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# Use of biofertilizers obtained from sewage sludges on maize yield

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ABSTRACT

Maize production plays an essential role in global food security. In order to maintain both high quality and maize production, there is a great demand for fertilizers. The main objective of this work was to study, over two experimental seasons, the effect of a biofertilizer obtained from sewage sludge (SS) on the yield and on the quality of maize crops (*Zea mays* L.). The biofertilizer was applied in two ways: (i) to soil, at rates of 0, 10 and 20 Mg ha$^{-1}$ before sowing, and (ii) via foliar fertilization, applying 0, 3.6 and 7.2 l ha$^{-1}$ three times during each growing season accounting for a total rate of 0, 10.8 l ha$^{-1}$ and 21.6 l ha$^{-1}$. This study is novel because there are no previous studies of the effect of this biofertilizer on any agricultural crops. The results obtained show that, when the SS was applied directly to the soil, the macro- and micronutrients analyzed in both soil and leaves showed no significant differences between either of the fertilizer treatments. Foliar application of SS, however, increased the leaf concentrations of macro- and micronutrients. When the SS rate was 7.2 l ha$^{-1}$, grain protein concentration increased significantly by about 30% and the yield increased significantly by about 17% compared with the control treatment (SS not applied). These results suggested that, in order to improve agricultural maize yields, quality and nutritional, this SS should be applied as a foliar fertilizer instead of applying it to soil.
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## 1. Introduction

Applying organic matter to agricultural soils is a common practice among farmers due to the fact that it improves the physical, chemical and biological soil properties, as well as supplying plants with nutrients (Aranda et al., 2015; Conti et al., 2014; Manna et al., 2007; Tejada et al., 2014a).

However, for organic matter to provide essential nutrients to the plant, it needs some time to mineralize (Tejada and González, 2003, 2004), so there is a time lag between applying the fertilizer and the plant'suptake of the nutrient applied. This mineralization time is variable and depends mainly on the organic matter's chemical composition, as well as on the soil's physicochemical characteristics, moisture and temperature (Tejada et al., 2014a). Furthermore, the dynamics of plant nutrient uptake is quite complex. On the one hand, it depends on soil properties affecting chemical forms and reactions in soil while on the other, it also depends on the crop's growth stages (Navarro Blaya and Navarro García, 2003). Therefore, a large group of researchers suggest foliar fertilization as a means of overcoming the limitations of soil with regard to nutrient uptake by plants. For a long time, and in order to prevent chlorosis problems (Fernández et al., 2008; Pandey et al., 2013; Zhang et al., 2013), foliar fertilization has-been used to apply micronutrients to peach, green peas and ginseng growing in soils with basic pH. However, in recent years, not only have micronutrients been applied, but also small amounts of macronutrients such as N, P and K, and humic substances have been applied in order to improve the nutritional status of different crops (e.g. roselle, maize and lentil) and to improving their yield (Abbas and Ali, 2011; Çelik et al., 2010; Hamayun et al., 2011). Several studies have shown the importance of foliar fertilization with humic substances. In this regard, it has been found that the use of these substances increased root length, leaf area index. It has also been found that foliar fertilization with humic substances had a stimulating effect upon respiration and photosynthesis in tomato and pepper crops (Yildirim, 2007; Karakurt et al., 2009). All of these positive effects on plants led to a significant increase in the yield of maize and rice crops (Tejada and González, 2003, 2004; Asumadu et al., 2012).

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**Table 1**
Climatic characteristics of the study area for both experimental years.

| | 2013 | | 2014 | |
|---|---|---|---|---|
| | Air temperature (°C) | Rainfall (mm) | Air temperature (°C) | Rainfall (mm) |
| January | 9.0 | 46.7 | 10.7 | 55.5 |
| February | 8.7 | 61.2 | 10.3 | 41.8 |
| March | 11.8 | 132.3 | 12.8 | 16.1 |
| April | 15.0 | 25.4 | 16.9 | 43.2 |
| May | 17.2 | 14.9 | 19.8 | 15.0 |
| June | 22.6 | 4.6 | 22.4 | 17.5 |
| July | 26.7 | 0.5 | 25.1 | 5.1 |
| August | 27.5 | 6.5 | 25.3 | 0 |
| September | 24.6 | 13.2 | 23.0 | 51.8 |
| October | 19.2 | 113.7 | 20.5 | 125 |
| November | 10.6 | 3.0 | 13.9 | 89.2 |
| December | 9.0 | 66.7 | 8.9 | 18.5 |

Furthermore, a large group of researchs also suggests that not only does foliar fertilization improve crop yields, but it also decreases the effects of the groundwater contamination caused by mineral fertilizers applied to soil, especially in the cases of N and P (Tejada and González, 2003, 2004; Çelik et al., 2010; Asumadu et al., 2012).

In recent years, there has been an increase in the use of hydrolysate organic biofertilizers obtained from different organic materials via enzymatic hydrolysis reactions (Romero et al., 2007; Parrado et al., 2008; García-Martínez et al., 2010a,b). These biofertilizers, generally comprising peptides, amino acids, polysaccharides, humic acids, etc. are directly absorbed by soil microorganisms and plants.

At present, these biofertilizers are used for the bioremediation of soils contaminated with pesticides and polycyclic aromatic hydrocarbons (Rodríguez-Morgado et al., 2014; Tejada et al., 2011, 2014b). However, we are not aware of their use in crop production. Therefore, applying these biofertilizers, rich in humic substances and macro- and micro-nutrients, to the soil or via foliar could also be a new alternative use of these novel compounds.

Along with rice (*Oriza sativa* L.) and wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) is one of the world's three most widely-cultivated crops and, from a global perspective, it is probably the most economically important cereal crop (Jones, 2009). For this reason, ascertaining the crop's response to this biofertilizer could be of great interest to the farmer. The main objective of this work, therefore, is to study the effect of a sewage-sludge derived biofertilizer (SS) when it is applied to the soil and via foliar at different doses on both maize yield and grain quality.

## 2. Material and methods

### 2.1. Site and properties of the biofertilizer

The study was conducted over two experimental seasons (April to October in both 2013 and 2014) at Trujillanos, (Extremadura, Spain). Table 1 shows the climatic characteristics of the study area during the experimental period (AEMET, 2015). The total annual rainfall was 489 and 479 mm for 2013 and 2014, respectively. The average mean air temperature was 16.9 and 17.5 °C for 2013 and 2014, respectively.

The main soil (0–25 cm) characteristics are described in Table 2. Soil pH was determined in distilled water with a glass electrode (soil:$H_2O$ ratio 1:2.5). Soil texture was determined by Robinson's pipette method (SSEW, 1982). Total soil organic carbon was measured by the Walkley and Black wet dichromate oxidation method (Nelson and Somers, 1982). Organic matter was obtained by multiplying total soil organic carbon by 1.724. Kjeldahl-N was determined by the MAPA (1986) method. Soil Olsen-P was determined according to the Olsen et al. (1954) method. Available K, Ca and Mg were extracted from the soil with 1 N ammonium acetate, following the indications of Knudsen et al. (1982), and determined by flame atomic absorption spectrometry. Availability index for Fe, Cu, Mn and Zn was determined according to Lindsay and Norvell (1978), by extraction with 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M tetraethyl ammonium, adjusted to pH 7.3. They were determined by atomic absorption spectrometry after extraction.

**Table 2**
Initial soil physico-chemical characteristics (mean ± standard error). Data are the means of three samples.

| | |
|---|---|
| pH (soil:$H_2O$ ratio 1:2.5) | 7.4 ± 0.2 |
| Electric conductivity (soil:$H_2O$ ratio 1:5) (dS $m^{-1}$) | 0.062 ± 0.08 |
| Coarse sand (g $kg^{-1}$) | 409 ± 17 |
| Fine sand (g $kg^{-1}$) | 165 ± 11 |
| Silt (g $kg^{-1}$) | 238 ± 15 |
| Clay (g $kg^{-1}$) | 188 ± 16 |
| Total C (g $kg^{-1}$) | 9.2 ± 1.2 |
| Organic matter (g $kg^{-1}$) | 15.8 ± 2.1 |
| Kjeldahl-N (g $kg^{-1}$) | 0.83 ± 0.11 |
| Olsen P (mg $kg^{-1}$) | 12.1 ± 1.9 |
| Available K (mg $kg^{-1}$) | 91.5 ± 12.1 |
| Available Ca (mg $kg^{-1}$) | 2260 ± 32 |
| Available Mg (mg $kg^{-1}$) | 445 ± 21 |
| Available Fe (mg $kg^{-1}$) | 87.8 ± 13.4 |
| Available Cu (mg $kg^{-1}$) | 5.2 ± 1.6 |
| Available Mn (mg $kg^{-1}$) | 132 ± 18 |
| Available Zn (mg $kg^{-1}$) | 2.2 ± 0.4 |

The biofertilizer utilized in the experiment (SS) was obtained through enzymatic hydrolysis of sewage sludge according to the method described by Rodríguez-Morgado et al. (2015). Its chemical composition is described in Table 3. The product is still not commercial. In fact, this study is focused upon its potential practical application.

Supposedly, its market price would be low because the hydrolytic process is inexpensive and the raw material (sewage sludge) has no cost. The enzyme price for producing 1000 l of sludge hydrolysate is in the region €8 and taking into account other additional costs, the final cost for 1000 l may be around €15.

### 2.2. Experimental layout

For each experimental season, field experiments were under taken, applying the biofertilizer via soil and foliar fertilization. The experimental layouts for each type of application are described below.

#### 2.2.1. Experiment 1: applying biofertilizers to the soil

For each growing season, the experimental field design was in a randomized complete block with three replications in a total of 9 plots. The plots (9 by 5 m) were fertilized as follows:

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