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Soil Characterization for Production of an Industrial Tomato Variety in South Portugal—A Case Study †

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Abstract: Appropriate soil conditions are important for the success of culturing tomatoes. In fact, there are mineral elements that are essential for the good and healthy development of tomatoes, namely, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, and zinc. Additionally, organic matter and pH play important parts in the process. In this context, this study aimed to characterize a soil destined to produce an industrial tomato variety in South Portugal. As such, mineral elements content, pH, electrical conductivity, humidity, organic matter, and color (without humidity and without humidity and organic matter) were analyzed in 16 soil samples before any type of soil preparation was carried out. Through principal components analysis (PCA), it was possible to observe that electrical conductivity and humidity are more correlated with each other than pH and organic matter. However, the pH of soil varied between 6.9 (minimum) and 7.3 (maximum): in accordance with the ideal range values for tomato production. Additionally, regarding quantification of mineral elements, Fe showed a higher content, followed by K, Ca, P, Mg, S, Zn, and As. However, regarding the color of the soil without humidity and without humidity and organic matter, there were significant differences between CieLab parameters (L, Chroma, and Hue). Nevertheless, soil conditions of the field presented good requirements for tomato production, despite the higher levels of Fe in the soil and the presence of As.

Keywords: *Lycopersicum esculentum* L.; tomato productions; soil analyses; soil characterization

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1. Introduction

Conditions of soil are a very important factor in the success of tomatoes culture. This culture grows well on most soils but prefers deep, well-drained, sandy loam soils, which are moderately tolerant regarding pH [1]. Soil chemicals (namely pH) and physical properties can influence water and mineral uptake by plants and therefore can influence the nutritional content of tomatoes [2]. For plant growth, there are twelve mineral elements essentials and most of them come from soil (namely nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, and zinc) [3,4]. Without these essential mineral elements, tomatoes cannot grow properly [3]. Each mineral element varies according to its mobility within the plant and every crop has different needs [3]. For instance, N, P, K, Ca, Mg, and S are needed in large quantities for good crop production, and Fe and Zn are needed in lower quantities. Additionally, if the soil cannot provide adequate amounts of N, P, and K, then there is a need for soil fertilization to lead to good crop production [4]. Additionally, the organic matter of soil is related to crop nutrient composition [5], and pH can affect plant growth and influence different soil properties (namely nutrient absorption) [6]. In addition to organic matter content and pH, the electrical conductivity of soil is related to crop productivity [5–8]. Regarding soil moisture (or the humidity of soil), a study carried out in [9] showed that soil moisture deficiency can affect tomato yield. Additionally, the color of soil is one of the most significant characteristics and can indicate erosion or excess of salinity [10].

2. Materials and Methods

2.1. Experimental Fields

This study focused on the characterization of soil from one experimental field, located in São João de Negrilhos (Aljustrel)—South Portugal (GPS coordinates: 37.948157, −8.173834)—intended to produce an industrial tomato variety (H1534). The location of the field is shown in Figure 1.

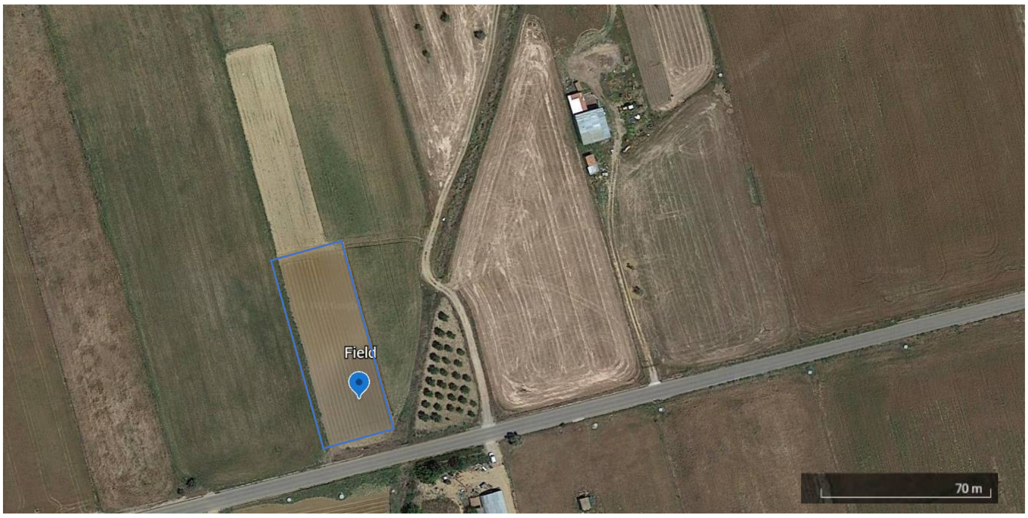


Figure 1. Geographic location of the field (images obtained through Google Earth). Indication (in blue) of the limit of soil sample collection in the field. (Note: when the soil samples were taken, there was no type of plantation in the field. The image shown is for geographic location only and does not correspond to the date of the collection of the soil samples).

2.2. Soil Analysis

In the experimental field (about 750 m^2) intended for tomato production, 16 soil samples (100 g, picked up at 30 cm depth) were collected in a hexagonal grid, for physical and chemical analysis, before any type of soil preparation was carried out. Soil samples were sieved (using a 2.0 mm nylon sieve) to remove stones and other debris before analysis. Mineral content in soils were determined, following [11], using a XRF analyzer (model XL3t 950 He GOLDD+) under helium atmosphere. Additionally, pH and electrical conductivity were carried out following [12], where we determined these parameters in the decanted supernatant of a mixture (ratio 1:2.5 g$_{\text{soil}}$ mL^{-1}$_{\text{water milli-q}}$) for 1 h with tiring (25 °C for 30 min) in a thermal bath. Humidity (also known as soil moisture) and organic matter were carried out following [13]. Colorimetric parameters of soil were carried out after the remotion of humidity and after the remotion of humidity and organic matter, following [14].

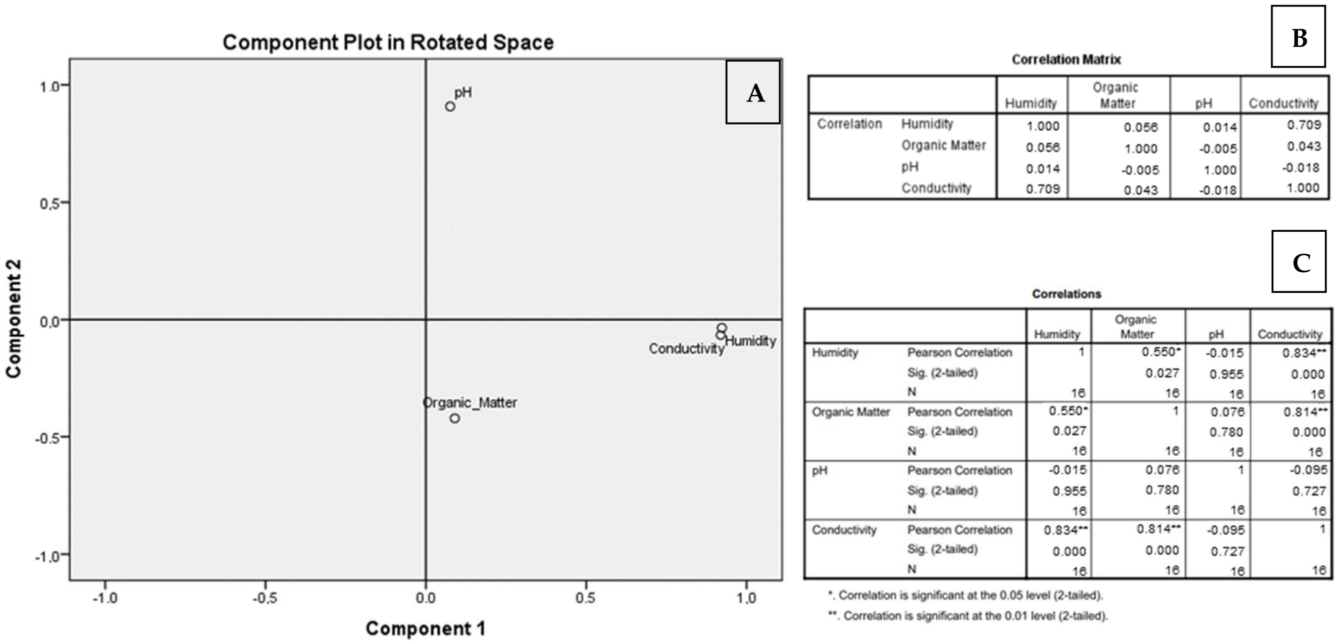
2.3. Statistical Analysis

Data normality and homogeneity of variance was carried out. The principal component analysis was performed on the correlation matrix and the first two components were retained and rotated using a Varimax rotation.

Additionally, data were statistically analyzed using a one-way ANOVA to assess the differences among the different types of soil (without humidity and without humidity and organic matter), followed by Tukey's test for mean comparison. A 95% confidence level was adopted for all tests.

3. Results

Regarding pH, organic matter content, electrical conductivity (named conductivity in Figure 2A), and humidity of soil samples (Figure 2A,B), through principal component analysis (PCA) it was possible to identify that the interrelations among the parameters are explained in the projections of components 1 and 2. Considering the F1/F2 factorial plane (component 1/component 2), there is a greater correlation between electrical conductivity and humidity (Figure 2A) with a correlation matrix of 0.709 (Figure 2B). Additionally, through Pearson's correlation, we can also observe that both parameters have the highest correlation value (0.834) (Figure 2C). Considering the pH and the organic matter, they are close to the origin according to F1 (but not close to the origin in F2), as such, the variability of both parameters is better explained by F2 than by F1. In the organic matter parameter, there is a greater correlation between humidity and conductivity than with pH (Figure 2B,C). The pH is the parameter with the lowest correlation between the remaining parameters analyzed (Figure 2A–C). Additionally, the pH of soil varied between 6.9 (minimum) and 7.3 (maximum) (data not shown).



Correlation Matrix

		Humidity	Organic Matter	pH	Conductivity
Correlation	Humidity	1.000	0.056	0.014	0.709
	Organic Matter	0.056	1.000	-0.005	0.043
	pH	0.014	-0.005	1.000	-0.018
	Conductivity	0.709	0.043	-0.018	1.000

Correlations

		Humidity	Organic Matter	pH	Conductivity
Humidity	Pearson Correlation	1	0.550*	-0.015	0.834**
	Sig. (2-tailed)		0.027	0.955	0.000
	N	16	16	16	16
Organic Matter	Pearson Correlation	0.550*	1	0.076	0.814**
	Sig. (2-tailed)	0.027		0.780	0.000
	N	16	16	16	16
pH	Pearson Correlation	-0.015	0.076	1	-0.095
	Sig. (2-tailed)	0.955	0.780		0.727
	N	16	16	16	16
Conductivity	Pearson Correlation	0.834**	0.814**	-0.095	1
	Sig. (2-tailed)	0.000	0.000	0.727	
	N	16	16	16	16

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 2. (**A**–**C**) Projection of the factorial plane created by the axes component 1 (or F1) (42.9% variance) and component 2 (or F2) (68.0% variance). (**A**) Correlation matrix from ACP analysis; (**B**) and correlation of Pearson; (**C**) pH, organic matter, electrical conductivity, and humidity of soil samples (n = 16).

The mineral content of the soil was assessed (Figure 3A–C) and Fe showed the highest content, followed by K, Ca, P, and Mg. Sulfur, Zn, and As were the mineral elements presented in lower concentrations in the soil samples, with As as a contaminating mineral element.

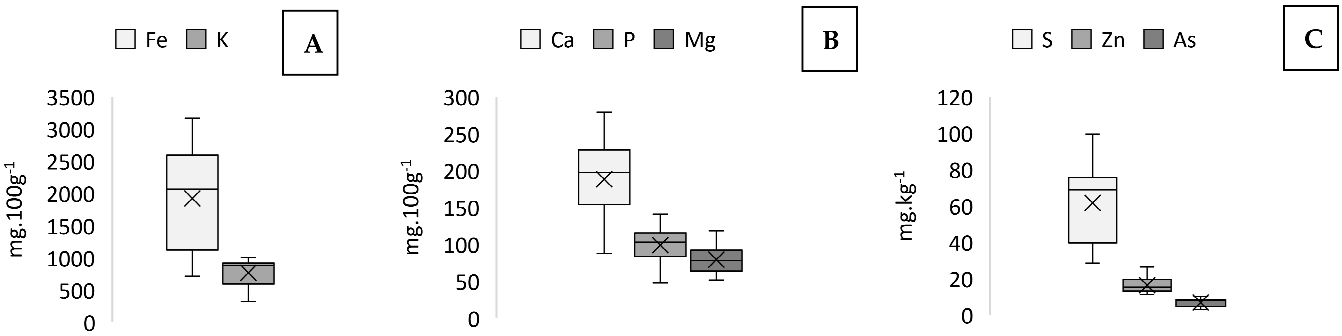


Figure 3. (**A**–**C**) Mean values ± S.E. of mineral content of soil samples (*n* = 16).

Colorimetric parameters were assessed in soil without humidity and without humidity and organic matter (Table 1). L and Chroma showed significantly higher values, and the Hue parameter showed significantly lower content in the soil samples without humidity compared with soil samples without humidity and organic matter.

Table 1. Mean values ± S.E. (*n* = 16) of colorimetric parameters (L, Chroma, and Hue) in soil without humidity and without humidity and organic matter. For each parameter, the different letters express significant differences the different type of soil (a,b).

Soil	L	Chroma	Hue
Without humidity	40.5 a ± 0.26	15.1 b ± 0.21	71.7 a ± 0.41
Without humidity and organic matter	39.4 b ± 0.43	24.1 a ± 0.25	49.5 b ± 0.56

4. Discussion

Considering the importance of soil chemical and physical properties that can affect water and mineral uptake by plants [2], soil chemical characteristics were assessed. Regarding pH, organic matter content, electrical conductivity, and humidity (or moisture) of soil samples (Figure 2), it was possible to identify that they correlated differently. In fact, electrical conductivity and humidity showed a greater correlation between each other. This correlation can be due to electrical conductivity being influenced by different properties—namely, clay content and soil water content [15]—since the range of values was very different between both parameters (humidity showed values between 10 and 19.8% and electrical conductivity varied between 134 and 244 µS.cm^{-1}—data not shown). Additionally, tomato plants are moderately sensitive to soil salts [16] and the values obtained for electrical conductivity of soil showed much lower values than the threshold of tolerance of tomato crops [17], indicating suitability for tomatoes production. Additionally, the pH of the soil is in accordance with the ideal range for tomatoes production [1]. Regarding macro and micro elements of soil, Fe showed a higher content, followed by K, Ca, P, Mg, S, Zn, and As (Figure 3). For instance, despite Fe being needed in fewer quantities for good crop production [4], the high content obtained in the soil—mapped as Luvisol (WRSDB, 2009) with the code "Pag"—is due to the pedogenesis that occurred on sands and gravels with reddish-brown clayey intercalations, containing abundant ferruginous pisoliths and ferromanganese and limonitic impregnations and crusts, of the Plio-Pleistocene (PQ) and Miocene (M) geological units [18]. As such, the color of the soil without humidity and without humidity and organic matter were red, being associated with Fe oxides [19] and in accordance with the abundance of Fe of soil in our study (Figure 3A). Soil color reflects Fe oxide composition and content. Additionally, a higher Chroma parameter can correlate to Fe oxide content [20]; it was observed in our data (Table 1) that, after the removal of organic matter,), there was an increase in Chroma, which is related to a higher Fe content inthe remaining mineral part. In fact, the color of soil is one of the most significant characteristics, being an indicator of soil formation [10], and can be used to describe soil profiles [19]. According to [4], our data showed higher content of P, K, Mg, and Ca in soil considering the desirable levels of nutrients for tomatoes production. Potassium, K, and Ca are absorbed by tomatoes in large amounts and a higher content of Mg can lead to an increase the tomato fruit production [4]. Regarding the contaminating mineral element (As), the content obtained was below the critical limits for a pH higher than 7.0 [21].

5. Conclusions

The soil samples collected in the experimental field located in São João de Negrilhos (Aljustrel) exhibited different interrelations between pH, organic matter content, electrical conductivity, and humidity (or moisture). A higher correlation was observed between electrical conductivity and humidity probably due to electrical conductivity being influenced by different properties, namely soil water content. The pH was in accordance with the ideal range for tomato production. Overall, soil conditions of the field presented good requirements for tomato production, despite the higher levels of Fe (due to the geological substratum) and the presence of As that were below the critical limits for the pH of the field.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/IOCAG2022-12226/s1.

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