

The Influences of Physico-Chemical Parameters of Soil Due to The Availability Soil's Ions.

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ABSTRACT

The chemical quality of the soil is related to the levels of chemical constituents such as mineral salts, and depends on its physical parameters. This study investigates the effect of physical and chemical factors of a soil on the availability of Na⁺, K⁺, Cl⁻, SO₄⁻², NO₃⁻³ ions. The analyzed soil samples, taken at a depth of 40 cm, revealed that the pH is neutral (pH = 6.73±0.50). The ion contents of SO₄⁻² and NO₃⁻³ are high, with values of 1123.02±785.87mg/l and 1123.02±13.98 mg/l respectively; these two parameters are negatively correlated with the rate of clays. A positive and significant correlation between the calcium carbonate CaCO₃, the chloride ion Cl⁻ and the nitrate ion NO₃⁻³ indicates that the higher the content of the calcium carbonate CaCO₃ in the soil, the more Cl⁻ and NO₃⁻³ are available. An organic matter rate of 2.43±1.35% is recorded, which better maintains the activity of microbial biomass. The organic matter positively influences K⁺ levels (r=0.58**) and negatively SO₄⁻² (r=-0.38*), however, the positive relationship between CEC and mineral elements makes it possible to adjust its positive soil fertilization strategy (especially for K⁺). The analysis of ACC canonical correspondences reflects the essential effect of the physico-chemical parameters of the soil on the availability of these ions. The cations and anions present in the soil are mainly controlled by their diversity and precipitation, which affect their absorption in the soil. The results were significant to see that there is a complexity between the physicochemical parameters of the soil and the availability of ions.

Keywords: Availability, Anions, ACC, Soil physico-chemical factors, Tiaret.

1.Introduction

Soil is a natural resource that supports plant growth, and it is a living and fragile environment, which is home to intense biological and physico-chemical exchanges and transformations. It is a biological and geochemical interface that is crucial in maintaining the functioning of ecosystems (Heineman, K.D *et al.*,2016). And is a very

complex heterogeneous medium, which consists of solid phases (the soil matrix) containing minerals and organic matter and fluid phases (the soil water and the soil air), which interact with each other and ions entering the soil system (Moghaddasi, S., 2017). Understanding soil biogeochemistry is essential for stewardship of ecosystem services provided by soils, such as soil fertility (for food, fibre and fuel production), water quality (Rumpel, C. *et al.*, 2014).

The diversity and availability of nutrients in the environment influence the interaction, distribution, abundance, diversity, local composition, and individual performance of plants. (Fujii, K.; *et a.l.*, 2018, Ushio, M *et al.*, 2017). A discussion of ion availability in soils of natural fertility is resolved primarily in an examination of soil factors (De Araújo, V.B.F *et al.*, 2019).

Minerals are ubiquitous in soil, as they are in most other natural environments. They are considered, along with organic matter, as fundamental constituents, the physical, chemical and biological properties of soils being directly related to their quantity and elemental properties. Because of their small size, minerals exhibit significant chemical reactivity that makes them sensitive to variations in environmental biogeochemical conditions (Jones AA & Bennett PC., 2017).

There is a fairly large variety of mineral constituents in ionic form in soils, the base ions are: Ca^{2+} , Mg^{2+} , K^+ , Na^+ , Cl^- . Several other cations and ions exist in the soil; some are trace elements and others have no effect on the soil but, they are present in the solution (water) of the soil such as nitrates and sulfates ... etc. It is a question of satisfying the needs of the crop according to the objectives of production and quality of the products harvested (Valé., 2006), Natural geo-materials (clays, soils, rocks) are highly heterogeneous materials. These heterogeneities come from a variable mineralogical assembly within the material, with grains having a polydisperse size, an irregular shape, and a different chemistry. These heterogeneities greatly influence the behaviour of soil physicochemical parameters such as organic matter and hydrogen potential (Poirier., 2019). The objective of the work is to study the effect of physical and chemical factors of a soil on the availability of Na^+ , K^+ , Cl^- , SO_4^{-2} , NO_3^- ions in the agricultural plot of the experimental farm of the University of Tiaret, as a sample of this theme.

2. Methods and Materials

The sampling was carried out in the plot of land of the experimental farm of the University of Tiaret (city of Tiaret), on an area of 26 Ha (figure N°1). Of these, Soil samples were collected in the experimental farm of the University of Tiaret. Overall, 10 sampling points, depth of 10 cm) identified from a mesh (Figure 1). The sampling points are placed at the intersection of the grid cells, according to a territorial grid of 200 m × 200 m.

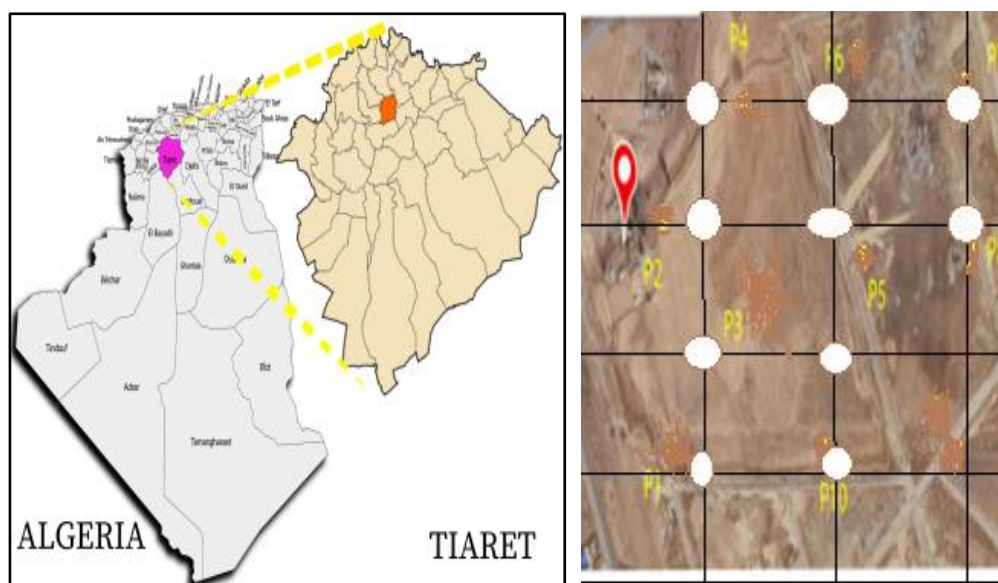


Figure 1: Representative map of sampling points in each municipality.

2.1 Preparation of soil samples for physicochemical analyses

In the laboratory, soil samples are subjected to different treatments: The particle size analyses were carried out by the Robinson method, using 20 g of fine soil and 50 ml of Calgon's solution (39.2 g of sodium metaphosphate NaPO_3 plus 10 g of sodium carbonate Na_2CO_3 per litre of distilled water). Soil texture calculations are made using the texture triangle.

The pH was measured by a pH meter, on 20g of the soil of each sample, however, the determination of organic matter is carried out by the Walkley-Black method. $\text{CaCO}_3\%$ is determined by the Bernard calcimeter, in contrast, CEC is measured by soil percolation with Ammonium Acetate solution (Wich et al; 2016). Organic carbon is oxidized by potassium dichromate in sulfuric medium with Mohr's solution (Najib et al; 2021). The determination of Na^+ , K^+ , Cl^- , SO_4^{2-} , NO_3^- ions is carried out by the mixed gas chromatography apparatus to be analyzed through a selected substrate. It consists in doing the extraction by soxhlet. Filling the soxhlet cartridge with 10g of soil with 10g of sodium sulphate, place a cotton buffer over the sample and extract 70/70 mixture of acetone and diethylether (140 ml) for 4 hours. The samples are then concentrated by a rotary evaporator always at 40 °C after placing in the CPG device.

2.2 Statistical analysis methods

The data collected from this study were processed by Statistica software version 12 (descriptive statistics and correlation matrix), and canonical analysis of correspondences CCA was carried out by Xlsat software version 2019.2.2.

3. Results

3.1 Presentation of results in the form of descriptive statistics

For each parameter, the calculation of 30 samples is given in Table 01.

Table 1: Descriptive statistics of soil physico-chemical parameters and mineral elements determined

	N	Mean	Min	Max	Std.Dev.
Na ⁺ (mg/l)	30	836,28	236,19	1953,50	498,73
K ⁺ (mg/l)	30	115,93	14,99	365,87	106,46
Cl ⁻ (mg/l)	30	4624,63	235,27	9284,72	2786,14
SO ₄ ⁻² (mg/l)	30	1123,02	535,87	3317,06	785,87
NO ₃ ⁻ (mg/l)	30	22,17	1,04	52,63	13,98
pH	30	6,73	5,85	7,83	0,50
CaCO ₃ %	30	9,90	5,27	18,13	3,72
Organic Matter %	30	2,43	0,75	6,11	1,35
Clay%	30	32,30	2,98	86,57	25,84
Sand%	30	6,79	3,26	20,74	4,70
Salinity Rate ms/s	30	1728,56	1118,00	2556,00	456,19
CEC	30	300,66	91,00	546,00	145,17

For the case of mineral elements, the reading of Table 01 shows that the concentrations of SO₄⁻² and NO₃⁻ ions are high, with values that are respectively: 1123.02±785.87 and 1123.02±13.98. The pH is slightly neutral; however, we observe a poverty of soil organic matter (2.43±1.35%) We also have a high rate of clays.

3.2 Effect of soil physico-chemical parameters on ion availability: Na⁺, K⁺, Cl⁻, SO₄⁻², NO₃⁻

The main goal of this approach is to highlight the explanatory variables, which are the physico-chemical parameters of the soil, the most strongly correlated with the dependent variables, which ions: Na⁺, K⁺, Cl⁻, SO₄⁻², NO₃⁻. The principle of this correlation matrix method is to introduce the study of the effect of these parameters on the availability of the ions in question. The result of this matrix is illustrated in Table 2.

Table 2: Correlation matrix between soil physico-chemical parameters of ion availability: Na⁺, K⁺, Cl⁻, SO₄⁻², NO₃⁻

	Na+	K+	Cl-	SO ₄ ⁻²	NO ₃ ⁻	pH	CaCO ₃	OM	Clay	Sand	Salinity rate	CEC
Na+	1,00	0,44	0,61	0,70	-0,23	0,22	0,19	0,17	0,11	-	0,03	0,20
K+	0,44	1,00	0,14	-0,06	0,01	0,58	0,15	0,58	0,45	-	-0,08	0,35
Cl-	0,61	0,14	1,00	0,63	-0,12	0,16	0,41	-0,13	-0,11	-	0,33	0,09

SO ₄ ⁻²	0,70	-0,06	0,63	1,00	-0,56	0,23	-0,26	0,38	-0,45	-	0,35	0,17
NO ₃ ⁻	-	0,01	-	-0,56	1,00	-	0,52	0,12	-0,51	-	0,26	0,14
Ph	0,22	0,58	0,16	0,23	-0,28	1,00	-0,12	0,22	0,01	-	-0,37	0,26
CaCO ₃	0,19	0,15	0,41	-0,26	0,52	-0,12	1,00	0,14	0,56	-	0,33	0,30
OM	0,17	0,58	-	0,38	0,12	0,22	0,14	1,00	0,15	0,1	-0,03	-0,51
Clay	0,11	0,45	-	-0,45	-0,51	0,01	0,56	0,15	1,00	0,0	0,74	0,56
Sand	-	-0,29	-	-0,27	-0,29	-0,34	-0,30	0,16	0,01	1,0	0,45	-0,17
Salinity rate	0,03	-0,08	0,33	0,35	0,26	-0,37	0,33	-0,03	0,74	0,45	1,00	0,34
CEC	0,20	0,35	0,09	0,17	0,14	0,26	0,30	-0,51	0,56	-	0,34	1,00

3.3 Relationship: physico-chemical parameters of the soil - the availability of mineral elements: Na⁺, K⁺, Cl⁻, SO₄⁻², NO₃⁻

In order to study the physico-chemical parameter effect of the soil on the availability of mineral elements: Na⁺, K⁺, Cl⁻, SO₄⁻², NO₃⁻; we performed a canonical analysis of correspondences ACC, taking these parameters into account for sampling dislocations. The result of this ACC is illustrated in **Figure 2**. The graphical representation of this analysis makes it possible to simultaneously visualize the objects (physico-chemical parameters of the soil), the sampling points, and the variables (soil ions).

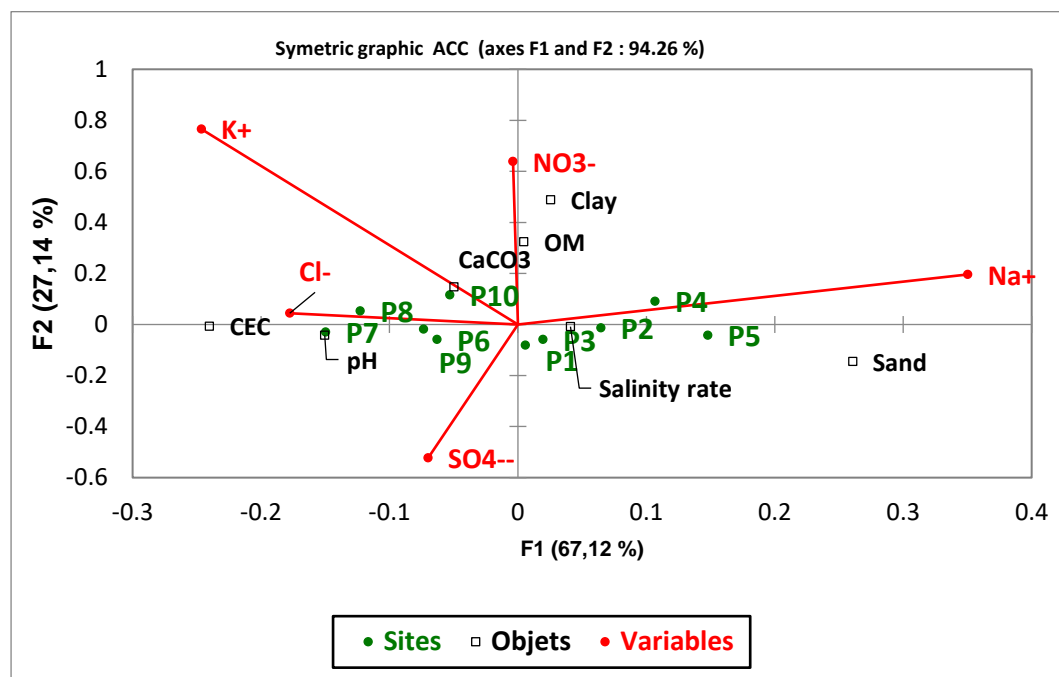


Figure 2: Relationship: physico-chemical parameters of the soil - the availability of mineral elements: Na^+ , K^+ , Cl^- , SO_4^{2-} , NO_3^- by Canonical Correspondence Analysis (CCA)

4. Discussion

In semi-arid environments, soil profiles are commonly saline or sodium, where salt has accumulated due to the low permeability of the sodium subsoil. Salinity is a major problem affecting crop production all over the world: 20% of cultivated land in the world, and 33% of irrigated land, are salt-affected and degraded (Machado, R. M. A., & Serralheiro, R, 2017). CaCO_3 values are average. According to Bradai, A *et al.*, (2019) scale, the high salinity rate value (1728.56 ± 456.19) indicates that the soil of this experimental farm is Sally.

The analysis of this matrix (Tab 2) shows that:

1. No significant effect of pH of ion availability, this explains the absent effect of neutral pH on the release of these elements into the soil; however, an acidic pH-OH protonates which attracts anions such as sulfate and chloride and nitrate. On the contrary, at a basic pH-OH groups tend to deprotonate, thus attracting cations (Dong *et al.*, 2022).
2. A positive and significant correlation between CaCO_3 and Cl^- and nitrates NO_3^- : the higher the CaCO_3 content in the soil, the more Cl^- and NO_3^- are available. Organic chlorine generally represents 80% of total soil chlorine (Le Dizès et Gonze, 2019); In reality, it appears that some of the organic chlorine is resistant to dehalogenation and accumulates in the soil. For this, the higher the limestone content of the soils, the higher the organic chlorine content. A positive and significant correlation ($r=0.52$) was recorded between nitrates and CaCO_3 .
3. The presence of organic matter in the soil influences positively the contents of K^+ ($r=0.58^{**}$) and negatively on SO_4^{2-} ($r=-0.38^*$). The mineralization of organic matter is rapid under the coupled actions of various types of bacteria, which allows the release of mineral substances such as carbon dioxide, nitric nitrogen, phosphate ions and sulfate. N is first released in reduced form (ammonium NH_4^+), then it can be oxidized in the presence of oxygen in the form of nitrite (NO_2^-) and nitrate (NO_3^-) by autotrophic bacteria, during nitrification. Sulphur is mineralized as sulphate (SO_4^{2-}) in the presence of oxygen (Wang *et al.*, 2019).
4. selective sorption and fixation of K and similar cations by clay minerals and soil clays and the mechanisms of these reactions are reviewed. In particular, recent observations on selective sorption of these ions in dilute solutions by weathered micas and vermiculite in relation to the interlayer structures are discussed in detail. Also, implications of the resistance to weathering of small mica particles to cation selectivity by soils are described (Bisoi, S., & Haldar, S., 2014).
1. A negative and significant correlation between anions (SO_4^{2-} , NO_3^-) and clay content. In clay soil, these anions are much more available from another type of

soil. Anions such as sulfates and nitrates in aqueous solution can be adsorbed by clay smectites if they can form positively charged coordination species (Johnson *et al.*, 2018).

5. The negative correlation between soil sand and mineral elements Permeability does not allow it to retain essential minerals, which gives it a low ion exchange capacity that depends on the rate and nature of soil colloids, which requires the application of organic matter to this type of soil in order to increase the ion exchange capacity of these soils (Tale & Ingole., 2015).
6. Electrical conductivity in a particulate medium usually occurs through the movement of ions through water from the electrolyte pores into vacuum and surface charge. Electrical conductivity increases with salinity rate; the latter is positively correlated with the ions of NO_3^- , SO_4^{2-} and Cl^- . The mineral salts present in the soil, in ionic form, are the main transporters of the electric current compared to the organic matter which conducts little (Tessler *et al.*, 2009).
7. Cation exchange capacity (CEC) measures the amount of cationic charges of the clay-humic complex. It reflects the capacity of the soil to retain these loads. The positive relationship between the CEC and the soil ions (which is significant) makes it possible to adjust its fertilization strategy (especially for K): the smaller the CEC, the less the soil will have the capacity to retain the elements brought and the more it will be necessary to split the inputs (Julien & Tessier., 2021).

The graph of the Canonical Correspondence Analysis CCA (Figure 2) indicates that two dimensions are open to interpretation:

- **F1** which represents 67.12%-point cloud (66% information can be explained in this dimension).
- **F2** which represents 27.14% of point clouds can be explained in this axis.
 - On the **F1** side on the positive side, we can see that for Sand and salinity rate objects are associated with a high content of Na^+ . it appears that the P1, P2, P3, P4 and P5 sampling points are saline lands. However, exchangeable sodium content is highly significantly influenced by organic matter, which increases as organic matter increases (Feller *et al.*, 2022).
 - In the negative side of the **F1** plane, a correspondence between the CEC, the Cl^- and the K^+ especially (result confirmed by the significant positive relationship between the K^+ and the CEC: ($r = 0.35$)).
 - On the **F2** side, on the positive side, NO_3^- seems to be more sensitive to the parameters of limestone, organic matter and clays. The mineralization of organic matter, it is rapid and is done by the coupled actions of various types of bacteria, which allows the release of mineral substances such as carbon dioxide, nitric nitrogen, phosphate ions and sulfate. N is first released in reduced form (ammonium NH_4^+), then it can be oxidized in the presence of oxygen in the form of nitrite (NO_2^-) and nitrate (NO_3^-) by autotrophic bacteria, during

nitrification. Sulphur is mineralized as sulphate (SO_4^{2-}) in the presence of oxygen (Wang *et al.*, 2019). Nevertheless, SO_4^{2-} prefer non-clay soils with low limestone content (plane F2, negative side). We also observe in this axis that, the sampling points from P6 to P10 have a neutral pH. The pH in the rhizosphere can cause the dissolution of certain minerals such as carbonates, oxides, phosphates, silicates and release, among others, trace elements immobilized in these minerals (Dong *et al.*, 2022).

In the context of such an expansion, the expansion of crop production depends on the increase in soil fertility. In this regard, soil quality and water availability play a central role in sustainable agricultural productivity. Any imbalance of mineral salts in the soil and water leads not only to a decline in plant productivity, but also to their abandonment as it progresses to change in the land regime from fertile to marginal land (Bhat, M. A *et al.*, 2020).

5. Conclusion

This research shows that the availability of ions in the soil is influenced by certain physicochemical parameters of the soil. The results obtained revealed that cations in the soil are mainly controlled by their speciation, and precipitation which influence their uptake in the soil by certain physico-chemical parameters, such as pH and total limestone, which respectively show highly significant correlations. The significant negative effect of fine sand and coarse sand content on the content of these elements in the soil indicates that the mobility of minerals depends on the texture of the soil, it is the particle size fraction (clay and fine sand) that conditions the mobility of these minerals in the soil.

Otherwise, the specific composition of the particle size fractions controls the processes of mineral accumulation, which depends essentially on the physico-chemical parameters and the particle size composition of the soil. Finally, our outlook is reports on the soil of the Tiaret region, protecting soils from erosion and practise modern farming techniques and methods.

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