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Anthropogenic Impact of Leaching on Gypsiferous Soils

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A POT EXPERIMENT had been conducted in the greenhouse of the National Research Centre in order to investigate the suitability of gypsiferous soils for plant growth. The selected soils, for this experiment, were different in their soil characteristics specially gypsum, calcium carbonate and soluble salts contents. The experiment design comprised control and leaching treatments. Maize and barley were the crop indicators and the germination percentages as well as dry weight of the harvested plants were the measurable parameters of the current study.

The obtained results showed that the leaching of gypsiferous soils improved their chemical characteristics. The maize germination percentages of the control treatment varied between 43 and 90%, while they ranged between 70 and 98% for the soils which were under the leaching treatment. However, barley germination percentages ranged between 50 and 93% for control treatment and between 70 and 100% for the leaching treatment.

The current study revealed clearly that the influence of the soluble salts that associate with gypsum in most of the gypsiferous soils is remarkable on the plant growth. Moreover, the obtained results could indicate that the continuous cultivation of the soil would lead to improve its physicochemical properties.

Gypsiferous soils are soils that contain sufficient quantities of gypsum (calcium sulphate) to interfere with plant growth. Soils with gypsum of pedogenic origin are found in regions with ustic, xeric and aridic moisture regimes (Nettleton *et al.*, 1982). They are well represented in dry areas where sources for the calcium sulphate exist. They do not usually occur under wet climates. Moreover, most natural gypsiferous soils are also saline therefore, leaching is necessary to keep the salt content low. In most cases the gypsum is associated with other salts of calcium and salts of sodium and magnesium.

Although, the impact of gypsum content on plant growth is well known, it has been found that the associated soluble salts have a great influence on the plants too. Aziz (2004), showed that the total soluble salts greatly inhibit germination in the soil. Minashina (2005), explained that an increase in the soil water content leads to changes in the salt composition of the solution where the portion of calcium sulphate increases due to gypsum dissolution. The further dilution of solution, during the soil leaching procedures, may lead to the appearance of magnesium sulphate as a result of the reaction between magnesium bicarbonate and calcium sulphate with precipitation of calcium carbonate.

In order to investigate such influence, a pot experiment had been conducted in the greenhouse of the National Research Centre using different 8 soils. They were collected from different localities in Egypt and they were different in soil characteristics where they had various levels of gypsum, calcium carbonate and soluble salts contents. A leaching process was carried out on all the selected soil samples in the current experiment. The pots were sowed with maize followed by barley.

Material and Methods

Soil profiles

Five soils profiles were selected from various regions in Egypt. A soil profile was dug at each location to the hard rock or water table. The soil profiles were then thoroughly examined, morphologically described and the physiographic features of the location were identified according to FAO Guidelines for Sol Description (2006).

Soil samples

Eight soil samples were chosen, air-dried, sieved throw 2mm sieve and undergone various laboratorial analyses to determine some of their physic-chemical properties as follows:

1) The soil reaction (pH) was measured according to Rhoades (1982).
2) Soil salinity was determined following Black *et al.* (1982).
3) Total carbonates were estimated using the Schreiber's calcimeter after Nelson (1982).
4) Gypsum content was determined.

5) Soluble cations and anions were determined according to Black *et al.* (1982).

Planting experiment

A number of 8 soil samples were collected from various localities in Egypt. The collected samples are different in their soil characteristics special gypsum, calcium carbonate and soluble salts contents. The experiment design comprised the selected 8 soil samples in triplicates and two groups of pots. The first group was used without any treatment as a control. The soil of the second group of pots were undergone a leaching process which has carried out at six intervals over a period of 45 days. All pots were sowed with maize followed by barley where they grow for 40 days. Observations were recorded on germination percentage and dry weight of the grown plants. Obtained data were statistically analyzed according to Snedecor & Cachran (1967) and the LSD at 0.01 level was used for comparison between treatments.

Results and Discussion

Soil characterization

The studied soil samples were collected from different 5 soil profiles and characterized by different contents of gypsum, calcium carbonate and total soluble salt concentrations, (Table 1). The soils nos. 1, 2, 3, 7 and 8 had high gypsum content varied from 17.2 to 86.0%, whereas the soils nos. 4, 5 and 6 had low gypsum content between 2.8 and 5.5%. The soils nos. 1, 4, 7 and 8 were very saline where the EC of the soil paste water extract ranged from 21.3 to 116.5 dS/m. The soils nos. 2, 3, 5 and 6 were moderately saline as the EC values fluctuated between 3.9 and 5.6 dS/m. Soil no. 6 was the only one had high calcium carbonate content (14.8%). The soil texture varied from loam to loamy sand.

TABLE 1. Some physicochemical properties of the studied soils.

Sample No.	Sp	pH (1:1)	EC dS/m	Soluble cations meq/l				Soluble anions meq/l			$CaCO_3$ %	Gypsum %	Texture class
				Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	Cl^-	SO_4^-			
1	20.0	8.4	21.3	110.1	5.3	73.0	36.0	0.3	119	105	2.0	86.0	Gypsic layer
2	17.5	8.5	5.6	36.2	2.8	8.0	13.0	0.2	44	16	2.3	17.2	Loamy sand
3	26.3	8.3	5.2	13.5	1.9	9.0	11.0	0.3	19	16	1.3	17.3	Loam
4	15.0	8.3	59.1	420.7	8.3	35.3	138.0	0.2	498	104	0.8	2.8	Loamy sand
5	16.7	8.5	3.9	11.8	1.5	8.0	10.0	0.1	20	11	3.0	3.4	Loamy sand
6	21.7	8.2	4.3	10.6	1.3	7.0	9.5	0.2	18	11	14.8	5.5	Sandy loam
7	16.7	8.4	116.5	892.1	9.1	125.0	202	0.2	1080	148	2.5	24.1	Loamy sand
8	22.0	8.2	86.6	595.2	7.8	143.0	215.5	0.1	740	221	1.8	60.2	Gypsic layer

Following the keys to soil taxonomy (USDA, 2006), the selected soil profiles were classified (Table 2) according to their morphological features and laboratory analytical data as follows:

Profile no. 1 as Petrogypsic Haplosalids.
Profile nos. 2 and 5 as Gypsic Haplosalids.
Profile nos. 3 and 4 as Typic Haplosalids.

TABLE 2. Soil profile location and classification.

Soil profile					Soil sample No.
No.	**Location**	**Land use of represented area**	**Classification**	**Layer No.**	
1	El-Ismaillia	Non cultivated	Petrogypsic Haplosalids	1	1
2	El-Ismaillia	Cultivated	Gypsic Haplosalids	1	2
				2	3
3	Wadi El Natroun	Non cultivated	Typic Haplosalids	1	4
4	North of Tahrir	Cultivated	Typic Haplosalids	1	5
				2	6
5	El Fayoum	Non cultivated	Gypsic Haplosalids	1	7
				2	8

Leaching experiment

The results which are illustrated in Fig. 1, show that leaching removed most of soluble salts out of the soils under investigation. However, they had responded variably to leaching. Although soil no. 7 had initially higher soluble salts concentration (116.5 dS/cm) than soil no. 8 (86.6 dS/cm) and soil no. 4 had higher soluble salts (59.1 dS/cm) than soil no. 1 (21.3 dS/cm), at the end of the leaching process, the soils nos. 4 and 7 contained less soluble salts concentration than soils nos. 1 and 8. The reason may be due to the higher gypsum contents of the soils nos. 1 and 8 (86.0 and 60.2%, respectively), than soils nos. 4 and 7 (2.8 and 24.08%, respectively). The ratios between soluble univalent salts and bivalent ones were narrow in the case of soils nos. 1 and 8 whereas, they were wide in the case of soils nos. 4 and 7.

The linear regression equations, which represent the leaching process of the soils, are as follows:

Soil 1: $Y = 22.12 - 2.34X$ ($R^2 = 0.979$)

Soil 4: $Y = 60.10 - 7.86X$ ($R^2 = 0.949$)

Soil 7: $Y = 130.30 - 16.91X$ ($R^2 = 0.981$)

Soil 8: $Y = 89.00 - 5.28X$ ($R^2 = 0.975$)

These equations revealed that soils nos.1 and 8 behaved similarly in the leaching process (regression lines are nearly parallel), although soil no. 1 had higher gypsum content (86%) and less soluble salts (21.3 dS/cm) than soil no. 8. The slopes of the two linear equations of soils nos. 1 and 8 are low as compared with the slopes for the soils nos. 4 and 7. The last two soils showed faster removal action of the soluble salts through leaching than the first ones. These results could be attributed to the different gypsum contents and crystal forms as well as their distribution in the soil fabric.

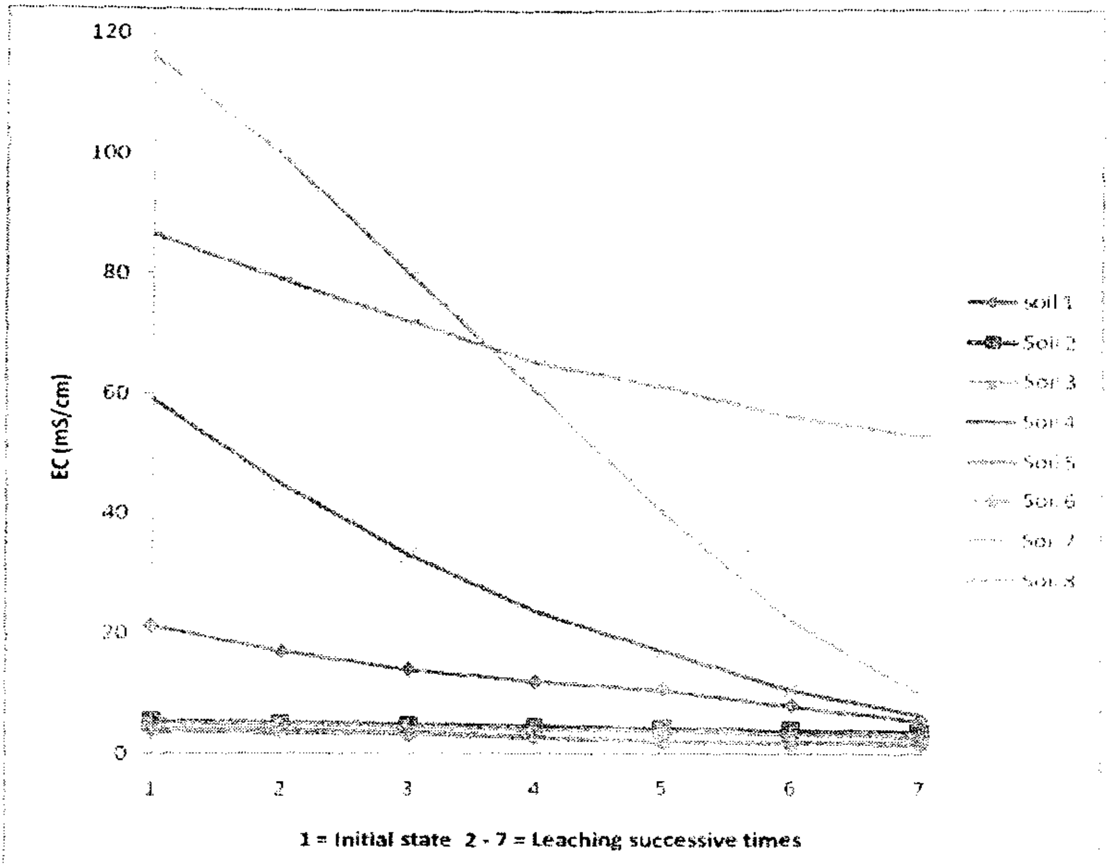

Fig. 1. Leaching Experiment.

Planting experiment

It could be noticed that soil salinity levels were decreased at the end of the cultivation period (40 days) as they compared with the corresponding ones of the control treatment, (Tables 3 and 4). Maize was the first crop to be planted after the soil leaching intervals were completed. Data in Table 3 show that maize germination percentages were increased with the decrease of the soluble salts concentration in the soils. While, the germination was nil in the soils nos. 4,7 and 8 under the control treatment, it reached to 97,70 and 0% under leaching, respectively. The germination percentage of the control treatment varied between 43 and 90%, while it ranged between 70 and 98% for the soils which were under the leaching treatment. The dry weight of the harvested plants was between 4.24 and 7.56 g/pot in the case of control treatment and it became between 6.90 and 12.39 g/pot under leaching treatment. The statistical analysis revealed that there is highly significant negative correlation coefficient between the soluble salts content and the germination percentage of maize (-0.83 for the control treatment and -0.96 for the leaching treatment). The high values of germination percentages of the control treatment could be due to that some of the selected samples were taken from gypsiferous soils which were under cultivation long time ago.

Barley was the following plant to be sowed in the experiment. Table 4 presents the average values of the obtained data which manifested higher germination percentages than those of maize experiment where, it ranged between 50 and 93% under control treatment and between 70 and 100% under leaching treatment. Dry weight values were also increased as they compared with maize dry weight values. They reached 4.2 to 6.77 g/pot for the control treatment and 4.33 to 17.52 g/pot for leaching treatment. Highly significant negative correlation coefficients between the soluble salts content and the germination percentage were computed (-0.89 and -0.97 for the control and leaching treatments, respectively) for barley experiment.

TABLE 3. Average values for maize experiment (First cultivated crop).

Soil No.	EC (dS/m)		Germ. (%)		Dw (g/pot)		Linear regression equation	Correlation Coefficient
	C	L	C	L	C	L		
1	20.60	4.05	43	73	4.24	6.90	**Control treatment:** Germ.% = 74.4071– 0.8504 EC*** Dw g/pot= 5.9312 – 0.0670 EC***	-0.8316 -0.8307
2	4.36	3.87	80	97	6.39	10.89		
3	3.53	2.36	83	97	6.83	11.01		
4	27.50	2.70	0	97	0.00	11.87		
5	2.46	1.30	87	98	5.70	12.39	**Leaching treatment:** Germ.% = 95.8324 – 1.9745 EC*** Dw g/pot= 11.0139 – 0.2279 EC***	-0.9590 -0.9164
6	1.39	1.40	90	95	7.56	10.45		
7	108.20	5.55	0	70	0.00	8.48		
8	82.55	49.20	0	0	0.00	0.00		

Germ. = Germination
Dw. = Dry weight

TABLE 4. Average values for Barley experiment (Second cultivated crop).

Soil No.	EC (dS/m)		Germ. (%)		Dw (g/pot)		Linear regression equation	Correlation Coefficient
	C	L	C	L	C	L		
1	15.74	2.71	50	92	4.20	11.64	**Control treatment:** Germ.% =83.6520 – 1.6282 EC *** Dw g/pot= 6.0876 – 0.1174 EC ***	-0.8789 -0.8818
2	3.69	2.13	85	100	6.10	17.11		
3	3.15	2.20	90	95	6.43	16.34		
4	25.35	1.60	0	96	0.00	16.80		
5	1.35	1.05	93	98	6.77	16.92	**Leaching treatment:** Germ.% = 98.9930 - 3.1797 EC *** Dw g/pot= 15.9677 - 0.5207 EC ***	-0.9662 -0.8725
6	1.30	0.74	90	100	6.39	17.52		
7	66.85	2.65	0	70	0.00	8.33		
8	42.80	31.25	0	0	0.00	0.00		

Germ. = Germination
Dw. = Dry weight

LSD analysis

Although the variability of the soils under investigation, the LSD analysis, (Tables 5-10) revealed that there was a clear distinction between two groups of the soils. The first group comprised the soils nos. 1,4,7 and 8 which were characterized by high soluble salts accumulation whereas the second group contained the soils nos. 2, 3, 5 and 6 that had low soluble salts contents. This distinction was reflected on the germination percentages of maize under the control treatment where, the first group of soils showed no germination except for the soil no. 1 that showed the lowest percentage (43%).

TABLE 5. LSD for EC of Control – Maize.

Ranking	Soil no.	Mean	Non–significant range
1	7	108.20	a
2	8	82.55	b
3	4	27.50	c
4	1	20.60	d
5	2	4.36	e
6	3	3.53	e
7	5	2.46	e
8	6	1.39	e
LSD 0.01= 2.9075 Error sum square= 1.4863.			

TABLE 6. LSD for germination of Control – Maize .

Ranking	Soil no.	Mean	Non–significant range
1	6	90	a
2	5	87	ab
3	3	83	ab
4	2	80	b
5	1	43	c
6	4	0	d
7	7	0	d
8	8	0	d
LSD 0.01= 6.0801 Error sum square= 6.5			

TABLE 7. LSD for dry weight of Control – Maize .

Ranking	Soil no.	Mean	Non–significant range
1	6	7.56	a
2	3	6.83	ab
3	2	6.39	bc
4	5	5.72	c
5	1	4.24	d
6	4	0.00	e
7	7	0.00	e
8	8	0.00	e
LSD 0.01= 0.8893 Error sum square= 0.1391			

TABLE 8. LSD for EC of Leaching – Maize.

Ranking	Soil no.	Mean	Non–significant range
1	8	49.20	a
2	7	5.55	b
3	1	4.05	c
4	2	3.87	c
5	4	2.70	cd
6	3	2.36	d
7	6	1.40	d
8	5	1.30	d
LSD 0.01= 1.2414 Error sum square= 0.2710.			

TABLE 9. LSD for germination of Leaching – Maize.

Ranking	Soil no.	Mean	Non–significant range
1	5	98	a
2	2	97	a
3	3	97	a
4	4	97	a
5	6	95	a
6	1	73	b
7	7	70	b
8	8	0	c
LSD 0.01= 3.3726 Error sum square= 2.00			

TABLE 10. LSD for dry weight of Leaching – Maize.

Ranking	Soil no.	Mean	Non–significant range
1	5	12.39	a
2	4	11.87	ab
3	3	11.01	bc
4	2	10.89	bc
5	6	10.45	c
6	7	8.48	d
7	1	6.90	e
8	8	0.00	f
LSD 0.01= 1.0046 Error sum square= 0.1775			

The germination percentages of the second group of soils varied between 80 and 97% under the control treatment.

Under leaching treatment, this distinction had been found between the soil no. 8 which showed no germination and all other soils of the current experiment that experienced germination percentages fluctuated between 70 and 98%. However, the lowest values were recorded for the soils nos. 1 and 7 and could be attributed to their high gypsum contents (86 and 24%, respectively). The germination absence of soil no. 8 could be due to its the high soluble salts concentration which was still too high after leaching as well as its high gypsum content. Consequently, the dry weight of the grown plants under the leaching treatment recorded higher values than those of the control treatment. It could be noticed that soils nos. 2 and 3 had relatively high gypsum contents of almost 17% and that did not inhibit the plant growth, but even they showed high germination percentages of the first cultivated crop under both control and leaching treatments. The soil no. 6 showed high germination percentages under different treatments, although it had high lime content which was determined to almost 15%.

These results prove an improvement of the soil properties, specially the soil salinity level.

The LSD analysis, (Tables 11-16), showed that the clear distinction between the first group of soils nos. 1, 4, 7 and 8 and the second group of soils nos. 2, 3, 5 and 6, continued for the control treatment under barley cultivation. However, the germination percentages were increased for both control and leaching treatments, as they compared with those under maize cultivation. This result is evidently attributed to the successive cultivation of the soil which could lead to improvement of its physicochemical properties.

Under leaching treatment, this distinction was found as that under maize cultivation between the soil no. 8 and all other soils that recorded germination percentages of 70 to 100%. The lowest values were also found for the soils nos. 1 and 7 and could be due to their high gypsum contents. However, the nil germination for soil no. 8 may be attributed to the high contents of soluble salt and gypsum. The dry weight as well showed an increase for barley cultivation under leaching treatment. The results of the current experiment revealed that the soil conditions had been improved by leaching.

It can be concluded, according to the results of the current study, that the soluble salts that associate with gypsum have remarkable effect on the plant growth either as using the seedling rate percentage or the dry weight of the plants as indicators for soil properties improvement. Accordingly, leaching of the gypsiferous soils has improving impact on the soil properties depending on the soil conditions such as, texture, structure, gypsum content and crystal forms, soluble salts content and type as well as lime content.

The obtained results showed that the impact of soil gypsum on leaching process as well as plant growth depends not only on its content but also on its form. Similar results were attributed by Aziz (2004), to the gypsum form. She explained that the soil with high gypsum content (31%) could support high germination percentage (90%) due to the intercalary gypsum crystal form and very small granules besides some intergrowth grains. These forms of gypsum besides porphyric fabric of soils permit small roots to penetrate in the soil and absorb water and nutrients as well which enable convenient conditions for plant growth. On contrary, the soil with low gypsum content (3%) gave lower germination than the one that had high gypsum content due to the influence of small crystallites of gypsum scattered in the groundmass forming the chitonic related distribution. This may, also, explain the different effect of leaching on the studied soils. Moreover, the calcium carbonate content had no significant effect on the plant growth.

TABLE 11. LSD for EC of Control – Barley.

Ranking	Soil no.	Mean	Non–significant range
1	7	66.85	a
2	8	42.80	b
3	4	25.35	c
4	1	15.74	d
5	2	3.69	e
6	3	3.15	e
7	5	1.35	e
8	6	1.30	e
LSD 0.01= 3.9989 Error sum square= 3.8117			

TABLE 12. LSD for germination of Control – Barley.

Ranking	Soil no.	Mean	Non–significant range
1	5	93	a
2	3	90	a
3	6	90	a
4	2	85	b
5	1	50	c
6	4	0	d
7	7	0	d
8	8	0	d
LSD 0.01= 4.1306 Error sum square= 3.000			

TABLE 13. LSD for dry weight of Control – Barley.

Ranking	Soil no.	Mean	Non–significant range
1	5	6.77	a
2	3	6.43	ab
3	6	6.39	ab
4	2	6.10	b
5	1	4.20	c
6	4	0.00	d
7	7	0.00	d
8	8	0.00	d
LSD 0.01= 0.3928 Error sum square= 0.0271			

TABLE 14.LSD for EC of Leaching – Barley.

Ranking	Soil no.	Mean	Non–significant range
1	8	31.25	a
2	1	2.71	b
3	7	2.65	b
4	3	2.20	b
5	2	2.13	b
6	4	1.60	b
7	5	1.05	b
8	6	0.74	b
LSD 0.01= 1.564 Error sum square= 0.43			

TABLE 15. LSD for germination of Leaching – Barley.

Ranking	Soil no.	Mean	Non–significant range
1	2	100	a
2	6	100	a
3	5	98	ab
4	4	96	ab
5	3	95	bc
6	1	92	c
7	7	70	d
8	8	0	e
LSD 0.01= 3.2655 Error sum.square= 1.875			

TABLE 16. LSD for dry weight of Leaching – Barley.

Ranking	Soil no.	Mean	Non–significant range
1	6	17.52	a
2	2	17.11	ab
3	5	16.92	abc
4	4	16.80	bc
5	3	16.43	c
6	1	11.64	d
7	7	8.33	e
8	8	0.00	f
LSD 0.01= 0.5250 Error sum square= 0.0485			

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التاثير البشرى لغسيل الأراضى الجبسية

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الأراضى الجبسية فى مصر هى الأراضى التى تحتوى على نسبة عالية من الجبس (كبريتات الكالسيوم). و يهدف هذا البحث الى دراسة ملائمة الأراضى الجبسية لنمو النبات، ولتحقيق هذا الهدف أجريت تجربة أصص فى صوبة المركز القومى للبحوث وتم اختيار عينات الأراضى لهذه التجربة ذات صفات مختلفة خاصة محتواها من الجبس وكربونات الكالسيوم و الاملاح الكلية الذائبة. وتم اختيار محصولى الذرة والشعير كدليل لنسبة الإنبات وكذلك الوزن الجاف. وتوضح النتائج المتحصل عليها ان غسيل الأراضى الجبسية أدى الى تحسن الخواص الفيزيوكيماوية لهذه الأراضى وان نسبة الإنبات فى محصول الذرة فى معاملة الكنترول تراوح ما بين ٤٣ الى ٩٠ ٪ بينما فى معاملة الغسيل كان من ٧٠ الى ٩٠٪ ، علاوة على ذلك فإن نسبة الإنبات فى محصول الشعير تراوحت ما بين ٥٠ الى ٩٣ ٪ فى معاملة الكنترول وبين ٧٠ الى ١٠٠ ٪ فى معاملة الغسيل. ولقد بين هذا البحث تأثير الأملاح الكلية الذائبة المصاحبة للجبس فى معظم الأراضى الجبسية على نمو النبات بالإضافة إلى ذلك فإن النتائج المتحصل عليها تدل على أن استمرار الزراعة فى هذه الأراضى يؤدى إلى تحسن الخواص الفيزيوكيماوية لها.