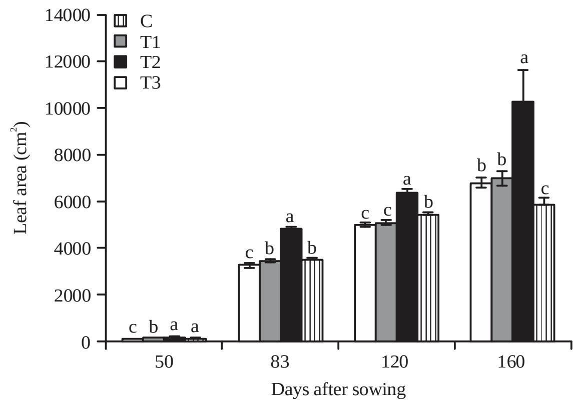


Fig. 2: Time course analysis of leaf area after sowing sugar beet seeds on the soil without treatment (C) Amended with different concentrations of compost: 2.5 t $ha^{-1}$ (T1), 5 t $ha^{-1}$ (T2) or 7.5 t $ha^{-1}$ (T3). Values are mean and standard errors (5%) of 4 replicates. Data followed with the same letters is not significantly different from the control (p<0.05)

**Effect of compost application on sugar beet growth parameters:** The effect of compost on leaf biomass was studied at different stage of growth of sugar beet. Time course analysis of fresh and dry weight of the leaves revealed that with the application of compost, the foliage fresh and dry weights were significantly enhanced (Fig. 1). The T2 (5 t $ha^{-1}$) was the optimal dose in our case for this crop, at which a significant increase was observed at almost all stages of development. The effect of compost on leaf area was also studied. Figure 2 shows that there is an increase in the leaf area with an optimum at the dose T2 during all analysed stages of sugar beet development. A gain of approximately 3500 cm² when compared to the control at 160 days after sowing was observed with T2. However, at elevated dose of compost (T3 = 7.5 t $ha^{-1}$) there was a decrease of the leaf area and it becomes significantly lower than that obtained with the control, at the end of the experiment. This decrease can be explained by the presence of toxic elements or by competition between soil microorganisms toward the plant mineral N availability.

The effect of compost was also studied on root biomass. Similar results as for leaves were observed with roots (Fig. 3).

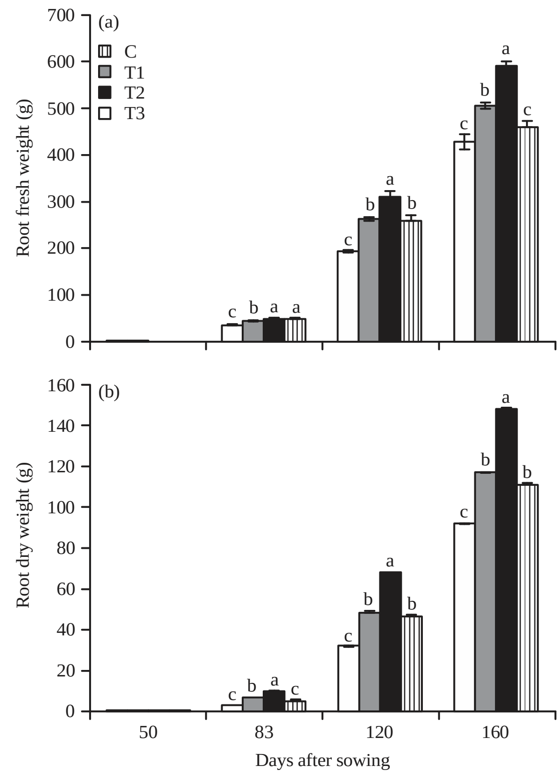


Fig. 3(a-b): Time course analysis of (a) Fresh weight and (b) Dry weight of the roots after sowing sugar beet on the soil without treatment (C) Amended with different concentration of compost: 2.5 t $ha^{-1}$ (T1), 5 t $ha^{-1}$ (T2) or 7.5 t $ha^{-1}$ (T3). Values are mean and standard errors (5%) of 4 replicates. Data followed with the same letters is not significantly different from the control (p<0.05)

Indeed, application of compost increased root fresh weight and root dry weight in dose dependent-manner, with 5 t $ha^{-1}$ being the optimal concentration. Increasing compost concentration to 7.5 t $ha^{-1}$ resulted in lower root biomass.

The ratio leave/root was determined (Table 4). This ratio was significantly higher at the beginning of the experiment and decreased in all the treatment after. With the T2 treatment this ratio was significantly lower than the control at 120 and 160 days after sowing. This inversion means that development of the underground part is higher than the aerial one.

**Effect of compost application on sugar yield and qualitative parameters:** After thinning, we found that the number of plants per meter linear is between 4-5 plants $m^{-1}$ linear which gives an average population of 90,000 plants $ha^{-1}$ in the control. This population was not affected whit the treatment T1 (2.5 t $ha^{-1}$) or T3 (7.5 t $ha^{-1}$). However, the optimum dose T2 (5 t $ha^{-1}$) induced a significant increase (Table 5).

Root yield was also evaluated (Table 5). Application of 5 t $ha^{-1}$ of compost significantly enhanced root yield (1.7 fold-increases), while increasing compost concentration to 7.5 t $ha^{-1}$ enhanced root yield only by 1.4 fold increase.

Sugar beet yield, quality and impurity, e.g. α-amino N, Na and K contents, were also analysed (Table 5). After treatment with 2.5, 5 or 7.5 t $ha^{-1}$ of compost, N, K and Na content in these treatments did not differ significantly from the control. Subsequently, sugar loss was not affected. The results showed also that compost treatment did not affect significantly sucrose concentration, neither sugar recovery nor quality index. However, a significant increase (1.7 fold increase relative to the control) in recoverable sugar yield was obtained when 5 t $h^{-1}$ of compost was applied. This was mainly due to the increase in root yield.

**Effect of compost application on some heavy metals uptake:** The effect of compost on the concentration of Cu, Mn and Zn was analysed in leaves and roots of sugar beet plants at 160 days after sowing (Table 6). The Cu uptake was not significantly affected neither in leaves nor in roots whatever the concentration of the added compost. No significant effect of compost treatment on Mn or on Zn uptake was observed.

## DISCUSSION

This study aimed to study alternative sugar beet production and in particular, to evaluate the effect of three concentration of compost on sugar beet performance. Therefore, soil characteristics, sugar beet growth parameters and sugar yield and quality were determined. In general and for all doses of the applied compost we found that there was an increase in the biomass and leaf area of sugar beet and

Table 4: Effect of various treatment of compost on the ratio fresh weight leaf/root of sugar beet plants at different days after sowing

| | Days after sowing | | | |
|---|---|---|---|---|
| Treatments | 50 | 83 | 120 | 160 |
| Control | 11.5±0.14[a] | 2.75±0.05[b] | 1.02±0.005[a] | 0.53±0.012[a] |
| T1 | 11.1±0.33[a] | 2.88±0.99[b] | 0.89±0.008[b] | 0.45±0.001[b] |
| T2 | 10.6±0.24[b] | 3.14±0.04[a] | 0.78±0.022[c] | 0.43±0.022[b] |
| T3 | 11.6±0,39[b] | 2.72±0.05[b] | 0.88±0.032[b] | 0.45±0.010[b] |

Values are means and standard errors from 4 replicates (5%), values followed by the same letters are not significantly different from the control ($p<0.05$)

Table 5: Effect of various treatment of compost on yield and impurity components of sugar beet plants

| Treatments | Control | T1 | T2 | T3 |
|---|---|---|---|---|
| Number of plants ($ha^{-1}$) | 85536.0±6031[b] | 81429.0±7940[b] | 97500.0±11889[a] | 77679.0±7525[b] |
| Root yield (t $ha^{-1}$) | 42.2±1.9[b] | 51.1±2.1[b] | 70.3±2.4[a] | 59.2±8.1[a] |
| Na content (%) | 3.25±1.06[a] | 2.56±0.88[a] | 3.31±1.16[a] | 4.285±0.55[a] |
| N content (%) | 1.25±0.62[a] | 0.813±0.24[a] | 1.45±0.77[a] | 1.29±0.31[a] |
| K content (%) | 3.54±0.34[a] | 3.70±0.40[a] | 4.06±0.13[a] | 3.85±0.36[a] |
| Sucrose (%) | 18.08±0.40[a] | 16.83±0.41[a] | 18.23±0.72[a] | 16.33±1.85[a] |
| Sugar loss (%) | 2.02±0.38[a] | 1.82±0.18[a] | 2.11±0.44[a] | 1.80±0.18[a] |
| Sugar recovery (%) | 16.06±0.55[a] | 14.20±0.55[b] | 16.12±0.55[a] | 14.53±0.55[b] |
| Recoverable sugar yield (t $ha^{-1}$) | 6.83±0.63[b] | 7.49±0.51[b] | 11.46±1.74[a] | 8.04±1.76[b] |
| Quality index (%) | 92.85±1.55[a] | 93.35±0.90[a] | 92.61±1.36[a] | 91.93±0.11[a] |

Values are means and standard errors from 4 replicates (5%), values followed by the same letters are not significantly different from the control ($p<0.05$)

Table 6: Effect of various treatment of compost on the concentration of some heavy metals in leaves and roots of sugar beet plants

| | Heavy metals | | | | | |
|---|---|---|---|---|---|---|
| | Cu (ppm) | | Mn (ppm) | | Zn (ppm) | |
| Treatments | Leaves | Roots | Leaves | Root | Leaves | Roots |
| Control | 0.16±0.013[a] | 0.15±0.06[a] | 1.3±0.04[b] | 0.49±0.05[a] | 0.38±0.06[a] | 0.40±0.09[a] |
| T1 | 0.16±0.031[a] | 0.13±0.04[a] | 1.4±0.12[b] | 0.43±0.06[a] | 0.35±0.08[a] | 0.35±0.09[a] |
| T2 | 0.16±0.009[a] | 0.12±0.03[a] | 1.3±0.07[b] | 0.48±0.03[a] | 0.36±0.04[a] | 0.48±0.14[a] |
| T3 | 0.14±0.024[a] | 0.12±0.02[a] | 1.1±0.44[b] | 0.43±0.11[a] | 0.34±0.09[a] | 0.52±0.01[a] |

Values are means and standard errors from 4 replicates (5%), values followed by the same letters are not significantly different from the control ($p<0.05$)

sugar yield. However, an optimum increase was observed when 5 t $ha^{-1}$ of compost were applied. This improvement of yield seems to be due to an enrichment of soil nutrients and modification of various physical and chemical parameters of the soil.

The compost used here is a mixture of sewerage sludge, cattle manure, grass and sugar beet leaves and tops. It exhibited an alkaline pH that was not affected by the compost used, whatever the applied dose. These observations are in agreement with those of Wu *et al*. (2000), who reported alkaline pH for composts made with sludge and garden residues. Many other authors reported no effect on pH (Bevacqua and Mellano, 1994; Crecchio *et al*., 2001; Zebarth *et al*., 1999). However, there are several studies that revealed either an increase of acidic soil (Hue, 1992; Whalen *et al*., 2000; Baziramakenga *et al*., 2001; Butler and Muir, 2006; Valarini *et al*., 2009) or a decrease (Chang *et al*., 1991), While increasing pH is clearly valuable in terms of improving microelement availability, lowering pH should be limited to avoid enhancing the solubility of toxic elements. In this study, we did not detect Cd, Ni or Pb and most other heavy metals such as Cr, Zn, Mn, Ba, Sr and Ti were detected at very low concentrations. In addition, we did observe any significant increase in the uptake of Cu, Mn and Zn in roots and leaves of plants cultivated in the presence of increasing concentrations of the compost.

Electrical conductivity, which is directly related to the salt concentration in the soil solution, has been shown to increase with increased compost application rates (Chang *et al*., 1991; Eghball, 2002). In our conditions, EC was not significantly affected whatever, the dose of applied compost. This is an interesting feature because salinity problems could threaten the production of sensitive crops by lowering germination and causing a significant reduction in shoots and root growth. Sugar beet used in this study is sensitive to salinity at the germination stage (Khayamim *et al*., 2014).

Our compost had an initial value C/N ratio of 17.9 and decreased to 9-10. Decrease in C/N indicates that the material was degraded and mineralized. The C/N ratios for composts were similar to that reported by Iniguez *et al*. (2005), C/N ratios of 13.9 and 19.9 for composts with sludge and agave residues. Incorporation of N rich, low C/N ratio residues of fresh plant material, manures or composts leads to rapid mineralization and a large rise in soil mineral nitrogen. Kirchmann (1985) suggests that at a C/N ratio of 15 or less mineralization occurs, above this N will be immobilized.

Other important feature of the compost used is its great contribution to increase the relative humidity then the Water Holding Capacity (WHC) of the soil. An increase in the relative humidity over the control was observed when 5 and 7.5 t $h^{-1}$ were applied, respectively. This is directly related to increase in soil organic matter. Indeed, an increase of 0.5% of the soil organic matter treated as compost increases the soil's ability to retain and store water. These results are comparable to those described by Clapp *et al*. (1986) and Mustin (1987). Increasing the water holding capacity of soils provides more available water to plants and can also help in resistance to drought. Baziramakenga *et al*. (2001), Giusquiani *et al.* (1995) and Hernando *et al*. (1989) have all found increased soil water holding capacity after application of urban wastes. Chang *et al*. (1983) also noted increased hydraulic conductivity. Edwards *et al*. (2000) found that compost made from a mixture of potatoes, sawdust and manure increased soil moisture over untreated soil.

In our conditions the compost had a beneficial effect on the SOM. Enrichment of the soil with organic matter has been reported by several researchers (Mustin, 1987; Houot *et al*., 2002; Francou, 2003). The benefits of increased soil organic matter content in terms of crop yield and nutrient uptake have been demonstrated. McConnell *et al.* (1993) reported that compost applied at rates varying from 18-146 t $ha^{-1}$ produced a 6-163% increase in soil organic matter. It is well documented that different quantities of N, P, K and minor nutrients are removed from and returned to the soil depending on the crop species (Sylvester-Bradley, 1993). The quantity and quality of crop residues will clearly influence the build-up of soil organic matter and the subsequent availability and timing of release of nutrients to following crops. This is particularly true for the total nitrogen concentration and mineral forms of nitrogen assimilated by plants ($NO_3^-$ and $NH_4^+$). In this study, roots, foliage fresh and dry weights were significantly increased with increasing doses of compost and are related to elevated rates of N and K. Recoverable sugar yield was increased significantly when 5 t $ha^{-1}$ of compost was applied. At this concentration the soil exhibited a significant increase in N, K and P when compared to non-amended soil or treated with lower dose. Increasing N and K fertilizers rates significantly increased root yield and quality (Salami and Sadat, 2013). These results appear to be mainly due to the role of N in developing root dimensions by increased cell division and elongation. The positive effect of N fertilizer might be due to the increased efficiency of N-fertilization in building up metabolites translocations from leaves to developing roots, thus increases dry matter accumulation. The increase of root and sugar yield with compost may be attributed to increased size and number of leaves, which led to increasing leaf area and photosynthetic activities. This was reflected in greater root and sugar production per unit area (Malnou *et al.*, 2008).

The results indicate that 5 t $ha^{-1}$of compost treatments not only affected positively crop development, but also sucrose yield. This beneficial effect was reversed with the highest dose of 7.5 t $ha^{-1}$. This could be explained by the increase of the concentration of some trace elements although most of the heavy metals analysed in this study were below the limited concentration authorized and Cu, Zn and Mn uptake were not increased or affected by the added compost.

Therefore, the application of municipal solid waste compost is compatible with good levels of sugar beet yield and quality.

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