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Effect of Phosphogypsum on Formation and Development of Soil Surface Crust and Wheat Crop Growth

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ABSTRACT

Soil crusts are formed at soil surface due to the impacts of raindrops and break of aggregates, resulting in reduction of seedling emergence, reduction soil infiltration rate and increasing of runoff which induces soil erosion. In order to reduce the negative effects of crusts, an experiment was conducted under natural rainfall to determine the effect of adding Phosphogypsum (PG) on the formation and development of soil surface crust and its effect on the wheat yield. Two soil textures from two different locations, clay and silty clay were used. Three levels of PG (0, 5, and 10%) added on the surface of each soil and sown with wheat seeds. The results showed that thickness, penetration resistance and bulk density of the crust were decreased, in addition to decreasing of fine soil fractions in the crust, when PG levels were increased.

The results also showed that the above characteristics of the crust were increased with increasing of rainstorms duration. Finally, the results showed that the wheat crop characteristics, such as plant height, the number of grains in the spike, seed weight and dry weight were increased by increasing of PG added levels.

تأثير إضافة الجبس الفوسفاتي في تكوين وتطور قشرة التربة السطحية ونمو محصول الحنطة

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الخلاصة

تتكون القشرة على سطح التربة نتيجة تأثير قطرات المطر وتهدم تجمعات التربة وهذا قد يؤدي الى تقليل بزوغ البادرات وتقلل من معدل غيض الماء وتزيد من الجريان السطحي الذي يؤدي الى تعرية التربة. ولتقليل التأثيرات السلبية لقشرة التربة السطحية أجريت تجربة لبيان تأثير إضافة الجبس الفوسفاتي في تكوين وتطور قشرة التربة السطحية ومدى تأثيرها في نمو محصول الحنطة. أُستخدم في التجربة تربتين احداها طينية والاخرى طينية غرينية بثلاثة مكررات لكل تربة وثلاثة مستويات من الجبس الفوسفاتي (0 و 5 و 10%) في سنادين بلاستيكية، زرعت ببذور الحنطة ثم أضيف الجبس الفوسفاتي على سطح التربة وعرضت للتساقط الطبيعي على فترتين متعاقبتين، في الفترة الأولى عرضت إلى ثلاثة عواصف مطرية ليتم بعدها قياس بعض صفات القشرة مثل سمك القشرة ومقاومتها للاختراق وكثافتها الظاهرية والتوزيع ألحجمي لدقائق التربة، ثم عرضت التجربة إلى ثلاثة عواصف مطرية أخرى ليتم بعدها قياس نفس صفات القشرة السابقة، وفي نهاية الموسم الزراعي تم قياس بعض صفات محصول الحنطة مثل ارتفاع النبات والوزن الجاف وعدد الحبوب في السنبلة ووزن 1000 حبة. أظهرت النتائج انخفاض سمك القشرة ومقاومتها للاختراق وكثافتها الظاهرية وزيادة نسبة الدقائق الناعمة في القشرة مع زيادة نسبة إضافة الجبس الفوسفاتي ولكلا التربتين. كما لوحظ تحسن نمو محصول الحنطة مثل ارتفاع النبات وعدد الحبوب في السنبلة ووزن الحبوب والوزن الجاف مع زيادة مستويات إضافة الجبس الفوسفاتي.

Introduction:

The phenomenon of soil surface crust is one of the widespread problems in soils in different areas, especially under arid and semi-arid climate, which is one of the factors that adversely affect the characteristics of both the soil and agricultural production (Robinson and Philips, 2001). McInter (1958) found that the soil surface crust is composed of two distinct parts: a) an upper skin seal attributed to compaction thickness (0.1 mm) due to raindrop impact and b) washing area (washed in) thickness (20 mm) with a low porous due to the movement of fine particles and deposited in the pores interfaces. Surface crusts thickness is (less than 2mm to 3 mm) and characterized by greater density, finer pores and lower saturated hydraulic conductivity than the underlying soil (Morin et al. 1981).

Agassi et al. (1986) and Van der and Claassens (1990) and Mamedov and Levy (2001) noticed that the decrease of soil aggregation and the increase of surface runoff of soils that have high clay and silt content are a result of the crust formation. Seker (2003) found that the intensity clogged and composition of the soil surface crust is directly proportional to the intensity of rainstorms.

Gal et al. (1984), Toma and Saigusa (1997) observed that the addition of PG to the soil surface can affect the formation of the soil crust and the infiltration rate by two physical ways: intervene mechanically in organized clogged layer of the soil surface by which lowering crust formation, and the second is the protection the soil surface from the direct raindrops impact which reduces the dispersion of soil clays and protects it from the washing layer, resulting in slowdown of crust formation, reducing the surface runoff and increasing of the permeability of the crust.

Hurtado et al. (2011) and Yasein and Juwier (2013) noticed an improvement in the physical and chemical soil properties when adding PG, consequently an improving the quantity and quality of the wheat crop.

The aim of this study is to determine the impact of PG on the formation and development of soil surface crust and its effect on the growth of wheat yield under natural rainfall condition.

Materials and Methods:

A factorial experiment was conducted at growth season 2013-2014 at the University of Mosul, College of Agric. and Forestry, Mosel, Iraq. Randomized complete blocks design (RCBD) was used with two types of soil deferred in texture and location. The first soil was clayey textured and the other was silty clay. Soil samples were air dried, crashed and passes through a sieve with diameter openings of 2-mm for initial physical and chemical properties (Table 1). Other soil samples were also air dried and sieved by a sieve with a diameter of 4-mm and packed in plastic bags 20 cm diameter and 15 cm height. Three levels (0, 5 and 10%) of PG with three replications were added to the top of the soil in plastic bags after sowing them with wheat seeds (*Triticum aestivum* L.), (PG is product of phosphate fertilizer industry, its particle density between 2.12-2.34 g cm^{-3}، and its bulk density is between 0.87-1.68 g cm^{-3}, it composed of small to medium- sized grains ranging from 0.025-0.25 mm, and is mainly composed of 90% Calcium sulphates with a little of Phosphoric acid, Sulfuric acid and Fluoric acid).

The experiment subjected to natural rainfall for two periods. In the first period, the experiment was exposed to three consecutive rainstorms which had a cumulative rainfall depth of 31 mm using (rain gauge), and in the second period the experiment exposed to other three consecutive rainstorms, which had a cumulative rainfall depth of 40 mm. After each period the experiment was left for about 15 days to determine the crust thickness by using Vernier Caliper and penetration resistance by using Pocket pentrometr. Soil pH and EC in soil extract determined according to the methods given in Ryan et al. (2001), particles size distribution was determined by Hydrometer method according to the Gee and Bauder (1986), bulk density by Core method (core diameter 20 mm and a height of 3 mm) according to the Blacke and Hartge (1986).

Some crop growth parameters and yield components such as plant height, dry weight, spike length and number of seeds in spike were measured.

The Data were subjected to analysis of variance (ANOVA) using the Duncan's multiple range test (DMRT) for multiple comparisons of paired means of treatments (Steel and Torrie, 1980).

Table (1): Some physical and chemical properties of both study soils.

Properties / texture	pH	EC $dS\ m^{-1}$	BD $Mg\ m^{-2}$	Clay	Silt	Sand	O.M	$CaCO_3$	Mg^{+2}	Ca^{+2}	Na^{+}
				%			gm kg^{-1}		mmol 100 g^{-1} soil		
C	7.35	0.41	1.38	55.1	38.8	6.1	19.00	370	2.35	1.75	0.85
SiC	7.63	0.48	1.63	44.1	43.2	12.7	4.50	390	7.78	3.50	1.50

BD=bulk density, C=clay, SiC= Silty Clay, EC=electrical conductivity

Results and Discussion:

1- Soil Crust Characters:

A- Crust Thickness (CT):

There is a linear relationship between the crust thicknesses and the precipitation. Tables 2, 3, 4 and 5 shows differences in crust thickness formed in both PG levels added to the soils. The CT was decreased with the increasing rates of PG added to soils. The CT were 1.35 and 1.25 mm for clay and silty clay soils respectively at 10% PG, as compared with the control level for both soils that have the same value (2.0 mm) at the first period of soil exposer to rainstorms. Lower CT was observed at the second period when 10% of PG level was added. It was 1.45 and 1.95 mm, respectively for clay and silty clay soils as compared with that of control that was 3.55 and 3.85 mm for clay and silty clay soil respectively. The reduction of CT with the increasing of PG levels may due to the positive effect of PG, such as providing a protection to the soil surface aggregates against the rain drop effect. These results were agreed with that of Agassi et al. (1986) and Toma and Saigusa (1997), those found that there is an improvement in physical and chemical soil properties by adding of PG.

Table (2): Some characteristics of the soil surface crust (clay soil the first period)

characteristics / PG AR	CT mm	RP Kg cm^{-2}	BD Mg m^{-3}	Clay	Silt	Sand
				%		
Control	2.00	1.10	1.84	61.50	38.00	0.50
5%	1.50	0.95	1.45	57.50	38.90	3.60
10%	1.35	0.85	1.39	59.90	39.1 0	1.00

AR=PG added ratio, CT=crust thickness, PR=penetration resistance, BD=bulk density

Differences were also noticed in the CT at the second period between the same levels PG of added to both soils. The lower CT value (1.45mm) was for clay soil at the PG treatment of 10% as compared with 1.95 mm of the silty clay soil; while within the control levels, the CT of clay soil was 3.55 mm as compared with the 3.85 mm of the silty clay soil. It is indicating that the addition of PG improved the soil structure and increased the aggregate stability as well as reduced the crust formation.

Table (3): Some characteristics of the soil surface crust (silty clay soil the first period)

characteristics / PG AR	CT Mm	RP Kg cm^{-2}	BD Mg m^{-3}	Clay	Silt	Sand
				%		
Control	2.00	1.60	1.49	58.90	27.50	13.60
5%	1.55	0.35	1.43	57.40	26.50	16.10
10%	1.25	0.38	1.40	58.90	25.0 0	16.10

B- Crust Resistance to Penetrate (RP):

Tables 2, 3, 4 and 5 show the differences in crust penetration resistance with the addition of PG in both soils. The values of crust PR were 0.85 and 0.83 kg cm^{-2} at 10% of PG level, compared to 1.1 and 1.6 kg cm^{-2} for control, respectively for clay and silty clay soils at the first period. Similarly, at second period, strongest crust RP values 2.0 and 1.9 kg cm^{-2} for clay and silty clay soils, respectively, while the less RP values 1.3 and 1.15 kg cm^{-2} for clay and silty clay soils, respectively were at 10% PG. The decreasing of RP accompanied with the increasing of PG added at the both periods. It was obtained from the results that the addition of PG will protect the soil surface from direct raindrops and thereby reduces the break down of soil aggregates, by which reduce crust formation. The results were accordance to (Agassi et al. (1986), Robinson and Philips

(2001) and Hurtado et al. (2011) found that the addition of PG to the soil surface can reduce the continued development formation of the soil crust Because of the protection it provides to the soil surface from the direct impact of falling rain drops.

Table (4): Some characteristics of the soil surface crust (clay soil the second period)

characteristics / PG AR	CT Mm	RP Kg cm^{-2}	BD Mg m^{-3}	Clay	Silt	Sand
				%		
Control	3.55	2.00	1.63	63.5	36.0	0.5
5%	2.50	1.65	1.53	62.9	36.1	1.0
10%	1.45	1.30	1.42	57.4	39.0	3.6

When comparing the crust PR between the two soils, it was found that the crust RP was low in clay soil compared with silty clay soil at both periods. This is maybe due to the high adhesion strength of silty clay particles which increases RP. These results agreed with what Robinson and Philips (2001) found, that the sealing will characterized by small particles on the surface, sparse large pores, high bulk density and sometimes a laminar structure due to the particles stratification and orientation and as the result the soil surface will be more cohesive and more strength surface crusts, and therefore penetration resistance be high.

C- Crust Bulk Density:

Tables 2, 3, 4 and 5 show decreases in the BD with increasing of PG level. The values BD of control levels were 1.84 and 1.49 Mg m^{-3} in tables 2 and 3 as compared to 1.39 and 1.4 Mg m^{-3} of 10% PG, for clay and silty clay soils at the first period. Similarly, in the second period as in tables 4 and 5, the BD of the crust decreased as increasing of PG rates. The largest BD values were 1.63 and 1.58 Mg m^{-3} for control levels and the lower values were 1.42 and 1.41 Mg m^{-3} for 10% of PG for clay and silty clay soils. The results also showed that the crust BD of silty clay soil was more decreased than that of clay soil at the level 10% PG. These results are similar to findings of Gal et al. (1984) and Van der and Claassens (1990).

The obtained results may attributed to the positive effects of the PG for the protection of the soil surface from the direct effect of the rain drops and maintaining the soil aggregate stability, subsequently, reducing the continuous destruction of aggregates that lead to lowering the BD and improve the soil aeration.

Table (5): Some characteristics of the soil surface crust (silty clay soil the second period)

characteristics / PG AR	CT mm	RP Kg cm^{-2}	BD Mg m^{-3}	Clay	Silt	Sand
				%		
Control	3.85	1.90	1.58	61.4	27.5	13.6
5%	3.00	1.45	1.52	59.9	25.0	16.1
10%	1.95	1.15	1.41	57.5	26.4	16.1

D- Particles size distribution of soil crust:

When comparing the content of clay and silt with the content of sand in the crust at first period (Tables 2 and 3), it was observed high content of clay and silt and low content of sand in both soils. It was also observed decreasing in clay and silt content and increasing sand content in all added PG levels. It was more obvious in the first period compared to the second period. The clay percentage for silty clay soil in the second period (Tables 4 and 5) were 59.9 and 57.5% at the PG level 5% and 10% , while it was 61.0% in the control level, whereas the sand percentage were 16.1 and 16.1% at the PG level 5% and 10% respectively, while it was 13.6% in the control level . As for clay soil, the sand percentage were 1.0 and 3.0% at the PG level 5% and 10% respectively, while it was 0.5% in the control level. The increment of coarse soil fractions and reduction of fine fractions in the crust is may due to the role of PG in reducing dispersion of small parts and increasing of the soil stability. This may help reducing the motion of very soil fractions that contribute to crust formation (Agassi et al. 1986 and Van der and Claassens 1990).

2 - Wheat parameters:

A- Plant Height:

The results showed (Table 6) significantly increasing of plants height with increased PG levels. The heights were 41.33 and 41.3 cm at the level of 10% compared to control level that was 37.5 and 37.7 cm, respectively for clay and silty clay soils. The results suggesting that the addition of PG has improved the conditions of germination and then encouraged the vegetation growth.

B- Yield components:

All the yield component properties including spike length number of grains per spike and 1000-grains weight are improved by the addition of PG. The results in the table (7) showed an increase of spike length that were 4.8 and 4.7 cm at 10% level of PG as compared to control level that was 4.5 and 4.6 cm respectively for clay and silty clay soils.

At the same context, the number of grains per spike (Table 8) increased with an increment of PG level. The average numbers of grains in a spike were 19.67 grains per spike at the level of 10% in as compared with the numbers 18.27 and 18.2 grains per spike at the control level in the clay and silty clay soils, respectively.

The results of 1000-grains weight (Table 9) were also similar to other yield components results, the increasing of PG levels resulted in significant increase of 1000-grains weight. Weights of 1000-grains were 31.83 and 35.27g at the level of 10% PG in comparison with control that has weights of 30.3 and 28.8g for clay and silty clay soils, respectively. The addition of PG improves the number of grains per spike and 1000-grains weight. These results are agreed with that of Seker (2003) and Yasein and Juwier (2013) found.

On the other hand, no significant differences were found in all studied yield components within PG levels.

C- Dry Weight:

According to wheat crop parameters that mentioned above, it's self-evident the increment of dry weight. The results (Table 10) showed that the average dry plant weights were 3.5 and 4.8 g at the PG level of 10% as compared to 2.97 and 3.1 g of control for clay and silty clay soils respectively. This result is agreed with that’s of Seker (2003) who noticed that the dry weight increased when improved soil properties.

Table (6): Effect of PG on wheat plant height

Soil Texture	Treatments Level			Mean of Soil Textures
	Control	Level 5%	Level 10%	
Clay soil	37.50 b	44.40 a	41.33 ab	41.14 a
Silty clay soil	37.70 b	41.00 ab	41.30 ab	39.99 b
Mean of Treatments Levels	37.68 b	42.70 a	41.32 a	

Table (7): Effect of PG on spike length

Soil Texture	Treatments Level			Mean of Soil Textures
	Control	Level 5%	Level 10%	
Clay soil	4.50 a	4.77 a	4.80 a	4.69 a
Silty clay soil	4.60 a	4.73 a	4.70 a	4.68 a
Mean of Treatments Levels	4.55 a	4.75 a	4.75 a	

Table (8): Effect of PG on number of grains per spike

Soil Texture	Treatments Level			Mean of Soil Textures
	Control	Level 5%	Level 10%	
Clay soil	18.27 a	19.50 a	19.67 a	19.14 a
Silty clay soil	18.20 a	19.53 a	19.67 a	19.13 a
Mean of Treatments Levels	18.23 b	19.52 a	19.67 a	

Table (9): Effect of PG on weight of 1000 grain

Soil Texture	Treatments Level			Mean of Soil Textures
	Control	Level 5%	Level 10%	
Clay soil	30.30 d	31.53 c	31.83 c	31.22 b
Silty clay soil	28.80 e	33.00 b	35.27 a	32.36 a
Mean of Treatments Levels	29.55 c	32.27 b	33.55 a	

Table (10): Effect of PG on dry weight

Soil Texture	Treatments Level			Mean of Soil Textures
	Control	Level 5%	Level 10%	
Clay soil	2.97 c	3.33 b	3.50 b	3.27 b
Silty clay soil	3.10 a	4.15 a	4.80 a	4.02 a
Mean of Treatments Levels	3.04 c	3.74 ab	4.15 a	

References:

Agassi, M., I. Shainberg and J. Morin, (1986). Effect of powdered phosphogypsum on the infiltration rate of sodic soils. Irrig. Sci. 7: 53-61.

Blake, G. R. and K.H. Hartge, (1986). Bulk density.p.363-375. in A. Klute (ed.) Methods of soil analysis. Part 1: 2nd Ed. Agron, Monogr. 9.ASA and SSSA, Madison, W1.

Gal, M., L.Arcan, I.Shainberg and R.Keren, (1984). Effect of exchangeable Na and phosphogypsum on crust structure SEM observations. Soil Sci. Soc. Am. J. 48: 872-878.

Gee, G.W., and J.W. Bauder, (1986). Particle size analysis. In A. Klute (ed.) Methods of Soil Analysis, Part I. Am. Soc. Argon., Madison, Wisconsin. p:383-411.

Hurtado, M.D., S.M. Enamorado, L. Andreu, A. Delgado, and J. Maria, (2011). Drain flow and related salt losses as affected by Phosphogypsum amendment in reclaimed marsh soils from SW, Spain, Geoderma.161 (1-2): 43-49.

Mamedov, A.I. and G.J. Levy, (2001). Clay dispersivity and aggregate stability effects on seal formation and erosion in effluent irrigated soils. Soil Sci. 166:631–639.

McInter, D.S., (1958). Soil splash and the formation of surface crusts by rain drop impact. Soil Sci. 85:261-266.

Morin, J., Y. Benyamini and A. Michaeli, (1981). The effect of drop impact on the dynamics of soil surface crusting and water movement in the profile. J. Hydrol. 52: 321–335.

Robinson, D.A. and C.P. Philips, (2001). Crust development in relation to vegetation and agricultural practice on erosion susceptible, dispersive clay soils from central and southern Italy. Soil Till. Res., 60: 1–9.

Ryan, J., G. Estefan and A. Rashid, (2001). Soil and Plant Analysis Laboratory Manual. 2nd Ed. International Center for Agricultural Research in the Dry Areas (ICARDA) Aleppo, Syria.

Seker, C., (2003). Effects of selected amendments on soil properties and emergence of wheat seedlings. Can. J. Soil, Sci. 83(5):615-621

Steel, R.G.D. and J.H. Torrie, (1980). Principles and Procedures of Statistics. A biometerecal approach. McGraw-Hill, NY. 2nd (ed.), p.633.

Toma, M. and M. Saigusa. (1997). Effects of phosphogypsum on amelioration of strongly acid nonallophanic Andosols. Plant and Soil 192: 49–55.

Van der W. H., and .A.S.Claassens, (1990). Effect of surface treatments on soil crusting and infiltration. Soil Techno. 3(3):241-251

Yasein, A.F. and K.A. Juwier, (2013). Effects interaction of phosphogypsum levels, irrigation water salinity, and cotton cultivars on some chemical characteristics of soil affected with saline. Al Anbar J. Agric. Sci. 11(2):150-167.