Study Of Some Morphological Feautures Of Calcarious-Gypsiferous Soils And Its Management

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Abstract. The study was conducted to demonstrate some morphological features of gypsiferous soils and the possibility of managing these soils to improve their productivity. The soil samples were taken from three pedons (p1, p2, p3) for physical and chemical analysis. A plot experiment was conducted by randomized complete block design planted with barley seeds and three levels of npk. Results showed a sharp decline of organic matter, calcium carbonate and highest gypsum value with depth. Also results showed higher value for hue and value in p3 comparing with p1 and p2. The structure of soil surface was subangular blocky in p1 and p2, while it was structureless in p3. The boundaries at p1 and p2 were clear and wavy or irregular, but defuse and irregular at p3. The index accumulation values of clay (ci) showed pedogenic migration of clay from the surface horizons to the subsurface horizons. All soil pedons were classifieds according to soil survey staff (2006, 2015) to a series level: (fine silty clay, mixed, thermic typic calcigypsids). Results of the field experiment showed superiority of adding mineral fertilization in (plant height, spike length, number of seeds per spike and seed weigh) compared to control treatment.

Keywords: gypsiferous soils, morphological characteristics, soil management, barley

Introduction

Gypsiferous soils are soils that contain sufficient quantities of gypsum to interfere with plant growth. These soils are predominant in different regions of the world, especially in the arid and semi-arid areas where amount precipitation are less than 400 mm with available gypsum sources (5) and (1). According to SSS, (14) gypsiferous soils containing gypsic horizon with a thickness of 15 cm or more within the first meter of soil and have at least 5% or more gypsum content at underline horizon, the multiply of thickness of the gypsum horizon (cm) to percentage of gypsum must be equal to or greater than 150, this layer is called Gypsic horizon. Jhon, (7) and Azizi et al, (2) founded that increases in gypsum content leaded to weak soil structure due to poor cohesion between gypsum parts of soils, Ghabour et al, (6) founded an increasing in barley yield in gypsiferous soil with addition of chemical fertilizer (NPK) and they attributed this to the effect of fertilizers on improving the physical and chemical properties of these soils. Somaye et al, (15) noted in a study of gypsiferous soils that the gypsum is one of the most important limitations of barley cultivation in gypsiferous soil and it is necessary to fertilize these soils to improve their productivity. Rasheed and Latef (11) concluded that the soil management and irrigation system have an impact on the pedological development of gypsum,
which should be taken into consideration into program me playing of soils management. Ul-Haq et al, (16), Kijjanapanich et al, (9) and Khalifah et al, (8) mentioned that soils that have high gypsum content led to many cultivation problems, such as a low water holding capacity and low fertility. For these reasons our study was aimed to study some morphological characteristics of their gypsiferus soil and possibility improve their productivity by using chemical fertilizers as amended factor.

Materials and Methods

The study was carried out on of the gypsiferus soils of Zummar area at northern Nineveh provenance at northern Iraq (Fig. 1).

![Figure 1. Site map of the studied area](image)

The study area is 310 meters above sea level. The average annual temperature (20.2 °C) and annual rainfall (269 mm). It has a hot dry climate in summer but cold and rainy winters (Table 1). Three pedons with different gypsum content was dug at each location in field located western of the main road Hakna-Zummar area (42° 34’ 02″E and 36° 36’ 34″ N), the distance between P1 and P2 was 850 meters, again it was 650 m between P2 and P3.

The pedons were then thoroughly examined, morphologically described and the physiographic features of the location were identified according to the fundamentals of (13). Disturbed soil samples of three pedons were sampled homogenously from each horizon for physical and chemical analyzes, which included color, Particle Soil Distribution, pH, EC, Na, Ca, Mg, OM, CaCO₃ and CaSO₄.2H₂O (12). The physical function of soil development was calculated by divided the clay ratio in B horizon to its ratio in A horizon (Collins and Fenton 1982), and the Clay index accumulation (Cl) calculated by the equation, described by (4).

Part of the field near P3 divided into 5x20 m plots, designed with RCBD with three replicates, planted with barley crop (*Hordum Vulgaris L.*) and fertilized with three levels (0.80 and 120 kg ha⁻¹) of Compound Fertilizer (NPK), which is based on rainfall. At the end of the agricultural season some plant and yield parameters were measured, which included plant height, spike length, number of grains per spike, number of spikes per sq. meter, weight of 1000 grains, and biological yield. The results were analyzed and compared between the mean of the coefficients with the least significant difference at 5% (3).
Table (1). Average monthly climate (2001 – 2016) for the study area

|          | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Rainfall mm | 12.4 | 24.2 | 54.2 | 57.1 | 41.8 | 43.5 | 28.9 | 6.7 | -   | -   | -   | -   |
| Max. Temp. rate °C | 29.7 | 19.1 | 14.1 | 13.3 | 15.4 | 22.5 | 28.0 | 32.1 | 38.5 | 41.9 | 41.5 | 35.9 |
| Mini. Temp. rate °C | 13.0 | 6.3  | 2.7  | 0.3  | 3.9  | 7.5  | 13.2 | 17.0 | 21.1 | 26.1 | 23.0 | 18.7 |

Results and discussion

1- Morphological and Physical characteristics: Field observations, in all pedons were observed secondary gypsum in small crystalline with diameters of a few millimeters and in different forms which placed on groundmass, these results are consistent with those indicated by (7 and 2).

A- Color: Table 2 noted that the degree of Hue of the Ap was 10YR in the three pedons, Values was (4) in P(1 and 2) and (6) in P3. When comparing the degree of value of C horizon with the surface horizons and the subsurface horizons of the three pedons it was founded significant differences, these differences are due to the effect of low organic matter content and effect of gypsum content in development of light color of soil, these results are consistent with those indicated by (2).

B- Structure: Table 2 noted that the structure of soils was a sbk of Ap and B horizons of P (1 and 2) and Structureless in P3. The differences in soil structure in surface layers compared to the subsurface layers may be due to the amount of organic matter and biological activity, and this is consistent with what (11) have pointed out, in addition to differences in texture, gypsum and carbonate accumulation. These results are in agreement with the results of (7), who indicated that the soil structure with increasing the amount of added gypsum to the soil.

C- Boundaries: Table 2 noted that the boundary between the horizons of the surface soils was clear, wavy or irregular and diffuse in P (1 and 2), while it was irregular and diffuse in P3. These results are in agreement with the results of (15) who indicated that increasing the soil content of gypsum has led to weakness and poor structure, and thus making the boundary between horizons diffuses and unclear.

D- Texture: The results of mechanical analysis of the soils (Table 2) showed that there were a similarity in the soil texture type of soil horizons at all pedons, whereas the clay content was 340, 354 and 360 g kg⁻¹, and the silt content was 325, 340 and 314 g kg⁻¹, while the sand content was 335, 315 and 326 g kg⁻¹ respectively for the surface horizons of the three pedons.

E- Bulk density: Table 2 shows that the surface bulk density of the surface pedons was 1.4 Mg m⁻³ for P1 and P2, while it was 1.43 M m⁻³ for P3, as shown in table (2) the density of three pedons was increased with the depth, the highest bulk density was 1.6 Mg m⁻³ for Cy of P (2 and 3). The reason for the high density is the poor soil structure and the dispersion of the aggregates due to the high gypsum content of these soils, results agree with the results of other Researchers (1 and 2).

| Pedon no.1 | Ap  | 0-18 | 1.40 | 340 | 325 | 335 | CL | dark brown | 7.5YR4/4 | dark yellowish brown 10YR4/4 | 1f sbk | Clw |
|-------------|-----|------|------|-----|-----|-----|----|------------|--------|--------------------------|------|-----|
|             | Bk  | 18-56| 1.43 | 295 | 380 | 225 | CL | dark brown | 7.5YR4/4 | brown 7.5YR5/4 | 3msbk | Clir |
|             | Cy  | 65-95| 1.47 | 290 | 375 | 235 | CL | dark yellowish brown 10YR4/4 | pink white 7.5YR8/2 | Om | ------ |
Pedon no. 2

| Horizon | Depth cm | CL       | Color                | Texture | Structure |
|---------|----------|----------|----------------------|---------|-----------|
| Ap      | 0-15     | 1.40     | 345 340 315          | CL      | 1msbk     |
|         |          |          | dark brown 10YR3/3   |         | Clw       |
| By1     | 15-27    | 1.53     | 386 345 269         | CL      | om        |
|         |          |          | very pale brown 10YR7/3 |       | Clb       |
| By2     | 27-47    | 1.58     | 395 325 280         | CL      | 1f-msbk   |
|         |          |          | dark yellowish brown 10YR4/4 |   | Clir      |
| Cy      | 47-100   | 1.60     | 378 320 302         | CL      | om        |
|         |          |          | dark yellowish brown 10YR6/6 |  | -----     |

Pedon no. 3

| Horizon | Depth cm | CL       | Color                | Texture | Structure |
|---------|----------|----------|----------------------|---------|-----------|
| Ap      | 0-15     | 1.43     | 360 314 326         | CL      | ogr       |
|         |          |          | yellowish brown 10YR3/2 |       | dir       |
| By      | 15-55    | 1.55     | 388 310 302         | CL      | om        |
|         |          |          | brown gray 10YR5/2   |         | dir       |
| Cy      | 55-110   | 1.60     | 380 325 318         | CL      | om        |
|         |          |          | brown 10YR5/3       |         | -----     |

*CL: clay loam, SiC: silty clay
*1msbk: weak medium subangular blocky, 3msbk: strong medium subangular blocky, *1fsbk: weak fine subangular blocky, 1f-msbk: weak fine to moderate subangular blocky, *om: structureless massive, ogr: structureless granular.
*clw: clear wavy, clir: clear irregular, clb: clear broken, dir: diffuse irregular.

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Pedon no. 1

**Location** 50m west Zummar-Haukna road

**Physiography** Foot hill

**Topography** Gently sloping

**Slope** 1 – 2%

**Climate** Semi-arid

**Parent material** Calcareous material

**Gr. water level** Deep

**Drainage** Good

**Land use** Wheat and Barley Crops

![Figure (2) Picture for P2](image)

**Date** 26 March 2017

| Horizon | Depth cm | Morphological features |
|---------|----------|-----------------------|
| Ap      | 0-18     | Yellow brown dark 10YR4/4 (dry), yellow brown 7.5YR4/4 (Moist), Loamy clay, sub angular blocky medium, presence of microorganisms activity, presence of presence of CaCO₃, many fibrous roots, clear and wavy boundaries, consistency soft when dry. |
| Bk      | 18-56    | Dark brown 7.5YR5/4 dry, Dark brown 7.5YR4/4 (Moist), Loamy clay, sub angular blocky medium, presence of presence of CaCO₃, few fibrous roots, clear and wavy boundaries, consistency soft when dry. |
| Cy      | 56-95    | Pink white 7.5YR8/2 (dry), Dark yellow brown 7.5YR4/4 (Moist), Loamy clay, structureless, white layer of calcigipsic material, consistency soft when dry. |
Pedon no. 2

Date  26 March 2017
Location  250m west Zummar-Hukna road
Physiography  Foot hill
Topography  Gentle sloping
Slope  1 – 2%
Climate  Semi-arid
Parent material  Calcareous material
Gr. water level  Deep
Drainage  Good
Land use  Wheat and Barley Crops

| Horizon | Depth cm | Morphological features |
|---------|----------|------------------------|
| Ap      | 0-15     | Dark yellowish brown 10YR4/3 (dry), Dark brown 7.5YR3/3 (Moist), loamy clay, sub angular blocky medium, active presence of organisms, presence of CaCO₃ in abundance mixed with gypsum, many fibrous root, Irregular and diffuse boundaries, consistency friable when dry. |
| By₁     | 15-27    | White 10YR8/2 (dry) Very pale brown 10YR7/3(Moist), loamy clay, sub angular blocky medium, active presence of organisms, few fibrous root and many, few fibrous roots with some thick roots of weeds, presence of CaCO₃, clear and broken boundaries |
| By₂     | 27-47    | Yellowish brown 10YR5/4 (dry), Dark yellowish brown 10YR4/4 (Moist), loamy clay, sub angular blocky small, few fibrous roots with some thick roots of weeds, presence of CaCO₃, clear and diffuse boundaries |
| Cy      | 47-100   | Pale yellow 7.5YR8/2 (dry), dark yellowish brown 10YR4/4 (Moist), loamy clay, presence of CaCO₃ is mixed with gypsum at the top and is lowered downward, structureless and massive, consistency friable when dry. |

Pedon no. 3

Date  26 March 2017
Location  250 m west Zummar-Hukna road
Topography  Gently slope
Physiography  Foot hill
Slope  1 – 2%
Drainage  Good
Parent material  Calcareous materials
Gr. water level  Deep
Land use  Wheat and Barley Crop
According to chemical analysis (table 3), gypsum content showed an increase with depth of all pedons, and its ranged from 2.9 g kg\(^{-1}\) in the surface of p1 to 115.8 g kg\(^{-1}\) in the subsurface of p2. This suggests that during wetter and drier periods by leaching and capillary rise the gypsum was removed from soil surface and re-deposited in the lower pedons layers. These results are in agreement with the results of (11). It is also noted that the pH values ranged from (6.70-7.27 in all study pedons with low EC and was 22.4, 22, and 21 g kg\(^{-1}\), respectively, in the SAR values. Soil content of organic matter surface horizons of three pedons, and soil content of calcium carbonate CaCO\(_3\) ranged between 125% and 320 g kg\(^{-1}\) in three study pedons and also notes the gradual decline of the calcium carbonate content with depth, indicating the weakness of washing process due to lack of rainfall, and may reflect the heterogeneous distribution in carbonate of these soils and gypsum with depth of pedogenic sedimentation and Stratification of parent material.

Table (3). Chemical properties of study soil pedons

| Horizon | Depth cm | pH | EC dS m\(^{-1}\) | SAR | O.M | CaCO\(_3\) g kg\(^{-1}\) | Gypsum |
|---------|----------|----|-----------------|-----|-----|-----------------|---------|
| p1 Ap   | 0-18     | 7.00 | 0.66           | 0.06 | 22.4 | 320             | 3.2     |
| Bk      | 18-56    | 6.80 | 0.37           | 0.04 | 3.9  | 300             | 2.9     |
| Cy      | 56-95    | 6.74 | 0.35           | 0.03 | 8.6  | 125             | 109     |
| p2 Ap   | 0-15     | 6.90 | 0.46           | 0.03 | 2.20 | 250             | 37.7    |
| By\(_1\) | 15-27   | 7.00 | 0.51           | 0.04 | 0.95 | 200             | 50      |
| By\(_2\) | 27-47   | 7.10 | 0.62           | 0.04 | 0.86 | 220             | 75      |
| Cy      | 47-100   | 6.70 | 0.62           | 0.04 | 0.96 | 155             | 115.8   |
| p3 Ap   | 0-15     | 7.27 | 0.81           | 0.03 | 2.10 | 155             | 81      |
| By      | 15-55    | 7.13 | 0.70           | 0.05 | 0.85 | 125             | 97      |
| Cy      | 47-110   | 6.75 | 0.72           | 0.05 | 0.65 | 125             | 113.7   |

3- **Degree of soil pedons development:** Results in table (4) indicated that soils of three pedons showed a weak development, evidenced by the weakness of formation and development of subsurface horizon (B) due to increasing amount of gypsum in the soil. Sufficient quantities of gypsum can affect soil properties and causing physicochemical, fertility, plant growth and crop production problems.

The values of clay accumulation index (CI) in the three pedons as showed in table (4) were (190, 96, 340 and 420), respectively, and the clay content ratio in A horizon to its content in B horizon was 1.16,
(1.12 and 1.14) and 1.08 respectively. This means that the case of biogeogenic transfer of clay from surface horizons to sub-surface horizons in previous periods under wet conditions higher than current conditions, which helped the activity of loss and gain and formation of B horizon, these results are consistent with findings of researchers (4) who noted that the soil horizons may be developed due to the biogenic processes, which will lead to the redistribution and arrangement of the soil partials with depth, especially clay content partials due to the activity of loss and gain operations especially in B horizon by the effect of rain falling amount.

**Table (4).** Development of soil pedons

| Pedon no. | T (cm) | CI = (B - C) T | B/A |
|-----------|--------|----------------|-----|
| Pedon no. 1 | 38     | 190            | 1.16|
| Pedon no. 2 | 12     | 96             | 1.12|
|           | 20     | 340            | 1.14|
| Pedon no. 3 | 40     | 420            | 1.08|

*CI: clay accumulation index, A:% clay in A horizon, B:% clay in B horizon, C:% clay in C horizon, B/A: physical function of soil development, T: thickness of B-horizon

4- Effect of chemical fertilization on the germination of barley: Table 5 shows an improvement in barley germination in the fertilized soil in comparison with non-fertilized soil. The plant height and spike length in the fertilized soil with 120 kg ha\(^{-1}\) (NPK) was 51.7 and 5.6 cm compared to 39.7 and 5 cm respectively in non-fertilized soils, the number of seeds in the soil fertilized with 120 kg ha\(^{-1}\) (NPK) was 32.7 grain spike\(^{-1}\) compared to 21 grain spike\(^{-1}\) in the non-fertilized soil. These results have agreement with those obtained by (6, 15 and 9).

**Table (5).** Effect of NPK fertilization on germination of barley

| Treatment kg ha\(^{-1}\) | *Wg Gm| *NS m\(^{-2}\) | *NG in spike | *Sl cm | *Ph | *Dw kg ha\(^{-1}\) |
|-------------------------|--------|----------------|--------------|--------|-----|----------------|
| 120                     | 70.0 a | 129.7 a        | 32.7 a       | 5.6 a  | 51.7 a| 979.3 a       |
| 80                      | 61.7 a | 122.3 b        | 27.0 b       | 5.3 b  | 47.7 b| 906.7 b       |
| Control                 | 45.3 b | 115.3 c        | 21.0 c       | 5.0 c  | 39.7 b| 823.3 c       |
| R\(^2\)                 | 0.671  | 0.485          | 0.960        | 0.842  | 0.996| 0.767         |

*Wg: weight of 1000 grain, NS: number of spike, G: number of grain in spike, Sl: spike length, Ph: plant height, Dw: dry weight

Table 5 shows also an improvement of the number of spike per sq. meter in the soil fertilized with 120 kg ha\(^{-1}\) (NPK), it was 129.7 spike per sq. meter compared with 115.3 spike per sq. meter in non-fertilized soil, which were reflected positively in the weight of 1000 grain, it was 70 g in soil fertilized with 120 kg ha\(^{-1}\) compared to 45.3 g in non-fertilized soil. The dry weight in the soil fertilized with 120 kg ha\(^{-1}\) was 979.3 kg ha\(^{-1}\) compared to 823.3 kg ha\(^{-1}\) in non-fertilized soil. This indicates that gypsum soil can be exploited and managed to reduce the gypsum effects in soil which are poor in nutrients, these results are consistent with what (16), (8) and (9) when they studied the gypsum soil in Iraq and stated that it must be taken into consideration when developing plans for the management of these soils by adding chemical fertilizers to improve their productivity.

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