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Comparison of Soils of Two Fields for Potato Production Located in the Same Region of Portugal †

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Abstract: Soil is considered a highly complex ecosystem, providing food and maintaining crop and animal productivities. Soil variability can affect plant production. Accordingly, this study aimed to compare soil chemical characteristics from two different locations in the same region of western Portugal (Lourinhã), intended for potato production. Soil was collected and analyzed for soil chemical properties (pH, electric conductivity, organic matter, and mineral element content). Through a principal components analysis (PCA), it was possible to identify that the interrelations among the mineral elements were explained in the projections of components one and two for both fields. Regarding Field A, Ca, K, Fe, P, S, Mg, As, Pb, and Zn are more correlated with each other than the other mineral element (Cd). On the other hand, in Field B, all the mineral elements correlate differently compared to Field A (except Cd), and show that K, As, Mg, Ca, Zn, Fe, and Pb are the most correlated with each other. Additionally, Fe and S are more correlated in Field A; however, in Field B, Fe and Zn are the ones that are more correlated with each other. Additionally, although both soils have the same pH (slightly basic soil—ideal for agriculture), they show a significantly different content of organic matter and conductivity, where Field B presents higher contents of both parameters. The obtained data are discussed, concluding that the soils, despite being geographically close, have different relationships between elements and different contents of organic matter and electrical conductivity, which may lead to differences in potato production.

Keywords: agricultural soils; principal component analysis; soil analyses; soil characterization

1. Introduction

In plants, soil is the primary source of their production, and it has been recognized that its physical conditions can affect crop production [1]. Soil is considered not only a highly complex ecosystem, but also a valuable resource, providing food and maintaining crop and animal productivities. Additionally, in soil, nutrient contents are a fertility indicator [2], and their variability can affect plant production, namely in the potato [3]. Potato is the third most important non-grain food crop worldwide [4], playing a huge part in the human diet by supplying different minerals required by the human body [5]. However, considering that in the potato plant the mineral element uptake occurs primarily through soil solution, if soils where crops are cultivated were to have a low fertility, it could contribute to a low mineral plant content due to the poor uptake and translocation of some mineral elements to the edible parts [5]. Potato production is dependent of certain nutrients from the soil, namely N, P, K, Ca, Mg, S, Fe, and Zn [6]. In addition, according to [7], the organic matter of soil is significantly related to crop nutrient composition, indicating that more organic matter can lead to a higher nutrient content in the crop. Additionally, soil pH can affect plant growth and influence several soil chemical, physical, and biological properties, namely nutrient absorption [8]. As such, organic matter and the pH of soil are widely used as indicators in monitoring fields used for crop production [9]. Electrical conductivity (EC), according to [10], can be used as a precision farming diagnostic tool, and is considered an integrated measure of several soil properties (namely salinity, clay, and water content) being (as organic matter and pH) related to crop productivity. For instance, sandy fields have a low electrical conductivity, silts have intermediate EC, and clays have high EC [11]. Nevertheless, it is important to understand soil chemical composition and its variations to managing soil utilization, since there is a greater demand for details about the distribution of soil properties [12]. Additionally, different geological location of soils and different topography makes it difficult to establish a relationship, due to the influence of topography on the movement of soil material, making this relationship site-specific [12]. In this context, this study aimed to compare soil chemical properties (pH, electrical conductivity, organic matter, and mineral element content relationship) from two different locations in the same region of Portugal (Lourinhã) intended for potato production.

2. Materials and Methods

2.1. Experimental Fields

This study focused on two experimental fields located in the same region of western Portugal (Lourinhã) (GPS coordinates: 39°16′38,816″ N; 9°15′9128″ W (Field A) and 39°16′12,576″ N; 9°14′14,492″ W (Field B)), intended for potato (*Solanum tuberosum* L.) production. The locations of both fields are shown in Figure 1.

Figure 1. Geographic location of the two fields (Field A and Field B) (images obtained through Google Earth). Indication (in blue) of the limits of soil sample collection in the fields. (Note: when the soil samples were taken, there was no type of plantation in the two fields. The images shown are for geographic location only—they do not correspond to the date of collection of soil samples).

2.2. Mineral Content, pH, Organic Matter, and Electrical Conductivity in Soils

In the experimental fields (intended for potato production), 9 soil samples of each field (100 g, picked up at 30 cm depth) were collected in a hexagonal grid, for physical and chemical analyses. Soil samples were sieved (using a 2.0 mm nylon sieve) to remove stones and other debris before analysis. Mineral content in soils was determined, following [13], using an XRF analyzer (model XL3t 950 He GOLDD+) under helium atmosphere before the implementation of potato culture. Additionally, pH and electrical conductivity were measured following [14] 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. Organic matter analysis was carried out following [15].

2.3. Statistical Analysis

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

Additionally, data were statistically analyzed using a One-Way ANOVA to assess differences among the different fields, followed by a Tukey's test for mean comparison. A 95% confidence level was adopted for all tests.

3. Results

Regarding the macro- and microelements of soil samples of both fields (Figures 2 and 3), through a principal component analysis (PCA) it was possible to identify that for both fields, the interrelations among mineral elements were explained in the projections of components one and two (F1 and F2). In Field A (Figure 2), Ca, K, Fe, P, S, Mg, As, Pb, and Zn were more correlated with each other than the other mineral element (Cd). Additionally, considering the factorial plane F1/F2, there was a cluster in the positive F1, presenting the most variables that were closely related (Ca, K, P, Fe, S, Mg, and As). Regarding Zn, it was found close to the origin according to F1 (but not close to the origin according to F2), verifying that its variability was better explained by F2 than F1. Additionally, Cd presented an antagonistic behavior with all other mineral elements analyzed confirmed through a Pearson correlation test (data not shown). Additionally, Fe and S were the pair that were the most related to each other (showing a correlation matrix of 0.934 (data not shown)), followed by the pair S and As with a correlation matrix of 0.866 (data not shown).

Considering Field B (Figure 3), except for the Cd trend, all other mineral elements correlated differently compared with Field A, and showed that K, As, Mg, Ca, Zn, Fe, and Pb were the most correlated with each other. Yet, considering the factorial plane F1/F2, there was two clusters in positive F1, one with K, Mg, and As, and another with Zn, Fe, and Pb, indicating that these mineral elements (in each cluster) were closely related. Regarding Cd, it presented an antagonistic behavior with several other mineral elements analyzed (with the exception of P and S), confirmed through a Pearson correlation test (data not shown).Additionally, regarding P, it also presented an antagonistic behavior with all other mineral elements (apart from Cd), presenting negative values in relation to other minerals (except Cd) through the Pearson correlation test (data not shown). Additionally, Fe and Zn were the pair that were most related to each other (showing a correlation matrix of 0.914—data not shown), followed by the pair As and Mg with a correlation matrix of 0.882 (data not shown).

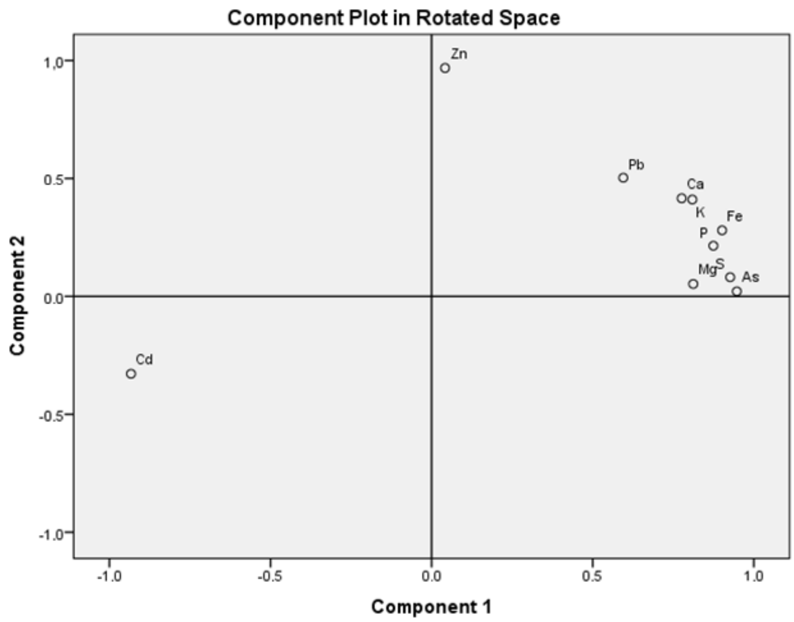

Figure 2. Projection of the factorial plane created with F1 (71.4% variance) and F2 (11.2% variance) axes of the macro and microelements of soil samples (n = 9) of Field A. (Observation: Eigenvalues are greater than 1 only in F1 and F2).

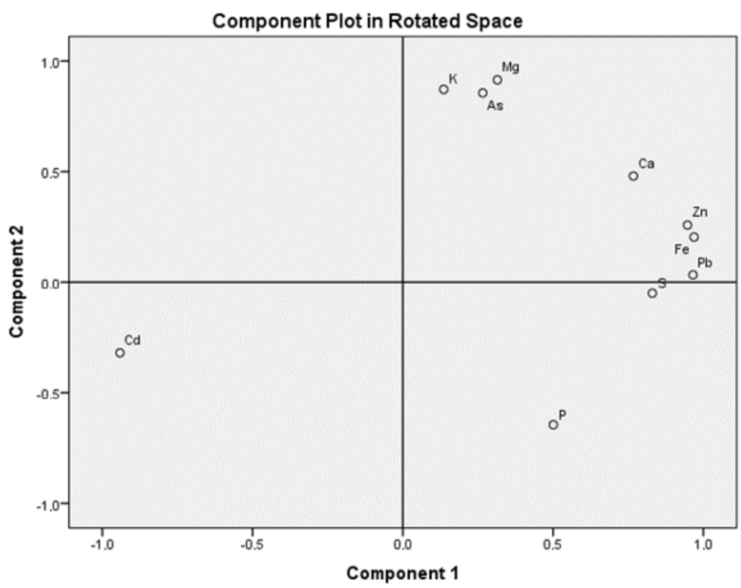

Figure 3. Projection of the factorial plane created with F1 (60.7% variance) and F2 (25.0% variance) axes of the macro and microelements of soil samples (n = 9) of Field B. (Observation: Eigenvalues are greater than 1 only in F1 and F2).

In both fields, the pH was the same, with an average of 7.4 (pH of 7.4 ± 0.03 for Field A and 7.4 ± 0.05 for Field B). However, regarding organic matter and the electrical conductivity of the soil (Figure 4), there were significant differences between the two fields. In fact, Field B showed higher values in both parameters compared with Field A.

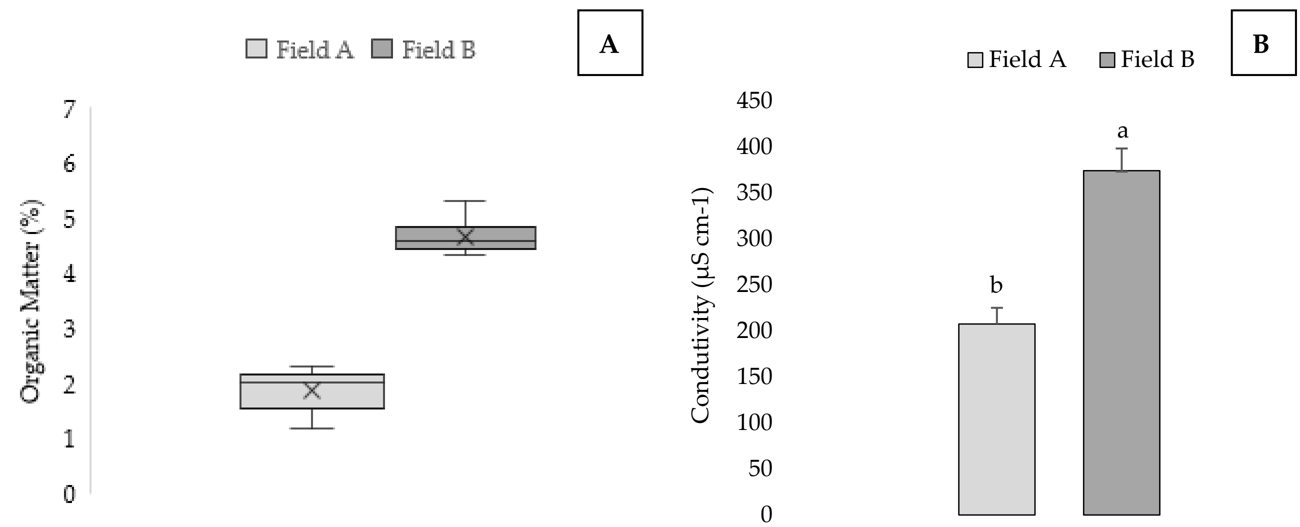

Figure 4. (**A**,**B**) Organic matter content (%) (**A**) and soil electrical conductivity (µS cm^{-1}) (**B**) of soil of both fields (Field A and Field B). Different letters after (a, b) express significant differences between Field A and Field B in condutivity.

4. Discussion

Soil is a primary aspect of crop production and a source of minerals, which accumulate in the edible parts [1,5]. As such, soil chemical characteristics from two different locations in the same region were compared. Regarding the mineral content, when comparing both fields—Field A (Figure 2) and Field B (Figure 3)—it was possible to identify that, despite Cd, all the remaining mineral elements that were analyzed correlated differently. These different correlations between minerals found in soil in the same region were probably due to a soil nutrient content variability [3] that can occur presumably due to the influence of topography in the movement of soil materials [12]. In fact, Field A presented a higher percentage in slope class of 0–5%, corresponding to low surface drainage (data not shown), and Field B in the slope class of 5–30%, corresponding to moderate surface drainage (data not shown). Nevertheless, the different correlations between the mineral elements were probably due to the different topography of the fields and location in different geological substrate according to the Geological Map of Portugal.: Field A is located in sheet 30A (Lourinhã) [16] and Field B in sheet 30B (Bombarral) [17]. Regarding Field A, it is on J^3Ca unit (Castelhanos marls and sandstones—Kimmeridgian) being predominantly composed of fine to coarse quartz sandstones with frequent calcareous clays [16]. Field B is on J^3C (Abadia beds—Kimmeridgian) being constituted by marls and thin intercalations of marly limestones, with ferruginous and limonitic concretions [17]. Additionally, for potato production, this crop prefers a fertile soil with higher organic matter [3]. Nevertheless, it is interesting to see that in Field A, S had a higher correlation matrix with other mineral elements (namely Fe and As) and in Field B, Fe had a higher correlation matrix with Zn, followed by Mg and As. Regarding both fields, this elements showed a higher correlation with As (contaminating mineral element), yet the contents obtained were below the critical limits for pH > 7.0 [18]. Considering the pH of both soils (7.4) being slightly alkaline, it was within the ideal range for agriculture (6.5–7.5) [19]. In fact, despite potatoes being tolerant regarding pH, this range is optimal for nutrient availability to plants [20]. According to a study carried out by [10], it was reported that well-drained soils (summit soils) had a lower electrical conductivity compared to the poorly drained soils (with lower slopes). However, our data disagree with the ones reported by [10], and it is important to mention that electrical conductivity is influenced by a combination of physical and chemical properties (namely soluble salts, clay content, soil water content, and organic matter) [21]. In addition, it is also important to say that Field B had a higher chance of soil salinization because the accumulation of salt (in irrigated agricultural soils) can lead to the loss of stands, reducing plant growth and yield [21]. Thus, in potato production, it is important to choose salt-tolerant varieties [22].

5. Conclusions

Through the comparison of the soils of two fields intended for potato production in the same region of Portugal, it was possible to verify that, despite being geographically close, they showed different relationships between mineral elements, organic matter content, and soil electrical conductivity. Additionally, despite Field A showing a lower organic matter content and the different correlations between mineral elements compared to Field B, due to the lower electrical conductivity, it presented as a field with greater potential for potato production. However, it needs to be fertilized with organic matter. Regarding Field B, it also could be used for potato production; however, it needs a variety of potatoes with greater tolerance to salt, considering the high electrical conductivity presented in the soil. In conclusion, both fields may present differences in potato production due to the differences verified in this study. Additionally, if the correction of organic matter is not carried out in Field A, apparently, Field B (despite a greater organic matter), due to its greater electrical conductivity, could lead to a greater loss of productivity.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/IOCAG2022-12184/s1.

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