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Morphological Description and Physico-chemical Characterization of Soils in the Ain Benoui Region, Biskra, Algeria

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ABSTRACT

Background: The aim of this study is to investigate the physico-chemical and morphological characteristics of soils in the Ain Benoui region, Biskra, Algeria.

Methods: In this context, a morphological description and physico-chemical analyses (pH, EC, CEC, porosity, true and bulk density, *etc.*) were carried out on soil samples collected.

Result: The results of this study show that the topography is flat with the presence of halophytic vegetation.The characteristics of the soils studied are as follows: The pH varies between 8.2 and 8.6 and the electrical conductivity between 1.87 and 19.88 dS/m. The total limestone content varies from 1.13 to 42.91% and the gypsum content from 0 to 64.5%. The organic matter content varies between 0.68 and 1.63%. As regards the physical characteristics of the soils, the bulk density varies between 1.11 and 1.94 g/cm^3. The true density varies between 2.27 and 2.62 g/cm^3 and the total porosity varies between 21.19 and 53.63%.

Key words: Arid zones, Characterization, Gypsum, Morphological, Physicochemical.

INRTODUCTION

Gypsum soils are widespread in arid and semi-arid areas, with a total area estimated at 707,000 square kilometres (Boyadgiev, 1985; Shruthi *et al.,* 2024). They are found in desert regions with an average annual rainfall of less than 250 mm (Watson, 1983, 1985).

They are found in North Africa, Southwest Asia and the Mediterranean part of Europe (Van and LOS, 1971), Argentina, Chile and Australia (F.A.O., 1990).

In Algeria, these soils are found in arid and Saharan regions where annual rainfall does not exceed 150 mm/year. They are often found in the steppe areas around the sebkhas and in the Saharan oases, especially in the north (Ziban Oasis, Ouargla, Oued-Righ). In these regions, gypsum basins are very common, but the genesis of gypsum soils is mainly due to the activity of groundwater and the intensity of evapotranspiration (Halitim and Robert, 1987; Bruthans *et al.,* 2017).

In the soil, gypsum occurs in different forms depending on the conditions under which it is precipitated. Several studies (Pouget, 1968; Dekkiche, 1974; Stoops and Ilawi, 1981; Nettelton *et al.,* 1982; Abrukova and Isayeh, 1983; Watson, 1985, 1988 and 1989; Pankhanova and Yamnova, 1987; Halitim, 1988; Boyadgiev and Sayegh, 1992; Herrero *et al.,* 1996; Bensaid, 1999) show that gypsum in soil can occur in powdery forms, pseudomycelia, aggregates, nodules, sand roses, crusts, massive crusts or polygonal crusts.

The presence of gypsum in the soil affects most of its properties and causes serious physical, chemical and fertility problems (Mashali, 1996; Hassan *et al*., 2012; Abbas *et al*., 2023; Dotaniya *et al*., 2023).

As regards the physical characteristics of the soils, the bulk density varies between 1.11 and 1.94 g/cm^3. The true density varies between 2.27 and 2.62 g/cm^3 and the total porosity varies between 21.19 and 53.63%.

The physical properties of gypsum soils are highly variable. They depend not only on the absolute gypsum content, but also on its distribution in the profile, the nature of the accumulations and the origin of the gypsum deposits. We can therefore say that gypsum is an element that, through its content and forms, profoundly modifies the profile morphology and affects soil properties. This is the context of our study.

MATERIALS AND METHODS

Fieldwork began with a survey of the study area to identify physiographic units. Selected profiles were distributed across the study area (Fig 1). Detailed morphological descriptions were made on six profiles and soil samples were collected for physico-chemical analysis. Soil samples were air dried and sieved to 2 mm after collection.

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In order to select a few samples with different gypsum contents, gypsum determination was carried out on all samples collected. Nine (09) samples were selected for this study, based on the classification established by Sys and Verheye in Sys *et al.* (1991) and Soliman *et al.* (2017), which relates the crop production index to the gypsum content in the soil (Table 1).

The physico-chemical analyses carried out include:

- pH measurement with a soil/water ratio of 1/2.5.
- Electrical conductivity (EC), with a soil/water ratio of 1/5, expressed in dS/m at 25^{o}C.
- Total lime content using the Bernard calcimeter method.
- Particle size analysis using the international Robinson pipette method.
- Organic carbon content by the Walkley and Black method using oxidation with potassium dichromate.
- Gypsum content by the Richard (1954) method using a soil/water ratio of 1/500.
- True density using the pycnometer method.
- Apparent density by the paraffin method.

Soil fractionation

Using sieves of 200 and 50 microns and soil samples of less than 2 mm, the following fractions were separated.

Coarse sand: Obtained after sieving at 200 µm, represented by the fraction remaining above this sieve.

Fine sand + silt + clay: Represented by the fraction obtained below the 200 µm sieve.

Fine sand: Obtained after washing half of the fine sand + silt + clay sample on the 50 µm sieve with distilled water and then air drying. The fraction of silt + clay remaining under the sieve is discarded as it is of insufficient quantity for the desired analyses.

RESULTS AND DISCUSSION

A morphological description was carried out on the selected profiles (Fig 2).

Table 1: Productivity indices of gypsumsoils (Sys et Verheye in Sys *et al.*, 1991).

Gypsum %	Index %
> 50	30
25-50	60
10-25	85
0.3-10	100
< 0.3	90

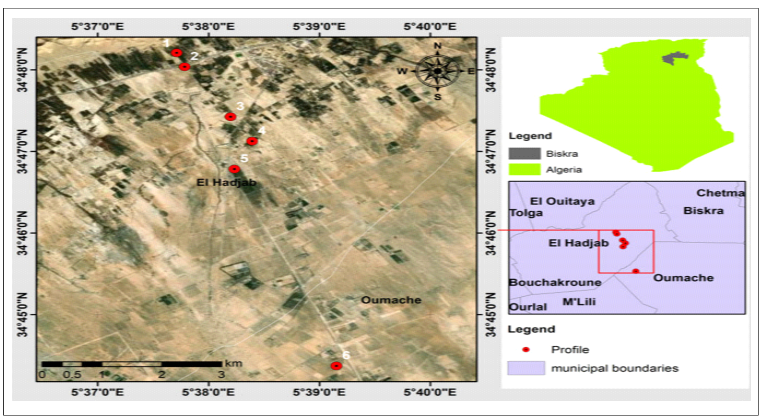

Fig 1: Location of the study area.

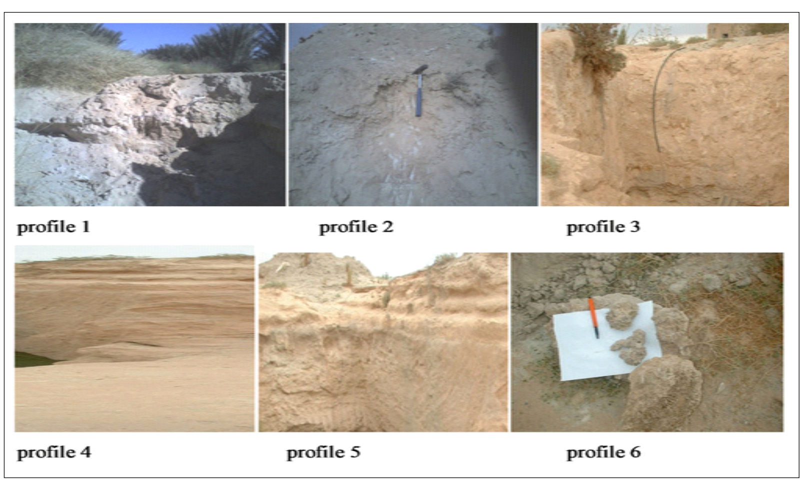

Fig 2: Photos of the studied profiles.

Profile: 1

Coordinates: N = 34° 48.210′, E = 005° 37.712′.
Topography: Flat.
Vegetation: Halophytic plants.
Water table depth: Very deep.
Horizon 0-25 cm: When dry, color is very pale brown (10 YR 7/3), particulate structure.

Profile: 2

Coordinates: N = 34° 48.038′, E = 005° 37.783′.
Topography: Flat.
Vegetation: Very dense halophytic plants.
Water table depth: Very deep.
Horizon 0 - 35 cm: When dry, color is very pale brown (10 YR 7/3), particulate structure, gradual transition, appearance of saline efflorescences on the surface. Haut du formulaire.

Profile: 3

Coordinates: N = 34° 47.425′, E = 005° 38.198′.
Altitude: 130 m.
Topography: Flat.
Vegetation: Halophytic plants.
Water table depth: 12-13 m.
Horizon 0-1.8 m: When dry, color is very pale brown (10 YR 8/4), particulate structure.
Horizon 1.8 m - 4 m: When dry, color is white (10 YR 8/2), compact medium, sharp and undulating transition, appearance of efflorescence.
Horizon > 4 m: When dry, color is yellow (10 YR 8/6), traces of redox, presence of large gypsum crystals.

Profile: 4

Coordinates: N = 34° 47.127′, E = 005° 38.393′.
Topography: Flat.
Vegetation: Halophytic plants.
Water table depth: 8-10 m.
Horizon 0 - 1 m: When dry, color is very pale brown (10 YR 8/3), medium polyhedral structure, diffuse transition, very compact horizon, presence of numerous roots of medium to coarse volume.
Horizon 1 - 3 m: When dry, color is white (2.5 Y 8/2), massive structure, some traces of redox, diffuse transition.
Horizon > 3 m: When dry, color is white (10 YR 8/2), compact structure, numerous fine gypsum remnants and sand roses at depth.
Haut du formulaire.

Profile: 5

Coordinates: N = 34° 46.784′, E = 005° 38.232′.
Topography: Flat.
Vegetation: Halophytic plants.
Water table: Very deep.
Horizon 0 - 1 m: When dry, color is light gray (2.5 Y 7/2), massive grainy structure, friable horizon.
Horizon 1 - 3 m: When dry, color is light gray (10 YR 6/1), massive grainy structure, friable horizon, blackish color, presence of calcareous nodules and roots.
Horizon > 3 m: When dry, color is white (5 Y 8/1), compact, massive grainy structure, friable horizon.

Profile: 6

Coordinates: N = 34° 44.370′, E = 005° 39.153′.
Topography: Flat.
Vegetation: Halophytic plants.
Water table depth: 5-6 m.
Horizon 0 - 1.5 m: When dry, color is pink (7.5 YR 7/4), friable massive structure, yellowish color, contains 10-15 cm of sand deposits, sharp transition.
Horizon 1.5 - 3 m: When dry, color is white (5 YR 8/1), compact structure, diffuse transition.
Horizon > 3 m: When dry, color is white (10 YR 8/2), non-compact structure, traces of white salt on the surface.

Physico-chemical characteristics of soils

Gypsum content

The gypsum content in the sampled soil samples varies from trace amounts to 64.5%. Horizons P1H1, P1H2, P1H3 and P4H3 contain traces of gypsum while horizon P3H3 is slightly gypsum rich. In addition, horizons P2H1 and P4H2 are strongly gypsum-rich. The remaining horizons are very gypsum rich soils (Table 2).

The selected samples according to the Sys et Verheye classification in Sys *et al.* (1991) are listed in the following table (Table 3).

pH (hydrogen potential)

According to the scale established by Baize (1988), the pH of the soils studied is alkaline. It varies between 8.2 and

Table 2: Gypsum content of soils.

Horizon	Gypsum %
P1H1	traces
P2H1	19.35
P3H2	55.9
P3H3	9.8
P4H1	39.56
P4H2	24.08
P4H3	traces
P5H1	53.32
P5H2	35.26
P5H3	39.56
P6H1	55.9
P6H2	64.5
P6H3	60.2

Table 3: Selected soil samples according to the classification Sys et Verheye in Sys *et al.* (1991).

Classes (Gypsum %)	Horizon	Gypsum content of the sample %
> 50	P6H1P6H2	64.560.2
25-50	P3H1P5H3	3539.56
10-25	P2H1P4H2	19.3525
0.3-10	P3H3	9.8
< 0.3	P4H3P1H1	tracetrace

8.6 (Fig 3). This was also observed by Pouget (1968) and Nwite and Alinchi (2022) in all the gypsum soils he studied. They found that the pH of gypsum soils was always above 7. In a semi-arid agricultural trial conducted in Kandahar, Afghanistan, the simultaneous use of farmyard manure and gypsum resulted in a notable reduction of soil pH throughout all growth phases of the common bean; the most pronounced decrease in pH was recorded at the time of harvest with the application of 10 t/ha of FYM combined with 4 t/ha of gypsum (Fazil *et al*., 2024). The control group, which did not receive gypsum, exhibited a soil pH of approximately 7.86, whereas the treatments that included gypsum, particularly at a rate of 4 Mg ha^{-1}, demonstrated significantly lower pH levels compared to the control in both the surface and subsurface soil layers (Abbas *et al*., 2023).

Electrical conductivity

The electrical conductivity (1/5) of the soils varies between 1.87 and 19.88 dS/m (Fig 4); the P1H1 horizon is saline (EC = 1.87 dS/m), the very saline horizons (P4H3, P3H3 and P3H1) are represented by horizons with electrical conductivities between 2.37 and 4.81 dS/m. The remaining horizons (P2H1, P4H2, P5H3 and P6H2) are extremely saline (EC between 9.41 and 19.88 dS/m). The remaining horizons (P2H1, P4H2, P5H3, P6H1 and P6H2) are extremely saline (EC between 9.41 and 19.88 dS/m). They are classified according to the electrical conductivity classification scale of Aubert (1978). Sally *et al.* (2020) found that soil ECe was slightly influenced by the gypsum application rate, increasing from 6.04 dS/m at 100% of the gypsum requirement (GR) to 6.72 dS/m with the application of 50% GR, representing a rise of 0.7 dS/m.

Organic matter

The scale used to classify soil organic matter is that of Charman and Roper (2000) in Hazelton and Murphy (2007). We note that the organic matter content varies between 0.68 and 1.63% (Fig 5). The P4H2 horizon is extremely poor in organic matter, while the P1H1, P3H3 and P4H3 horizons are very poor, with organic matter contents ranging from 0.68 to 0.86%. The horizons (P2H1, P3H1, P5H3, P6H1 and P6H2) are poor in organic matter, with contents ranging from 1.04 to 1.63%. These results are similar to those reported by F.A.O. (1990) on similar material. Agha and Al-Wazzan (2025) found that an increase in gypsum content within arid soils generally leads to a decrease in organic matter content as the proportion of gypsum rises, alongside the percentages of clay and available water. Araújo *et al*. (2016) demonstrated that the application of

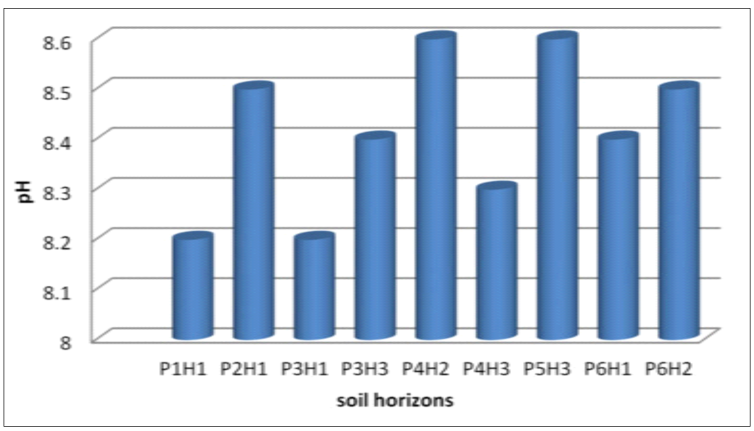

Fig 3: pH values of the studied soil samples.

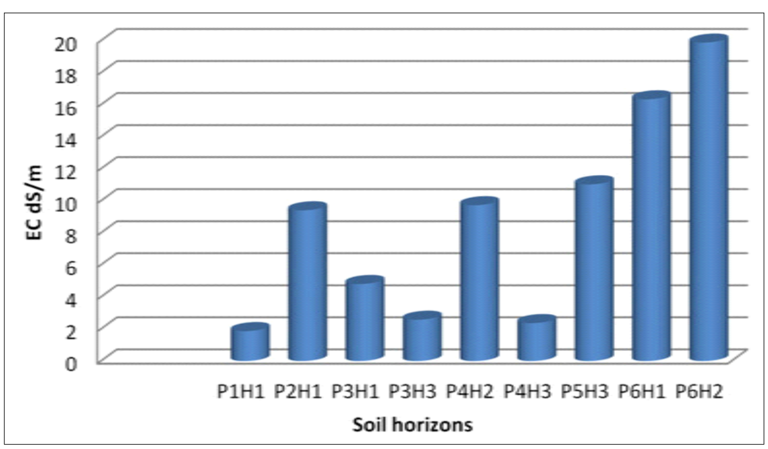

Fig 4: Electrical conductivity of the studied soil samples.

gypsum to sugarcane in Brazil resulted in an increase in total soil carbon stock (TC), particularly in the deeper soil layers (40-100 cm). Additionally, there was a rise in particulate organic carbon, suggesting that gypsum has the potential to improve carbon sequestration in specific cropping systems.

Total limestone

The total limestone content of the soils studied was classified according to the scale established by Baize (1988). The total limestone content of the soils studied varies between 1.13 and 42.91% (Fig 6). The P6H2, P6H1 and P3H1 horizons are slightly calcareous, with contents ranging from 1.13 to 5%. The P4H2, P2H1, P5H3 and P1H1 horizons are moderately calcareous, with contents ranging from 12.27 to 23.23%. The P3H3 and P4H3 horizons are strongly calcareous with 34.3 and 42.91% respectively. In most of the soils studied, the increase in gypsum content is accompanied by a decrease in limestone content in the soil and vice versa. This is confirmed by several studies on gypsum soils (Boyadgiev, 1974; Baci, 1984; F.A.O., 1990; Florea and Al-Joumaa, 1998; Lakshmi *et al.*, 2016).

Furthermore, the gypsum and limestone content varies according to the position of the profile along the sequence from the top (scarp) to the bottom (sebkha). At the top of the scarp are the calcids (TypicHaplocalcids), followed by gypsiorthids with a petrogypsic horizon (TypicPetrogypsids). The typical gypsiorthids act as a transition between the limestone zone and the gypsum zone (Bensaid, 1999; Hidayat and Rusdi, 2023).

Cation exchange capacity

The values of cation exchange capacity are very low to low; they range between 3.2 and 9.5 meq/100 g of soil (Fig 7), due to the low clay and organic matter content in the majority of the studied soils and because gypsum is a neutral salt with a low specific surface area, it is not a constituent of the soil's adsorbing complex (Poch, 1992; Bello *et al.*, 2021).

Exchangeable cations

The dissolution of gypsum and possibly calcite has led to an overestimation of bases, especially calcium (Abdesselam, 1999; Bala, 2005; Campana and Fidelibus, 2015). In our case, this phenomenon is very evident; the concentration of Ca^{++} alone remains higher than the value of the cation exchange capacity in all the soils studied (Table 4). As a result, the Ca^{++} concentration is overestimated and the sum of cations is significantly higher than the cation exchange capacity.

Soil texture

Particle size analysis of gypsum soils was carried out using the classic international method of Robinson's pipette.

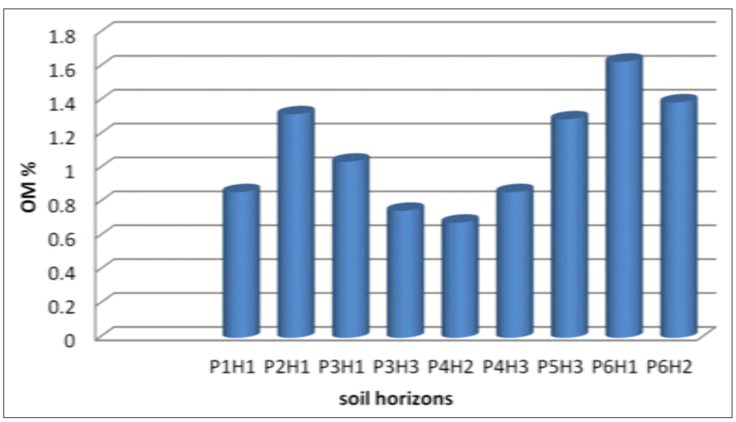

Fig 5: Organic matter content in the studied soils.

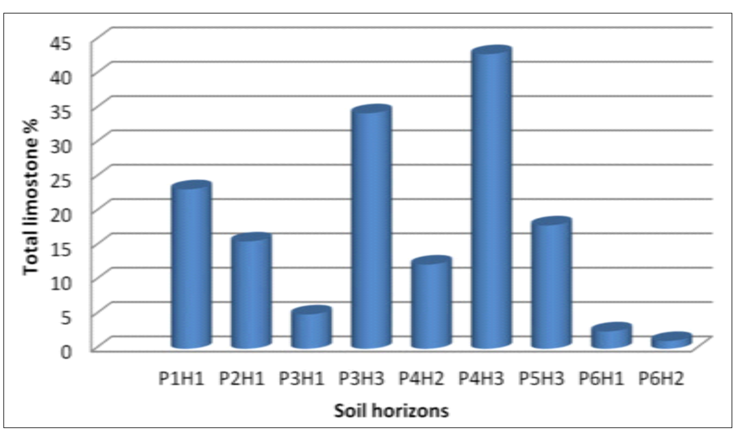

Fig 6: Total limestone content in the studied soils.

The presence of calcium from gypsum and limestone causes flocculation of fine particles. For this reason, the soil samples were separated into only three fractions: coarse sand, fine sand and silt + clay fraction.

This method was chosen because particle size analysis with gypsum removal does not give the true composition of the soil. In this case, the particle size distribution is determined on the basis of only a fraction of the actual soil constituents, especially in horizons with a gypsum content of more than 10% (C.I.R.A.D., 2004; Liao and Yang, 2021).

The particle size distributions of the soils studied are presented in the form of cyclograms (Fig 8).

Horizon P5H3 is characterized by the abundance of the fine sand fraction (51.14%). The silt + clay fraction is 27.04% and the coarse sand fraction is 21.82%.

Horizon P6H1 is characterized by a marked increase in the silt + clay fraction (51.54%) with a contribution from horizon P1H1. Horizon P1H1 is characterized by an abundance of sand; the coarse sand content is 62.35%, fine sand is 30.75% and the silt + clay fraction is 6.9%.

Horizon P2H1 is represented by a coarse sand content of 42.75%, a fine sand content of 44.06% and a silt + clay fraction of 13.19%.

Horizon P3H1 has a coarse sand content of 21.01%, a fine sand content of 44.79% and a silt+clay fraction of 34.2%.

Horizon P3H3 has a coarse sand content of 38.81%, a fine sand content of 46.02% and a silt + clay fraction of 15.17%.

Horizon P4H2 is characterized by the abundance of coarse sand with a content of 55.18%, fine sand with a content of 36.37% and a small amount of silt + clay fraction (8.45%).

Horizon P4H3 is characterised by a high amount of sands (91.57%); 51.58% for coarse sand and 39.99% for fine sand. The amount of silt + clay fraction is 8.43%.

Horizon P6H2 has a high content of fine sand (64.02%). The content of coarse sand is 12.81% and the silt + clay fraction is 23.17%.

We observe an abundance of sand (coarse + fine) in all the horizons studied, except for horizon P6H1, where there is a notable increase in the silt + clay fraction (51.54%).

Bulk and real density

The values of bulk density range between 1.11 and 1.94 g/cm^3 (Fig 9), generally higher than those found by Florea and Al-Joumaa (1998) on gypsum soil. However, the true density values are generally lower than those found by the same author, ranging from 2.27 to 2.62 g/cm^3. According to Agha and Al-Wazzan (2025), the observed decrease in bulk density with the increasing proportion of gypsum in soil samples 5, 6 and 7 can be attributed to a reduction in clay

Table 4: The values of cation exchange capacity and exchangeable cations in the studied soils.

Horizon	CEC meq/100 g	Ca^{++} meq/100 g	Mg^{++} meq/100 g	Na^{+} meq/100 g	K^{+} meq/100 g
P1H1	4.17	0.784	0.771	0.046	0.027
P2H1	4.56	1.079	1.64	0.081	0.075
P3H1	4.6	12.04	3.52	0.046	0.011
P3H3	3.2	4.69	2.3	0.039	0.015
P4H2	5.3	6.72	3.15	0.032	0.019
P4H3	4.6	5.78	3.00	0.039	0.019
P5H3	8.1	14.38	3.01	0.035	0.15
P6H1	8.1	11.10	2.20	0.046	0.038
P6H2	9.5	13.76	1.35	0.067	0.021

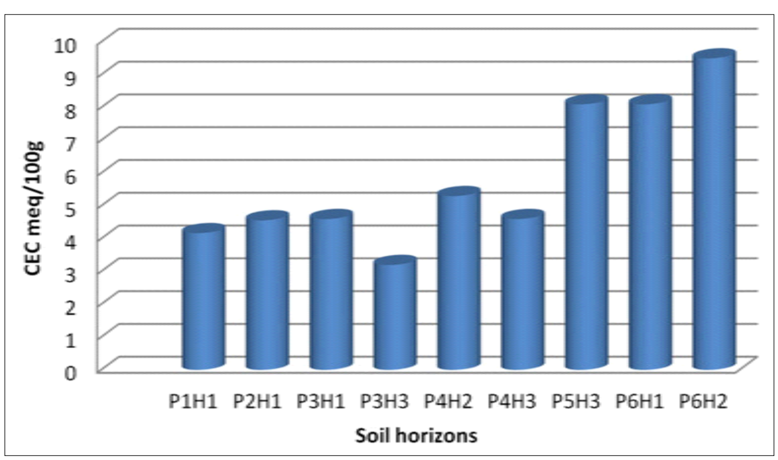

Fig 7: The values of cation exchange capacity in the studied soils.

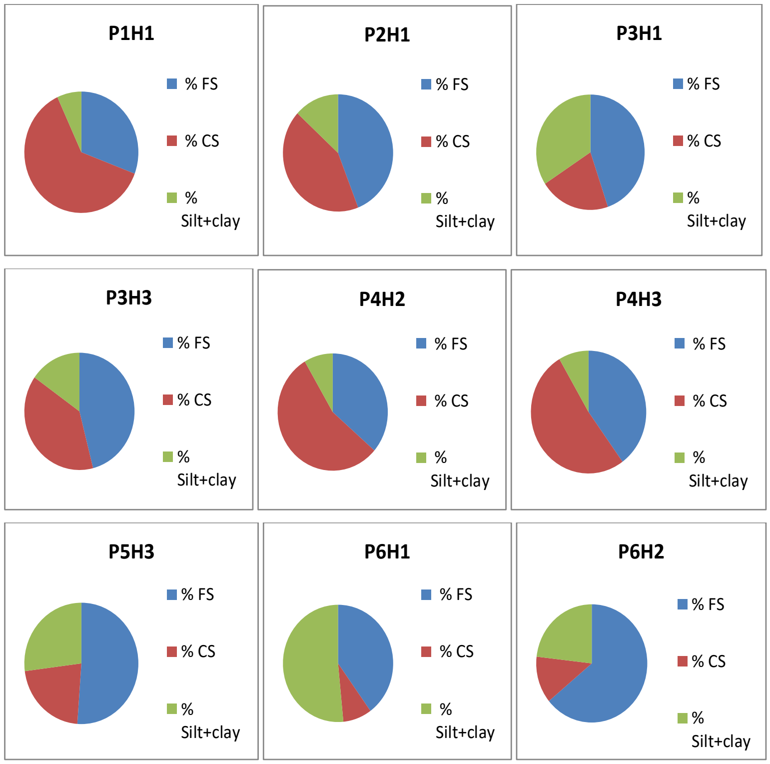

Fig 8: Particle size distribution of the soils.

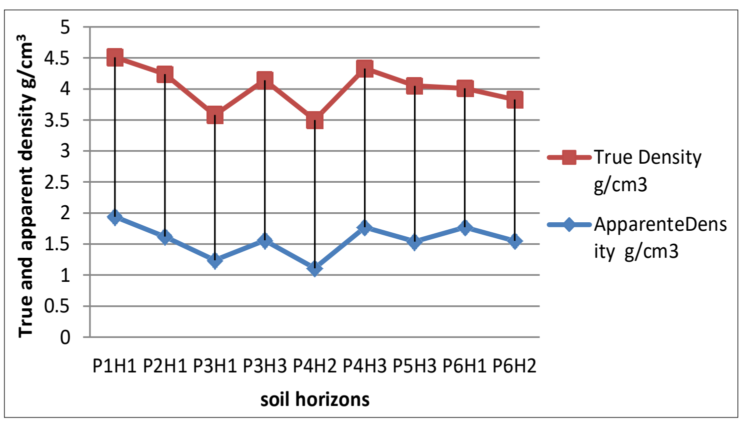

Fig 9: Bulk and true density of the soils studied.

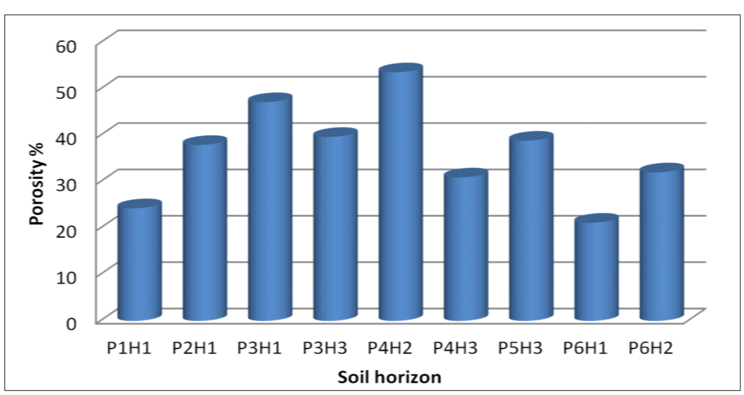

Fig 10: The porosity of the studied soil samples.

content. Furthermore, it was noted that the critical inflection point for bulk density occurs at approximately 300 g kg^{-1} of gypsum, beyond which further increases in gypsum have a limited effect.

Total porosity

The results of the total porosity analysis are shown in figure 10. The total porosity values range from 21.19% to 53.63%, with the majority falling between 21.19% and 39.69%. These values are low compared to those reported by Pankhanova and Yamanova (1987) and Poch (1992) for gypsum materials.

According to Sally *et al*. (2020), the amendement of soil by gypsum cause an incasing in soil total porosity. Agha and Al-Wazzan (2025), reported that the application of gypsum enhanced the overall porosity of the soil, as the calcium released from gypsum facilitates particle aggregation and decreases bulk density, which in turn increases the available pore space. The incorporation of gypsum into sodic Vertisols led to a decrease in soil dispersion and an increase in macroporosity due to improved aggregate stability, thereby affirming the beneficial impact of gypsum in the restoration of soil structure (Niaz *et al*., 2023).

CONCLUSION

The present study has focused mainly on the soils located within the sequence from Djebel Bougzel in the upstream part to the Sebkha in the downstream part, in the region of Ain Ben Noui (El Hadjeb community), southwest of Biskra. This region is characterised by an arid climate, with the presence of a typical saline water table and gypsum-limestone material.

The initial physico-chemical characterisation of the soils has allowed us to identify five (05) classes of soils with different gypsum contents.

The physico-chemical characterisation according to the studied soil classes allowed us to select a representative horizon for each class in order to compare them.

The comparison of the physicochemical characteristics of the classes showed that the pH is alkaline in all the classes studied and the electrical conductivity increases progressively from the first class (<0.3% gypsum) to the last (> 50% gypsum).

The texture of the classes studied is generally sandy, but there is an increase in the proportion of the silt + clay fraction, especially in the fifth class (>50% gypsum), which is 51.54%.

Total porosity is low in all studied horizons compared to those reported in other studies of gypsum material.

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Conflict of interest

On behalf of all authors of this manuscript, I hereby declare that there are no known financial, professional, or personal conflicts of interest that could have influenced the work reported in this manuscript. No funding or external support was received that could lead to any potential bias in the preparation, analysis, or publication of this study.

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