4-RESULTS AND DISCUSSION

4.1- Gypsum content of the studied soils:

One purpose of the current study aims to assessing the different methods which can be followed to determine various contents of gypsum to reach the most reliable values which will help in understanding the behavior of gypsic soils.

Gypsum of the studied soil samples was extracted by a soil : water ratio 1:500, as most of the investigated soils are very rich in their gypsum content. The selected four methods were conducted to determine the gypsum content of all soil samples which represent various layers of the sixteen studied soil profiles. Table (1) shows the primary data including total acidity and sulphate concentrations according to the strong acid resin method and the calculated percent of gypsum content. The same Table contains the chloride concentration, which has been determined by this method, as it is subtracted from the total acidity in order to get the sulphate concentration. Gypsum content of the studied soil samples, according to the four different analytical methods, are recorded in Table (2). Data show some differences between the obtained results of the same soil sample, which can be attributed to the determination methods. Therefore, ANOVA randomized complete blocks analysis had been carried out in order to find out the variabilities between different gypsum determination methods. Table (3) shows the differences between the applied methods. The statistical analysis shows that the differences between the obtained gypsum content percentages of the studied soil samples by applying different determination methods are true. A highly significant differences between the applied methods are recorded where the calculated F value for methods exceeds the tabulated ones (11.04 and 3.95, respectively) at 0.01 level. The Student-Newman-Keuls Test (Table 4) indicates that the increase of soluble calcium and magnesium (Ca+Mg) method is significantly different from the others. Although the mean values of the gravimetric, acid resin and acetone methods are 33.75, 33.41 and 30.42, respectively, the first two methods remain the most reliable methods for determining gypsum content in soils.

Table (1): Total acidity, sulphate concentrations and gypsum content in percentage based on the strong acid resin method.

Profile No.	Location	Depth In cm	Total acidity Meq/g soil	Chloride Meq/g soil	Sulphate Meq/g soil
1	El-Fayoum	0-30	3.25	0.89	2.36
		30-60	4.09	0.71	3.38
		60-200	3.89	0.44	3.45
2	El-Minia	0-20	2.50	0.10	2.40
		20-40	1.85	0.02	1.83
		40-70	1.19	0.04	1.15
		70-100	0.70	0.05	0.65
3	El-Minia	0-85	3.99	0.32	3.67
		>85	3.70	0.41	3.29
4	Wadi El-Farigh	0-20	0.20	0.10	0.10
		20-60	2.20	0.46	1.74
		60-110	0.55	0.11	0.44
		110-150	0.05	0.02	0.03
5	Wadi El-Natron	0-20	0.10	0.04	0.06
		20-70	3.05	0.60	2.45
		70-110	2.05	1.17	0.88
6	Hurghada	0-20	1.15	0.19	0.96
		20-50	6.30	0.07	6.23
		50-100	6.57	0.08	6.67
7	Hurghada	0-20	0.85	0.09	0.76
		20-50	5.75	0.12	5.63
		50-100	5.99	0.11	5.88
8	Dihbbah	0-10	1.45	0.15	1.30
		15-20	6.14	0.23	5.91
		20-120	1.75	0.14	1.61
9	Abo-Shrouf	0-30	6.39	0.25	6.14
		30-120	4.65	0.13	4.52
10	Gabal El-Dakrour	0-20	3.70	0.36	3.34
		20-80	1.90	0.19	1.71
		80-140	0.40	0.06	0.34
11	Ismailia	0-20	9.55	0.25	9.30
		20-40	9.45	0.09	9.36
		40-60	6.90	0.03	6.87
12	Ismailia	0-20	11.10	0.38	10.27
		20-40	10.05	1.00	9.05
13	Ismailia	50-80	9.57	0.01	9.56
14	Ismailia	0-35	9.07	0.02	9.05
		35-60	10.75	0.21	10.54
15	Gerza	15-55	3.65	0.36	3.29
		55-100	3.80	0.05	3.75
16	Beni-Suef	0-70	1.40	0.07	1.33
		70-150	1.65	1.42	0.23

Table (2): Gypsum contents in percentage for the studied soil samples by different determination methods.

Profile No.	Location	Depth in cm	Gypsum %			
			Resin	Acetone	Ca+Mg	Gravimetric
1	El-Fayoum	0-30	20.30	20.70	10.49	23.43
		30-60	29.10	24.50	18.10	26.51
		60-200	29.70	38.70	20.23	27.91
2	El-Minia	0-20	20.60	15.20	9.28	21.64
		20-40	15.74	12.80	10.90	14.30
		40-70	9.98	19.80	9.29	10.50
		70-100	5.59	7.10	9.18	10.32
3	El-Minia	0-85	31.60	34.40	29.10	26.80
		>85	28.29	34.40	20.65	25.69
4	Wadi El-Farigh	0-20	0.86	3.10	5.98	3.51
		20-60	14.96	8.30	10.19	15.38
		60-110	3.78	3.90	1.68	9.58
		110-150	0.26	3.10	0.86	3.30
5	Wadi El-Natron	0-20	0.52	4.20	3.80	6.54
		20-70	21.07	22.00	13.09	16.21
		70-110	7.57	20.17	6.80	11.33
6	Hurghada	0-20	8.26	2.10	3.15	9.12
		20-50	53.57	40.15	24.64	47.80
		50-100	57.40	47.30	50.29	59.10
7	Hurghada	0-20	6.57	17.20	5.86	10.31
		20-50	48.40	43.00	38.10	43.04
		50-100	50.60	43.00	33.70	47.16
8	Dihbbah	0-10	11.18	23.10	7.11	25.24
		15-20	50.90	38.60	28.05	46.05
		20-120	13.85	16.80	10.25	18.51
9	Abo-Shrouf	0-30	52.80	48.20	39.61	45.04
		30-120	38.87	31.00	28.75	26.07
10	Gabal El-Dakrour	0-20	28.72	15.00	11.16	18.05
		20-80	14.71	16.80	10.07	18.14
		80-140	2.92	12.80	3.44	7.18
11	Ismailia	0-20	79.98	74.10	37.38	80.30
		20-40	80.50	76.00	22.63	81.60
		40-60	59.08	26.80	38.20	60.25
12	Ismailia	0-20	92.19	18.20	8.42	90.82
		20-40	77.83	73.50	7.47	80.90
13	Ismailia	50-80	82.20	76.54	67.10	80.82
14	Ismailia	0-35	77.80	68.80	74.46	73.68
		35-60	90.64	81.70	95.67	90.30
15	Gerza	15-55	28.29	27.52	18.88	27.82
		55-100	32.25	25.80	35.79	38.78
16	Beni-Suef	0-70	11.44	31.11	29.89	19.53
		70-150	12.21	30.05	8.89	18.79

Table (3): One way ANOVA Randomized Complete Blocks

Source	SS	df	MS	F	P
Blocks	83956.03	41	2047.71	17.58	0.0000***
Main Effect Method	3856.40	3	1285.47	11.04	0.0000**
Error	14327032	123	116.48		
Total	102139.75	167			

Table (4): Student-Newman- Keuls Test

Factor :Methods	Rank	Trt.	Mean	N	0.01	0.05
Error Mean Square=116.48	1	4	33.75	42	A	A
Degrees=123	2	1	33.41	42	A	A
Significant level=0.01	3	2	30.42	42	A	A
LSD 0.01= 6.16202 / 0.05 = 4.6619	4	3	21.87	42	B	B

The correlation coefficients between the four different methods were then calculated based on the results of the 42 soil samples, (Table 5). These data reveal that the highest correlation coefficient value was obtained when the results of the acid resin method were compared with those of the gravimetric method. However, the lowest correlation coefficient value occurred between the results of the increase of soluble calcium and magnesium method and those of the gravirmetric method.

Table (5): Correlation coefficient values of different determination methods' results.

Determination Methods	Correlation coefficient
Resin vs Acetone	0.8529
Resin vs Ca+Mg	0.7126
Resin vs Gravimetric	0.9839
Acetone vs Ca+Mg	0.7656
Acetone vs Gravimetric	0.8552
Ca+Mg vs Gravimetric	0.6942

In order to estimate the efficiency of the applied determination methods at different gypsum content levels, correlation coefficient was calculated for gypsum content levels.

Data in Table (6) show clearly that the highest significant correlation coefficient values are obtained for the determined gypsum content by the strong acid resin method versus that determined by the gravimetric method. In this respect the values are 0.8515, 0.8480, 0.8165, 0.8720, 0.8736, 0.9029, 0.9580, 0.9741, 0.9795 and 0.9839 for soil gypsum contents levels ranging from less than and equals 5% to 100% as shown in Table (6). Generally, the correlation coefficient values increased with the increase of both numbers of observations and the soil gypsum content. On the other hand, although the correlation coefficients of the other two methods show some significance, they decrease with the increase of both number of observations and the soil gypsum content especially in case of increase soluble calcium and magnesium method.

Table (6): Correlation coefficients of the results of various methods Versus gravimetric method at different soil gypsum content levels.

Methods	<&=5%	<&=10%	<&=20%	<&=30%	<&=40%	<&=50%	<&=60%	<&=80%	<&=90%	<&=100%
Resin vs Gravi.	0.8515	0.8480	0.8165	0.8720	0.8736	0.9029	0.9580	0.9741	0.9795	0.9839
Acetone vs Gravi.	0.3333	0.6208	0.7402	0.8056	0.7875	0.8246	0.8286	0.9157	0.9370	0.8552
Ca+Mg vs Gravi.	0.2574	0.5125	0.5608	0.7182	0.8089	0.8515	0.8974	0.7483	0.7458	0.6942

Due to the fact that the soil samples are so variable in their gypsum content, a statistical analysis had been performed in order to find out the most appropriate method for determining the gypsum content based on its percentage. Therefore, the correlation coefficient had been calculated to different gypsum content ranges (Table 7).

Table (7): Correlation coefficients of the results of various methods Versus gravimetric method for some soil gypsum content ranges.

Methods	>0-20%	>20-40%	>40-100%	>0-100%
Resin vs Gravi.	0.8165	0.5308	0.9882	0.9839
Acetone vs Gravi	0.7402	0.4689	0.5127	0.8552
Ca+Mg vs Gravi	0.5608	0.8083	0.1835	0.6942

The highest correlation coefficient is obtained for the results of the strong acid resin method as they are correlated with those of the gravemetric method over the whole number of observations and the gypsum content which between >0 – 100%. However, lower value the correlation coefficient was obtained at the range >20 – 40% of gypsum. The correlation coefficient value is higher at the gypsum content ranges between >40 – 100% than that of the range >0 – 20%.

The soil gypsum contents obtained by acetone method are highly correlated with those determined by the gravimetric method up to content range between >0-20% (Table 7). The results of the studied soils that have more than 20% of gypsum are less significant when they are correlated with those obtained from gravimetric methods.

Concerning the determination of gypsum in soils by applying the increase of soluble calcium and magnesium (Ca+Mg) method, the highest correlation coefficient value is obtained when its results are correlated with those of the gravimetric method, at gypsum content ranges between >20 – 40%. While the lowest and insignificant value is occurred at gypsum content ranges between >40 –100%.

Significant correlation coefficients are computed for the results of Ca+Mg method when they correlated with the other three methods up to the content range between 40-60% of gypsum, (Table 7).

It can be concluded that the strong acid resin method is more reliable than the acetone as well as increase of soluble calcium and magnesium methods in determining soil gypsum, as it has the highest correlation coefficient value among the above mentioned methods.

4.2.The Diagnostic Features of the Gypsic Soils:

The gypsic soils are distributed over a considerable area all over the world under various environmental conditions. They may exist in several geological sediments, either recent or old ages alluvium and consequently various lithology. Gypsum accumulation may occur under Mediterranean desertic, tropical or subtropical and dry climate. Therefore natural vegetation have a wide range and several species particularly trees and grasses.

The estimated area of gypsiferous soils in Africa, as recorded by **(FAO, 1990),** is 35774 km^2 and in Egypt about 382.2 km^2.

The soils rich in gypsum content were observed in several geographic units in Egypt in the Nile Valley and Deserts . Therefore a detailed identification of the properties of such soils and the impact of gypsum accumulation on plant growth were studied in this investigation.

The physiographic descriptions of 16 representative profiles are recorded through the morphological observations in the field, (Appendix 1). Most of the sampled profiles are originated from calcareous and shale deposits. These profiles are characterized by deep solum and well drainage except Ismailia region (profiles no. 13 and 14) which is characterized by high water table level.Natural vegetations are scarce under such conditions and cultivated areas are covered with olive trees as in profiles no. 4 and 5 at Wadi El Farigh and Wadi El Natrun. However, soils of El Minya (photo 1) are cultivated with some field crops (wheat, clover and vegetables) since 10 years.

The texture of the studied profiles are mostly medium texture ranging from sandy loam to silty clay loam, (Table 8). However, surface layers of pure sand were observed in Ismailia area (profile no. 13) which is transported to overcome the wet conditions in this site. The grain – size analysis was difficult to be conducted on the hard cemented gypsic horizons as in profiles no. 6,7,11,12,13,14 and 15 (surface layer).

Lime content in the studied profiles has a wide range, from 0.04 to 35.56 % which could be observed clearly in the field as white concretions giving various reaction with HCl. In some cases the precipitation of $CaCO_3$ is cemented with gypsum forming large aggregates (photo 2 profile no. 3).

The accumulation of gypsum as a general characteristic of these profiles takes different forms. The powdery form, needle crystals and platy gypsic layers

Photo (1), Profile no. 2, EL-Minya (cultivated with field crop)

Table (8): Particle size distribution of the studied profiles.

Profile no.	Location	Depth, cm	Particle size distribution				
			Sand %		Silt %	Clay %	Texture class
			Coarse	Fine			
1	Qasr El Basal,El Fayoum	0-30	25.50	52.30	18.40	3.80	Loamy sand
		30-60	22.30	51.30	20.00	6.40	Sandy loam
		60-200	24.50	49.80	21.30	4.40	Sandy loam
2	El-Nasriyah Beni Mazar, El Minya	0-20	27.90	45.30	23.20	3.60	Loamy sand
		20-40	24.50	48.20	21.90	5.40	Sandy loam
		40-70	20.40	56.90	17.30	5.40	Loamy sand
		70-100	19.80	50.00	23.40	6.80	Sandy loam
3	60 Km North of El Minya	0-85	27.50	47.30	16.20	9.00	Sandy loam
		> 85	24.00	49.20	18.50	8.30	Sandy loam
4	Wadi El Farigh, 65 Km Cairo-Alex- road	0-20	34.40	36.50	19.60	9.50	Sandy loam
		20-60	36.40	23.60	12.50	27.50	Loamy
		60-110	36.85	29.80	15.00	18.36	Sandy loam
		110-150	65.00	17.50	10.00	7.50	Sandy loam
5	Wadi El Natrun, 14 Km. West of Cairo Alex. Road	0-20	50.55	38.10	5.00	6.33	Loamy sand
		20-70	13.20	24.25	50.00	12.33	Silty loam
		70-160	12.33	20.25	37.40	30.00	Silty clay loam
6	500 m from the road, 200 m from the sea, Hurghada	0-20	42.13	22.05	19.80	20.00	Loamy
		20-50	23.90	19.05	50.00	17.05	Silty loam
		50-100		Gypsic	layer		
7	1300 m from the road, 200 m from the sea, Hurghda.	0-20	53.15	24.35	7.50	15.00	
		20-50	51.00	35.00	6.30	7.50	Sandy loam
		50-100					Sandy loam
8	Dhibbah, Siwa oasis	0-15	6.70	23.30	50.00	20.00	Silty loam
		15-20	17.60	28.40	30.00	24.00	Loamy
		20-120	10.75	28.23	40.50	20.50	Silty loam
9	Abo shrouf, Siwa oasis	0-30	32.00	17.00	40.00	11.00	Loamy
		30-120	21.10	17.40	36.50	25.00	Loamy
10	North east Gabal El Dakrour, Siwa	0-20	33.80	18.20	31.00	17.00	Loamy
		20-80	41.40	22.10	17.00	19.50	Loamy
		80-140	5.15	12.15	52.70	28.00	Silty loam
11	Ismailia	0-20			Gypsic Layer		
		20-40			Gypsic Layer		
		40-60			Gypsic Layer		
12	Ismailia	0-20			Gypsic Layer		
		20-40			Gypsic Layer		
13	Ismailia	0-50					
		50-80					
14	Ismailia	0-35			Gypsic Layer		
		35-60			Gypsic Layer		
15	Girza	0-15					
		15-55	27.60	21.30	27.20	23.90	Loamy
		55-100	22.00	28.40	28.70	20.90	Loamy
16	Beni Suef	0-70	27.80	28.20	20.40	23.60	Loamy
		70-150	19.50	28.40	25.90	26.20	Loamy

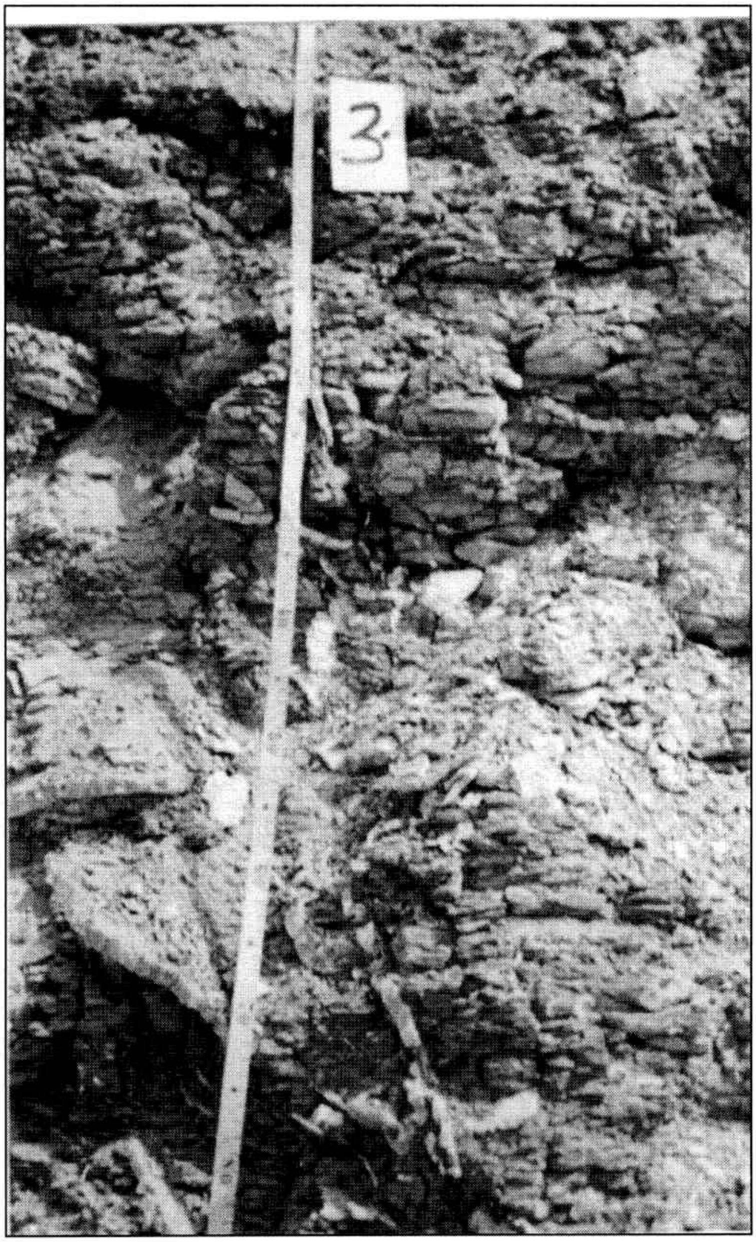


Photo (2) ,Profile no. 3 , north of EL-Minya (large cemented aggregetes of lime gypsum)

are common in most of the profiles. Hard, cemented, subsurface gypsic layers are found in profiles at Hurghada, Siwa and Ismailia, while at Girza (profile no.15) gypsum forms a hard surface layer (0-15 cm). The results in Table 9 reveal that gypsum content fluctuates between 2.10 to 81.70 %. These gypsum contents in the whole profile or some layers satisfy the requirements of gypsic horizon according to USDA (1999).

The gypsic soils under investigation are mostly highly or extremely saline (except profile no. 2, which is slightly saline). Data of Table 9 indicate that value of EC ranged between 3.8 and 176.60 dS/m. Most of these soluble salts are sodium chloride, sodium sulphate, magnesium chloride, calcium chloride and magnesium sulphate. Under such arid conditions and high salinity and accumulation of gypsum, the organic matter content of these profiles is rather low (0.14-2.50 %). The surface horizons have relatively higher content of organic matter in most of the profiles.

The investigated profiles have medium texture, low organic matter and poor in amorphous materials, therefore their cation exchange capacity ranging

Table (9): Some physical and chemical properties of the investigated soil profiles.

Profile no.	Depth, cm	$CaCO_3$ %	Gypsum %	O.M. %	C.E.C (meq/100g soil)	SP	EC** dS/m	PH* paste	Soluble salts**						
									Cations, meq/l				Anions, meq/l		
									Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3+HCO_3^{-}$	Cl^{-}	SO_4^{--}
1	0-30	4.65	20.70	2.14	17.39	23.3	136.0	7.66	160.0	270.0	1073.9	10.3	0.3	1415.0	98.9
	30-60	3.87	24.50	1.67	17.10	26.7	176.0	7.46	248.0	292.0	1326.1	11.6	0.2	1430.0	447.5
	60-200	1.29	38.70	0.89	16.41	24.7	44.2	8.70	36.0	59.0	413.0	8.5	0.3	467.0	49.2
2	0-20	15.05	15.20	1.89	17.61	22.7	8.8	8.59	22.0	21.0	60.8	3.1	0.1	80.0	26.9
	20-40	1.72	12.80	0.25	18.28	26.7	3.8	8.45	10.0	11.0	15.4	1.8	0.3	20.1	17.8
	40-70	0.22	19.80	0.33	15.26	25.7	5.0	7.25	12.0	15.0	21.2	2.7	0.3	35.0	15.6
	70-100	0.43	7.10	0.53	20.10	27.0	5.8	7.92	8.0	14.0	35.2	2.9	0.3	41.3	18.49
3	0-85	1.94	34.40	1.99	19.71	28.7	68.6	7.72	45.0	63.0	621.7	9.7	0.2	560.0	179.3
	> 85	8.34	34.40	1.67	21.02	27.0	95.1	7.15	119.0	39.0	804.4	10.0	0.4	880.0	92.0
4	0-20	5.59	3.10	0.40	22.02	28.7	14.7	7.67	10.0	30.0	108.3	7.1	0.3	110.2	44.9
	20-60	1.90	8.30	0.25	26.25	45.3	44.5	7.95	53.0	62.0	407.0	9.5	0.2	493.0	38.3
	60-110	1.20	3.90	0.18	23.60	30.3	17.5	7.94	19.0	16.0	180.6	5.3	0.2	191.8	29.0
	110-150	0.90	3.10	0.14	12.91	20.0	7.1	7.98	18.0	12.0	41.7	3.4	0.3	55.5	19.4
5	0-20	0.12	4.20	1.98	8.75	20.3	12.2	7.98	17.0	35.0	82.6	2.7	0.2	95.8	41.3
	20-70	0.04	22.00	1.32	22.71	29.0	101.4	6.88	105.0	258.0	824.4	9.7	0.3	1095.0	101.7
	70-160	0.09	20.17	1.10	27.39	84.0	17.9	7.06	75.0	35.0	120.5	5.0	0.1	160.8	74.6
6	0-20	24.00	2.10	2.29	22.57	24.0	39.1	7.83	37.0	48.0	369.6	6.9	0.2	390.3	70.9
	20-50	19.50	40.15	1.68	24.93	19.5	56.2	7.77	84.0	128.0	367.8	8.2	0.2	390.0	197.9
	50-100	34.50	47.30	0.40	15.60	34.5	32.9	8.07	49.0	65.0	273.9	6.8	0.3	322.0	72.4
7	0-20	20.00	17.20	0.41	12.57	20.0	21.0	8.11	37.0	55.0	170.8	5.6	0.3	213.0	55.1
	20-50	22.00	43.00	0.33	8.33	15.0	82.8	7.25	145.0	178.0	574.8	7.8	0.2	652.0	253.4
	50-100	27.50	43.00	0.27	7.10	27.5	38.2	7.58	49.0	89.0	272.2	8.1	0.3	315.0	103.0
8	0-15	31.11	23.10	1.57	24.23	26.7	89.7	7.55	184.0	220.0	495.1	9.8	0.3	657.8	250.8
	15-20	22.22	38.60	1.03	23.10	29.3	147.8	7.44	205.0	442.0	913.8	13.1	0.4	1236.1	337.1
	20-120	32.89	16.80	0.73	26.73	30.3	63.6	7.90	104.0	238.0	325.2	7.1	0.3	658.1	15.9

* Saturated soil paste

** Soil paste extract

Table (9) contin.

9	0-30	20.22	48.20	2.50	21.03	20.0	133.0	6.74	195.0	393.0	870.1	10.0	0.3	1413.0	54.8
	30-120	21.78	31.00	1.62	23.48	40.7	20.5	7.37	34.5	68.5	130.1	6.2	0.2	198.0	41.1
10	0-20	13.33	15.00	2.22	17.45	21.0	134.8	7.47	196.0	324.0	915.7	12.0	0.3	1338.0	109.7
	20-80	35.56	16.80	1.55	13.30	22.0	75.3	7.79	106.0	256.0	433.2	9.8	0.3	719.0	85.6
	80-140	12.44	12.80	1.10	24.10	42.0	10.2	7.77	15.0	23.0	65.8	5.4	0.2	70.0	39.0
11	0-20	7.66	74.10	1.84	15.40	29.7	55.8	7.94	100.0	135.0	372.2	8.1	0.3	495.2	119.7
	20-40	5.53	76.00	1.64	19.20	24.0	50.6	7.82	30.0	65.0	393.9	8.3	0.3	410.0	8 6.9
	40-60	17.02	26.80	1.52	15.18	38.0	75.4	7.79	22.5	30.0	640.0	8.6	0.4	660.0	40.7
12	0-20	3.40	18.20	1.10	14.10	25.0	160.8	7.80	145.0	90.0	1560.9	8.5	0.5	1630.0	173.8
	20-40	0.60	73.50	1.42	14.98	24.7	48.3	7.90	30.0	50.0	468.7	8.5	0.3	500.0	56.9
13	0-50	pure	Sand						Pure	Sand					
	50-80	0.43	76.54	0.52	20.80	20.7	14.9	7.88	15.0	7.8	125.0	1.2	0.5	133.5	15.0
14	0-35	0.17	68.80	0.43	21.50	18.3	18.7	8.10	55.0	35.0	100.0	2.0	2.3	120.0	69.7
	35-60	1.70	81.70	0.62	22.30	21.0	150.0	7.99	435	220.0	880.0	15.0	8.4	1030.0	511.6
15	0-15	Hard	Gypsi	Layer					Hard	Gypsic	Layer				
	15-55	6.81	27.52	0.44	21.50	35.0	94.0	7.34	210.0	100.0	670.0	10.0	7.0	850.0	133.0
	55-100	9.36	25.80	0.25	19.80	27.3	16.5	7.28	47.0	28.0	98.0	2.0	2.0	110.0	63.0
16	0-70	17.87	31.11	0.20	22.50	30.0	14.8	7.35	42.0	28.0	96.2	1.8	1.5	115.0	51.5
	70-150	11.06	30.05	0.31	23.00	38.0	45.0	7.37	120.0	90.0	262.0	8.0	6.0	360.0	114.0

between 7.10 and 26.25 meq/100g soil. These figures refer to the nutrients deficiency and poor fertility level of these soils.

Concerning the pH values of the different horizons of the studied profiles, which ranged between 6.74 and 8.70, there is no specific trend with relation to soil depth. The lowest value of pH was observed in profile no. 9 (Siwa) which may be due to the presence of calcium and magnesium salts.

4.3 Classification of the Gypsic Soils:

There are specific diagnostic horizons associated with the formation of gypsic soils. From the data in Tables 8 and 9 it is clear that the salic horizon is dominated in most of the studied profiles either it was surface or subsurface. However the intensity of this salic horizon varied from one profile to another according to the concentration of soluble salts and the thickness of the horizon.

The calcic horizon was found to be formed in profiles no. 2,6,7,8,9,10,11 and 16. Some of these profiles are calcareous sediments and the whole solum is regarded as calcic horizon (profiles no. 6,7,8,9,10 and 16) while profile no 2 has a surface layer (0-20 cm) and profile no. 11 has a deep layer (40-60 cm).

The gypsic horizon which is dominant in the studied profiles has high concentration of gypsum content over the whole solum except profiles no. 4 and 5 which have a limited depth with high gypsum accumulation. Indurated and cemented deep layers rich in gypsum are observed in profiles no. 6 and 7, which are located near the Red Sea coast (Hurghada). Also, profiles no. 11,12,13 and 14 which represent the Ismailia area are dominated with hard gypsic layers that were difficult for particle size distribution analysis. Some of these horizons can be regarded as petrogypsic.

Other diagnostic horizons can be identified in the studied profiles consideration are however, very limited that, the ochric epipedon (A) which is free from all accumulations and satisfy the colour requirement and low organic matter can be observed in profiles no 4,5,13 and 14 which mostly formed from wind carring sand over the calcareous sediments (examples are shown in photos no. 3 and 4 of profiles no. 4 and 5). The areas cultivated with field crops (profile no.2) or with olive

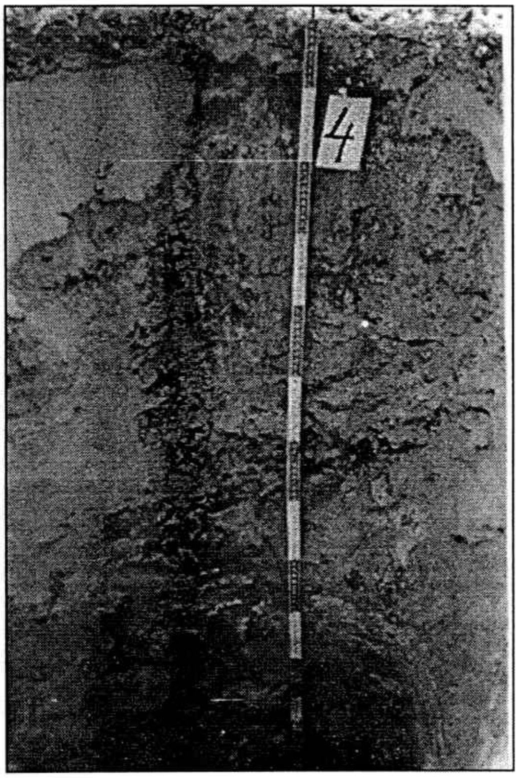


Photo (3) ,Profile no. 4 , Wadi ELFarigh
(sand over calcareous sediments)

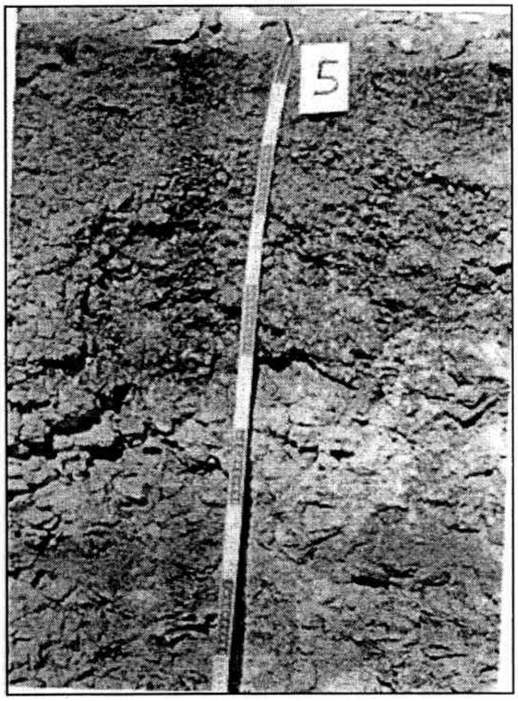


Photo (4) ,Profile no. 5 , Wadi ELNatrun
(ochric epipedon over salic and gypsic horizons)

trees (profiles no 4 and 5) have a plough layer (Ap) but hard to satisfy the requirement of agric or flaggen epipedon.

Regarding the master horizons which are the basis of profile description, most of the studied profiles are recent soils; therefore the solum is mostly distinguished to A/C or Ap/C or C1/C2 or C1/C (detailed profiles description is recorded in appendix).

According to the field description and the analytical data of the sampled representative profiles, it can be classified soil of the studied profiles into the according to soil great subgroups following the requirements mentioned in Soil Taxonomy (USDA, 1999).

Order: Aridisols

Suborder: Salids

Great soil Group: Haplosalids

1) Great Soil Subgroup: Gypsic Haplosalids: includes profiles no. 1 (El Fayoum), 3 (EL Minya), 5 (Wadi El Natrun) and 15 (Girza). Some profiles have besides the dominated salic and gypsic horizons, enrichment of calcium carbonates (more than 15 %) which satisfy the requirement of calcic horizon.

Therefore, the term Calcic and Gypsic Haplosalids is proposed for profiles no. 6 and 7 (Hurghada), 8, 9 and 10 (Siwa Oasis). Also profiles no.11 (Ismailia) and 16 (Beni Suef) can be included as Gypsic and Calcic Haplosalids since they have 80% gypsum, 17% $CaCO_3$ and EC about 45 dS/m .

2) Great Soil Subgroup: Petrogypsic Haplosalids as in profiles no. 12 and 13 in Ismailia area, with about 73 % and 76 % gypsum respectively, as indurated hard cemented shallow solum.
3) Great Soil Subgroup: Typic Haplosalids: profile no. 4 in Wadi El Farigh which has high salinity (EC 144.5 dS/m) satisfy the requirement of salic horizon.
4) Great Soil Subgroup: Gypsic Aquisalids: profile no 14 in Ismailia is a shallow profile with high water table and characterized by wet conditions.

Suborder: Calcids

Great Soil Group: Haplocalcids

5) Great Soil Subgroup: Gypsic Haplocalcids profile no 2 (El Minya)

According to the previously mentioned classification following USDA (1999), it can be concluded that most of the gypsic soils are included under the great soil subgroup of Gypsic Haplosalids and the proposed subgroup of Gypsic Calcic Haplosalids.

4.4. Micromorphological contribution to the gypsic soils:

One of the main objectives of this investigation on the gypsic soils is the comprehensive understandying which will be reflecting on the proper management and consequently successful investment of these areas in Egypt. Towards this goal detailed field description, chemical and hydrophysical criteria have to be supported by visualizing and identifying the minute constituents of the soil through the micromorphological study of soil thin sections.

The gypsifereous soils under consideration represented by 16 profiles from various sites have been sampled and thin sections from one horizon or more for each one were prepared (23 slides). Detailed description for the main members of organization have been cited in Table 1 in appendix including: Microstructure, groundmass (fine and coarse), the associated voids, the related distribution (c/f concept) and the pedofeatures. Special attention has been paid in this detailed identification to the forms of gypsum i.e. shape, size, distribution and associated constituents. About 30 pictures have been photographed, concentrating on gypsum forms, using various magnifications and facilities of cross polarizing to visualize the variations in the gypsum crystals in these investigated thin sections.

The detailed micromorphological description of the gypsic soils under consideration, which are included in the appendix, can be concluded in the followings:

4.4.1 Microstructure:

The identification and recognition of microstructure in the small thin sections (3X4 cm) is relatively difficult, however an attempt have been paid to describe the aggregates in the studied samples. The subangular, granular and fragmental aggregates are the most recognizable forms of microstructure. Regarding the development of these aggregates, they are mostly moderately to weakly developed.

4.4.2 Groundmass:

The coarse materials in the groundmass are mostly formed from light minerals (i.e. quartz, feldspars and mica) and some heavy and opaque minerals. Rock fragments and calcified shells form a considerable proportion of the coarse fraction as in profiles no. 8, 9 and 10, sampled from Siwa Oasis. In some cases large grains of gypsum are dominating the groundmass and form the skeleton of the soil materials as in profiles no. 6 from Hurghada, 13 and 14 from Ismailia. Such soils can be described as hypergypsic (gypsum ranges from 47.3 to 76.5 %). Since most of the studied gypsic profiles are medium texture (loamy sand or sandy loam), the coarse fractions have meso and macro size depending on the type of parent material and the pedogenic processes prevailing in each site. However moderately to poorly sorted grains are dominant in most cases.

The fine materials of these gypsic soils are mostly formed from clay minerals mixed with amorphous of iron oxides as in profiles no. 1, 2, 3, 9, 14, 15 and 16. In the calcareous profiles, the fine crystallites of calcite in the size of clay and silt are dominating in the groundmass as in the soils from Hurghada and Siwa Oasis (profiles no. 6, 7, 8, 9 and 10). The colour of the fine material is mostly yellowish brown to brown. In some slides darker colours in patches are observed due to the precipitation of iron and manganese compounds through the reduction and oxidation processes as in profiles no. 2, 15 and 16 (El-Minya, Girza and Beni Suef). The fabric (i.e. lipidity) of these fine materials can be described as dotted or speckled or cloudy are mixtures of these types.

The organic materials are very limited in these gypsic soils since most of the profiles are virgin, uncultivated areas. Some dark decomposed residues of plants are observed in some thin sections from the remanents of natural vegetation or previous cultivations in these locations, particularly in the surface horizons A or Ap (as in profiles 1,5 and 15).

4.4.3 Voids:

There are different types of voids observed in these examined thin sections due to the variations in the size, shape and arrangements of soil constituents i.e. coarse and fine materials besides the pedofeatures of these soils. Another important factor is the chemical nature of both fine and coarse fractions and the prevailing soil forming factors in each site.

It can be concluded from the observations cited in tables of appendix that the irregular vughs and compound and complex packing voids are the most abundant. However, channels and planes are found in some slides as in profiles 1,9 and 16. The simple packing voids between coarse grains (as in profile no.8 in Siwa) are rare due to the precipitation of carbonates or sulphates or other amorphous materials which cement and aggregate the particles, consequently interlocking these simple packing pores.

4.4.4 Related distribution: (c/f concept)

The related distribution or the coarse to fine concept as mentioned by **Stoops and Jongerius (1975) and Bullock et al (1985)** expresses the arrangement of the main constituents of the soil materials. The term porphyric can be the most proper to describe the coarse grains which are scattered in the fine groundmass of clayey or carbonate nature in these gypsic soils. In the same slide more than one type of related distribution can be observed. Enaulic and chitonic related distribution are also common, particularly when coarse crystals of gypsum coated or surrounded by fine crystallites of clay or carbonates (for example: profile no. 14 in Ismailia, photo no.5)

4.4.5 Pedofeatures:

The pedological features which are seen in thin sections are functions of all pedogenic processes which occur in the soil under soil forming factors. These features can be recognized in the field in some cases and can be taken into consideration not only in soil classification but also in soil management practices. The identification and description of the pedofeatures may explain several phenomena in the soil, for example, accumulation of salts, carbonates and gypsum. Also the oxidation reduction processes, coagulation of amorphous compounds and weathering of minerals can be identified through the recognition and describing the pedological features.

In the gypsic soils, under investigation, special attention has been paid to the description of pedofeatures related to gypsum. From the tables of micromorphology (appendix and photographs) and the associated formations, it can be stated that most of the pedofeatures are crystalline and amorphous kinds. These

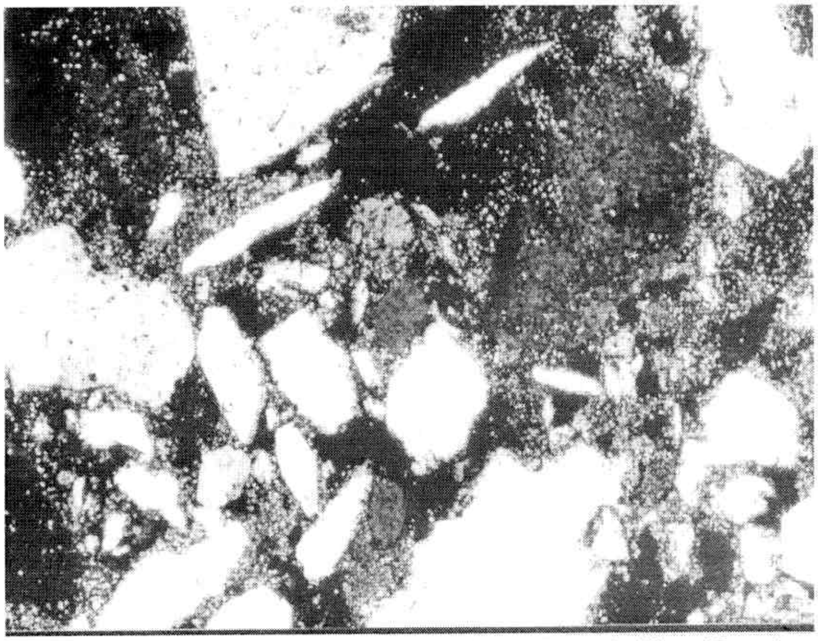
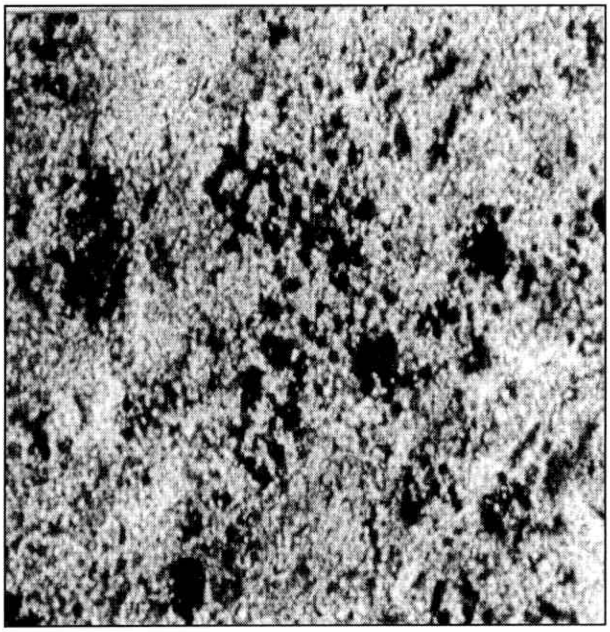


Photo (5), Enoulic and chitonic related distribution (gypsum crystals coated with fine crystallites of calcite), profile no. 14 in Ismailia of 0-35 cm X4

kinds of pedofeatures can be classified as infillings related to voids prevailing in the soil and nodules, intercalations and compound pedofeatures.

Calcareous nodules are very abundant in some profiles, according to their external morphology, they seem as aggregates, disjointed, amfboidal and digitated types in different sizes (as in profiles no. 7, 8, 14, 15 and 16). Some grain coatings of calcareous materials and dense complete infillings of some voids are observed as in profile no. 8. Calcified shells and fragments, as a residual product of previous conditions of marine and lacustrine origin, are included in the coarse materials and observed as in the soils of Siwa Oasis.

The compounds of iron and manganese have simple or compound nodules. They have darker colour than the groundmass with sharp or diffuse boundaries. According to their external morphology these iron nodules mostly aggregates, amboidal, digitated or compound mixed with calcareous or gypsic materials. These pedofeatures are clear in profiles located in El Fayoum, El-Minya, Girza, Wadi El-Farigh, Siwa, Ismailia and Beni Suef. (profiles no. 1, 2, 4, 9, 14, 15 and 16).



Phot (6) ,Microcrystallites of granular gypsum scattered in the groundmass, profile no. 4 , Wadi EL Farigh

Photo (7) ,Clusters of columnar gypsum crystals have parallel orientatioh , profile no. 1 , EL Fayoum of 30 – 60 cm X 10

4.4.6 Crystal forms of gypsum:

The gypsic soils under consideration have accumulation of gypsum which range from 3.10 to 81.70 %. These neoformations of gypsum as mentioned by **Buringh, (1960) and Altaie (1968)** can be regarded as two groups, with respect to their origin, primary or secondary gypsum. The primary gypsum crystallization may be produced by ancient regional hydromorphic conditions, and the secondary types are formed under the influence of landscape and geochemistry of the existing environments. According to the detailed examination of thin sections of these gypsic soils, the following forms of gypsum crystallization are distinguished:

- Microcrystallites of granular gypsum scattered in the groundmass are observed in the soil of Wadi El Farigh (profile no. 4) with low gypsum content (8.30%), Photo no.6
- Collumnar and granular of relatively large size infillings partly or completely in the large vughs and chambers, distributed in parallel orientation and forming clusters of crystals as in profile no. 1 El Fayoum photo no. 7.

- Granular isolated euhedral or subhedral prismatic grains scattered in the groundmass, usually large (meso and macro) crystals are observed in profiles of El Minya (profiles no. 2 and 3) where medium accumulation of gypsum occurs (12.8-34.4 %) due to unadequate drainage conditions and fluctuation of saline water table under high evaporation rate, (photo no. 8).
- Macro grains of intergrowth of irregular crystals, mostly cemented and form petrogypsic hard layers. These formations are evidently originated from old geological ages as in Hurghada (profile no. 6 with gypsum content of 47.30%). Weathering of these large crystals seems as parallel cleavage and some inclusions of calcareous or other amorphous materials (photo no. 9).
- Void gypsum as dense complete microcrystalline infilling of channels or large planes occur as a result of accumulation of saline water table in the deep layers (70-150 cm) in the soils of Beni Suef (profile no 16). These formations which may seem as sheets or pockets of white accumulation in the field traversing the clayey groundmass, are a result of

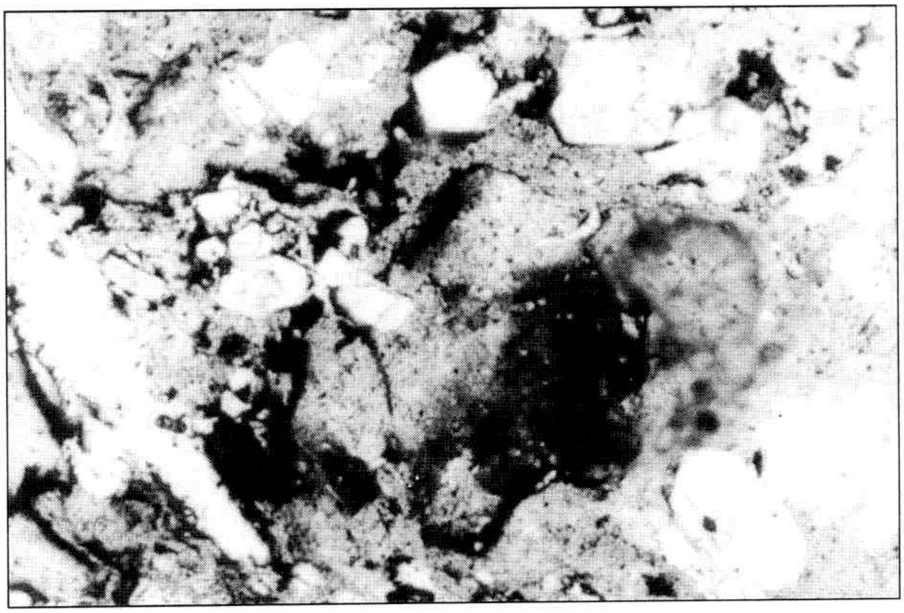


Photo (8) , Gredular , euhedral and subhedral grains of gypsum , profile no. 2 , EL Minya

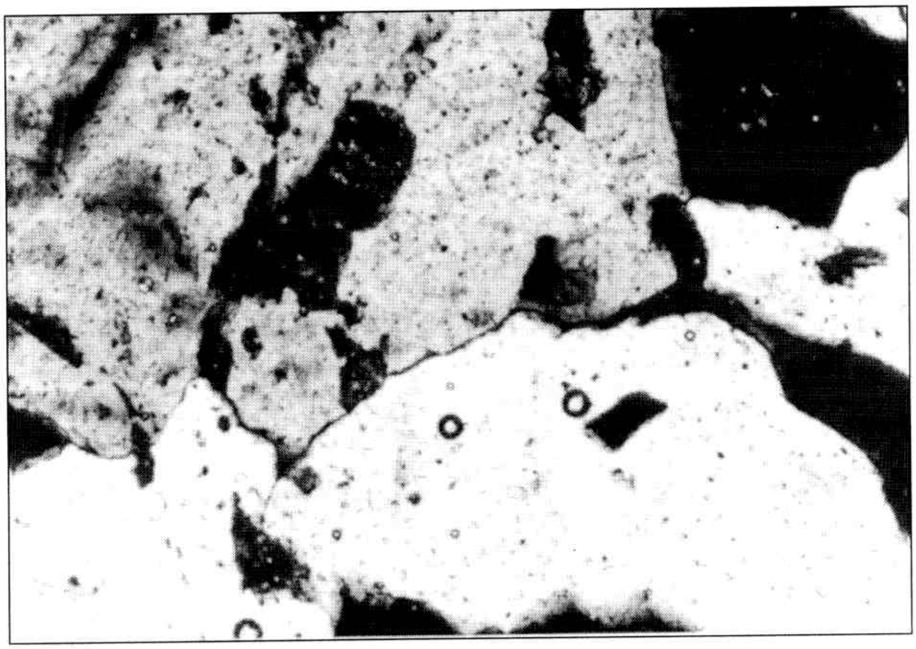


Photo (9) , Intergrowth of irregular cemented weathered large crystals , profile no. 6 , Hurghada

cracks produces by shrinkage processes. (photos no. 10 and 11).

- Abundant gypsum crystals as coarse grains dominating the groundmass in lenticular, granular and prismatic macro crystals as in Ismailia soil (profile no. 13) where high accumulation of gypsum occurs as a previous lacustrine submerged conditions. Under the same conditions intergrowth of gypsum may form cementation and blocking of voids lead to petrogypsic horizon (photo no. 12).

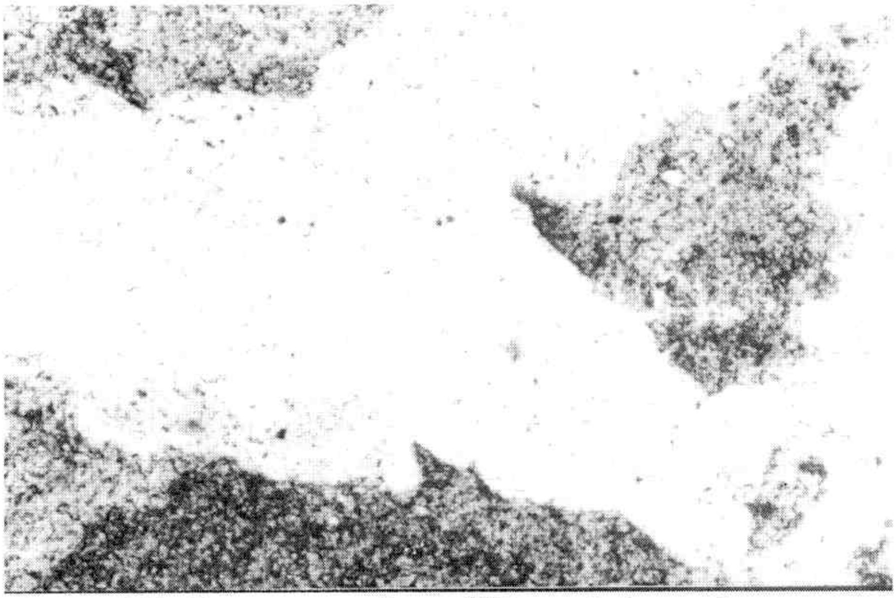


Photo (10), Dense complet infilling of channels profile no. 16, Beni Suef of 70-150cm X4

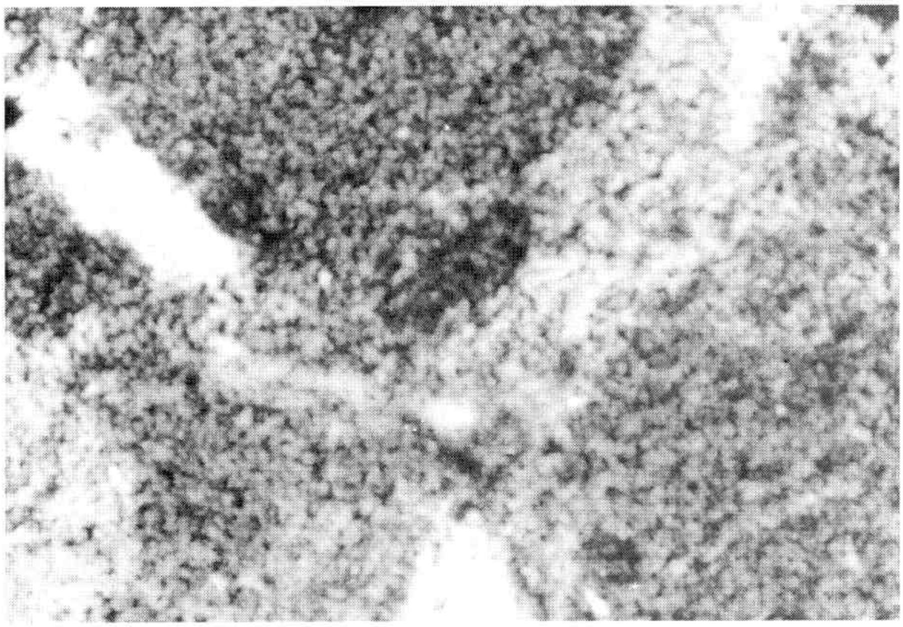


Photo (11), Planes filled with microcrystallites of gypsum, profile no. 16, Beni Suef of (70-150cm) X4

Phot (12), Abundant macro crystals of granular gypsum blocky voids, profile no.13 Ismailie of 50 – 80 cm X4

4.5- The influence of gypsum levels in soils on plants growth and their nutrient uptake:

The principal goal of the comprehensive investigation of the gypsic soils, under consideration, is to assess the impact of these formations on plant growth and consequently the potentiality and suitability of such soils to various crops.

Towards this aim, several pot experiments have been conducted on selected samples from the studied soil profiles where wheat and barley plants were used as indicator plants. However, a preliminary experiment was carried out (for two years) to identify and assess the influence of pure gypsum percent on the growth of wheat and barley plants.

4.5.1- Effect of increment gypsum content on plant growth :

4.5.1.1—Wheat:

Data of Table (10), photo 13 and Fig.2 show the influence of gypsum levels in soils on the plant growth as indicated by germination %, dry weight and some macro and micro- nutrients uptake by wheat seedlings.

Table (10): Effect of soil gypsum levels on plant growth and some macro- and micro- nutrients uptake by wheat plants (6 weeks old)

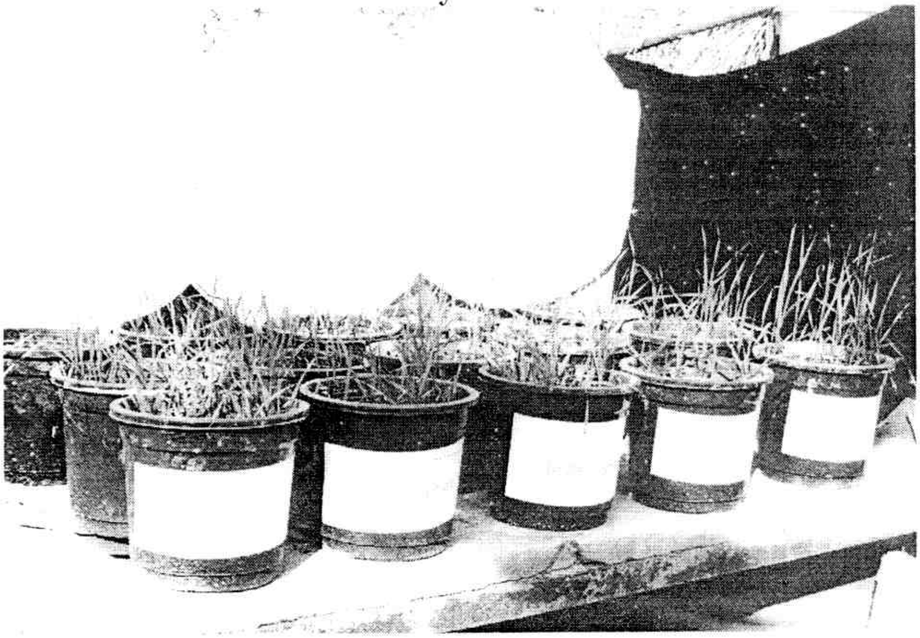
First year

Level of gypsum	Germi-nation %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
3%	38.9	5.1	94.3	5.7	48.5	1319.0	189.0
10%	47.8	6.6	94.5	6.3	57.6	1194.0	123.0
20%	43.3	5.7	88.1	5.4	50.9	1103.0	101.0
30%	37.8	4.7	79.9	5.1	47.4	662.0	57.0
40%	25.6	4.6	74.5	4.1	36.3	543.0	45.0
LSD 0.05	10.64	1.26	18.81	1.25	12.11	223.4	30.3
LSD 0.01	15.13	1.79	26.76	1.78	17.23	317.7	43.1

Second year

Level of gypsum %	Germi-nation %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
3%	68.9	15.3	250.2	20.7	135.7	4492.0	607.0
10%	78.9	18.9	362.6	35.7	149.7	3683.0	373.0
20%	72.2	15.8	251.3	15.3	136.5	3301.0	298.0
30%	66.7	14.9	242.7	14.7	115.9	2146.0	174.0
40%	53.3	13.3	239.2	13.2	105.8	1534.0	126.0
LSD 0.05	12.44	1.97	47.86	3.88	10.35	436.4	38.8
LSD 0.01	17.7	2.80	68.08	5.52	14.73	1620.7	55.2

First year



Second year

Photos (13), Effect of different gypsum level on the wheat growth

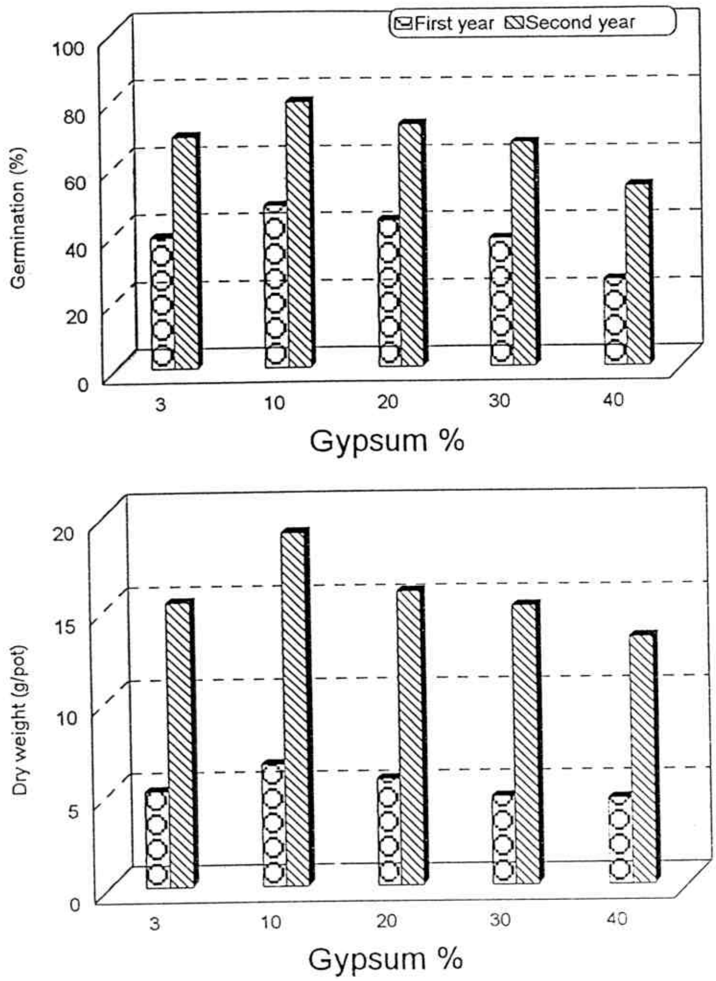


Fig. (2): Effect of different levels of gypsum on the germination % of wheat seeds and seedlings dry weight after 6 weeks from sowing.

- Germination % :

In general, the data of table (10) show that the highest germination % of wheat had been obtained from the soil contains 10% gypsum. Whereas, the lowest values were recorded from the soil that contains 40% of gypsum. The statistical analyses of the data indicate that the least significant difference (LSD) test indicate that there is no significant difference between values of the soils contain gypsum of 3, 10, 20 and 30 % at both 0.01 and 0.05 levels. However, such value in the soil contains 40% gypsum significantly different from those of soils that contain gypsum of 10 and 20% at 0.01 level and of soils contain gypsum of 3 and 30% at 0.05 level.

- Dry weight:

The plant growth of wheat seedlings (6 weeks old) as indicated by the shoot dry weight of wheat plant shows exactly the same trend of germination percentages as affected by soil gypsum content. Data of Table 10 show that the shoot dry matter is highest for the wheat grown under gypsum content of 10%, meanwhile the lowest values is recorded for seedlings grown under the highest gypsum level (40%). Statistically, there are significant differences between the values of dry weight in the 1 st year under 3, 10 and 20% gypsum contents and 30 and 40% of gypsum at the level 0.01, whereas the differences are significant between values under 10% and 3, 30 and 40% of gypsum at the level 0.05. The values of dry weight for the second year experiment show significant difference between cultivation under 10% gypsum content and all other experimental gypsum contents at a statistical level of 0.01. However significant differences between the dry weight values of plants under 10% from one side and 3, 20 as well as 30% from second side and 40% are observed.

Nutrients uptake:

Nitrogen

The highest nitrogen uptake has been detected in the plants that grown in the soil containing 10% gypsum in the 1 st year (94.5 mg N/pot) and the 2 nd year (362.6 mg N/pot), Table 10 and Fig.3. The lowest value was detected under 40% of gypsum in both years. The differences between the nitrogen uptake as affected by the soil gypsum levels are not significant for the 1 st year at 0.01 level, however significant differences are occurred between that of 10 and 3% levels and that of 40% level at 0.05. In the second year the differences increased between the nitrogen uptake by wheat plants, which were planted in the soil contain 10% gypsum and all the other levels of gypsum content at significant level of 0.05.

Phosphorus:

Phosphorus behaved nearly as nitrogen where the highest uptake was found in the wheat plants grown in the soil that had 10% gypsum content. The lowest value was recorded for the plants under 40% gypsum content The LSD test shows that the significant differences are

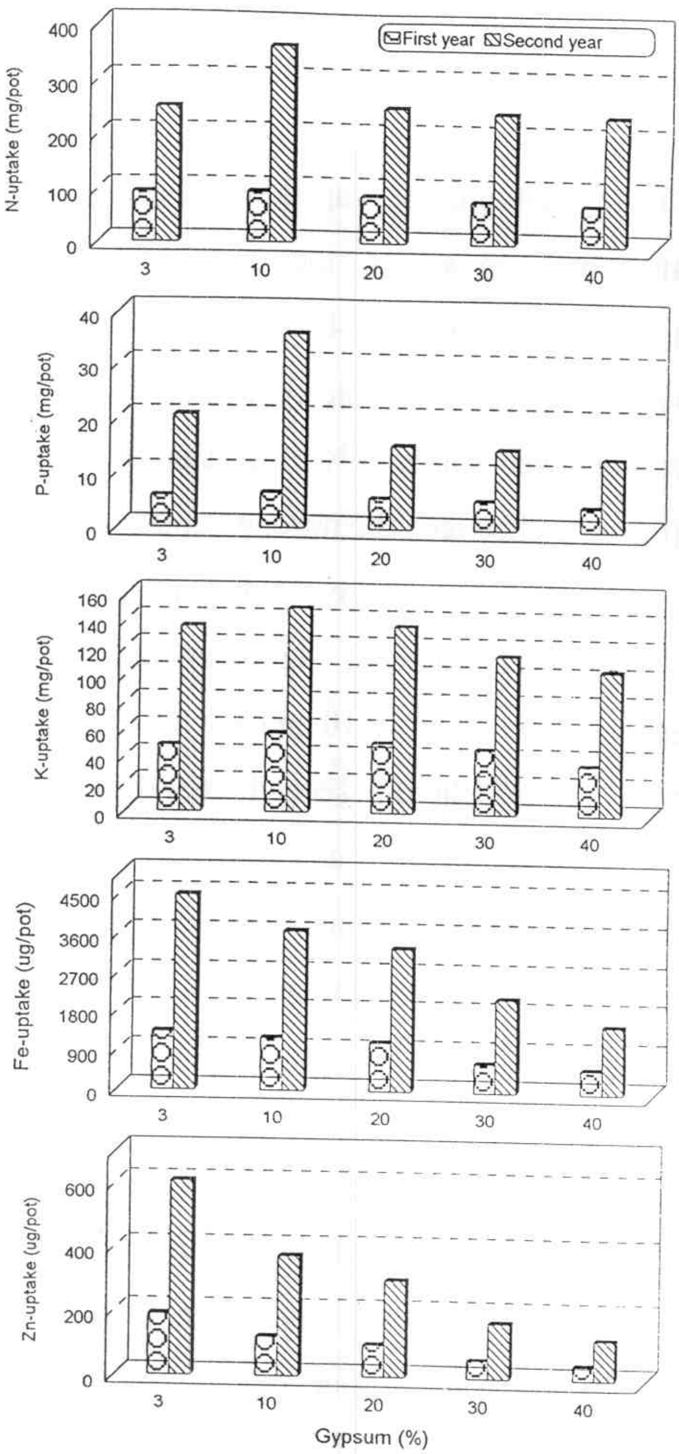


Fig. (3): Effect of different levels of gypsum on the uptake of N, P, K, Fe and Zn by wheat plants after 6 weeks from sowing.

between phosphorus uptake by plants under gypsum content of 3, 10 and 20% and that under 40% in the first year at 0.05 level. The phosphorus uptake by plants grown under 3, 20, 30 and 40% gypsum was found to be significantly different from these grown under 10% of gypsum.

Potassium:

Similar behavior to that of nitrogen was recognized for potassium. Its uptake in both years was highest in the plants that were grown in the soil contains gypsum of 10% (57.6 and 149.7 mg K/pot) .The soil that had 40% of gypsum shows the lowest potassium uptake, (36.3 and 105.8 mg K/pot) in the 1 st and 2 nd year, respectively. Also, significant difference was noticed between the values of potassium uptake by the plants grown under gypsum contents of 3, 10 and 20% and those under 40% in the first year. While in the second year a significant difference was found between the values of potassium uptake by the plants grown under soil gypsum content of 10% and that of plants under soil gypsum of 3, 20, 30 and 40%. The potassium uptake by the plants grown under gypsum content of 30 and 40%

showed significant differences with those of 3, 10 and 20%. It was noticed that the potassium uptake was increased in the 2 nd year more than in the 1 st one.

Iron:

Iron (Fe) values of uptake exhibit showed another trend other than that of the macronutrients (N, P and K). Fe-uptake is highest when the plants were grown under 3% soil gypsum content in both 1 st and 2 nd years. This uptake decreased with the increase of gypsum content in the soil. The significant differences became more pronounced in the second than in the first year. Comparing the least significant difference (LSD) in the first year with the obtained values of iron uptake, it can be noticed that in the level of 3, 10 and 20% gypsum the differences are not significant. While at the levels of 30 and 40% as one group and have significant differences.

In the second year there are significant difference (LSD is 436.4) between each level of gypsum.

Zinc:

Zinc behaved nearly as iron, where the highest uptake values were obtained for plants grown under 3%

gypsum content in both years. Zn-uptake decreased with the increase of gypsum content in the soil. In the first year, significant differences could be noticed between three groups of gypsum content, namely a group has only 3% treatment, the second group includes the 10 and 20% treatments and the third group contains 30 and 40% treatments. However, in the second year, significant differences occurred between all values of Zn-uptake under all soil gypsum contents.

These results prove that the moderate accumulation of gypsum in soils until 10% has beneficial influence on germination, dry weight, N, P and K content of wheat seelings. While a negative effect on the micronutrients uptake as Fe and Zn have been observed with the increase of gypsum content more than 3%.

4.5.1.2- Barley:

- Germination:

As compared with germination of wheat, barley shows higher values at all various gypsum contents and also in both years treatments (Table no.11, Fig 4 and photo no.14). Although in the first year, there was no

Table (11): Effect of soil gypsum levels on plant growth and some macro- and micro- nutrients uptakes by barley seedlings (6 weeks old)

First year

Level of gypsum	Germi-nation %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
3%	77.8	10.4	187.4	10.9	69.5	2824.0	422.0
10%	83.3	13.8	191.5	13.7	111.4	2711.0	242.0
20%	81.1	10.6	167.2	11.5	88.4	2075.0	182.0
30%	63.3	8.4	157.8	9.2	77.0	1201.0	96.0
40%	47.8	8.0	135.6	7.4	63.3	873.0	65.0
LSD 0.05	11.16	2.19	45.2	3.01	17.74	771.5	99.7
LSD 0.01	15.88	3.11	64.2	4.28	25.23	1097.3	141.9

Second year

Level of gypsum %	Germi-nation %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
3%	85.6	15.4	320.6	13.5	118.3	3961.0	563.0
10%	97.8	19.1	360.5	19.3	143.3	3747.0	362.0
20%	94.4	15.4	270.9	13.7	125.3	3054.0	300.0
30%	85.6	15.7	273.4	14.8	132.9	2229.0	198.0
40%	84.4	15.0	270.0	13.5	110.7	1814.0	154.0
LSD 0.05	15.76	1.90	44.0	2.16	18.07	547.2	75.7
LSD 0.01	22.42	2.70	62.6	3.08	25.70	778.4	107.7

First year

Second year

Photo (14), Effect of levels of gypsum on the barlay growth

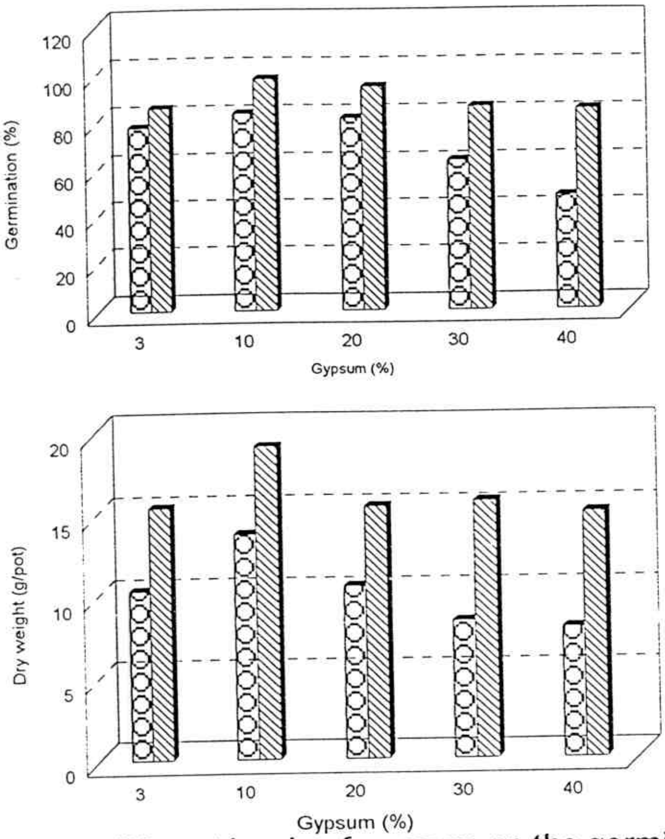


Fig. (4): Effect of different levels of gypsum on the germination % of barley and its dry weight after 6 weeks from sowing.

significant difference between germination under gypsum levels of 3, 10 and 20%, the differences were significant with the level of 30% and also 40%. Significant difference also was occurred between the germination % under 30% and 40% soil gypsum contents. On contrary, in the second year no significant differences were recorded between the germination percentages under all gypsum content levels. The highest values were obtained from plants grown under soil gypsum content 10% in both 1 st and 2 nd years experiments, (83.3 and 97.8%, respectively). However, the lowest germination percentages were got for barley cultivation under soil gypsum content of 40% in both years experiments, (47.8 and 84.4%, respectively).

Dry weight:

The highest dry weight was recorded at the gypsum content of 10% in both 1 st and 2 nd years, where they were 13.80 and 19.14 g/pot, respectively. On the other hand, the lowest values were found at the level of 40% gypsum, where they were 7.98 g/pot in the 1 st year and 15.00 g/pot in the 2 nd year. Statistically, there are no significant differences between the dry weight of plants grown under 3,20,30 and40% gypsum contents in the 2 nd.

Nutrients uptake:

Nitrogen

Nitrogen uptake by barley plants was higher in the second year than in the first at all soil gypsum content levels (Fig. no.5). The highest values of nitrogen uptake were obtained by barley plants grown under gypsum content of 10% in both first and second years, (191.5 and 360.5 mg N/pot, respectively). The lowest, ones, were found for plants that planted in the soil having 40% of gypsum. Significant differences were wider among the values of the first year than in the second. The uptake decreased as the soil gypsum content increased from 10% up to 40%.On the other hand,data indicate

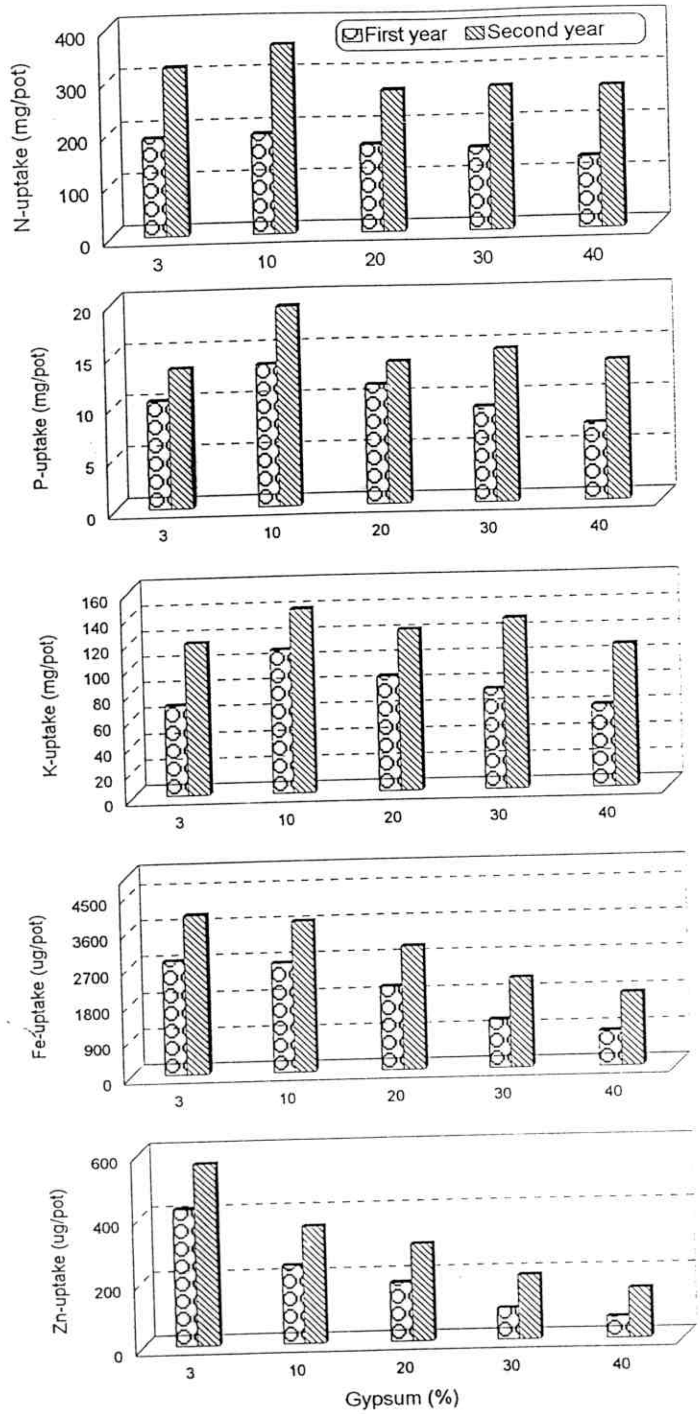


Fig. (5): Effect of different levels of gypsum on the uptake of N, P, K, Fe and Zn by barley plants after 6 weeks from sowing.

that values of N-uptake by plants grown on soil contained 3% gypsum was less than that plants cultivated at 10% of gypsum.

Phosphorus:

Phosphorus uptake have the same trend as N. Highest values of P uptake at 10% gypsum in both 1 st and 2 nd years were 13.73 and 19.29 mg/pot, respectively, while the lowest one at 40% of gypsum were 7.36 and 13.45 mg/pot in the 1 st and 2 nd years, respectively. The significant differences between P-uptake were much higher for values of the first year than in the second year, (Table no.11 and Fig. no.5) .

Potassium:

Potassium behaved almost as nitrogen and phosphorus, where the highest values of K-uptake were detected in the barley plants grown on soil contained 10% of gypsum in both 1 st and 2 nd years (111.4 and 143.3 mg K/pot, respectively). The lowest values were recorded for the plants grown under gypsum content of 40% in the 1 st and 2 nd years (63.3 and 110.7 mg K/pot, respectively). It is noticed that values of K-uptake decreased in both years as soil gypsum content increased, with the exception of K uptake under the gypsum content of 3% where it was found to be less than that of 10,20 and30%.

Iron:

Fe-uptake by barley showed another behaviour than that of the macronutrients (N, P and K), where the highest values were detected for the plants which were sown under the least soil gypsum content (3%) in both years (2824.4 and 3961.5 ug Fe/pot, respectively). It was also noticed that Fe-uptake gradually decreased in both years, with the increase of soil gypsum content. Highly significant differences were recorded between the values uptake of Fe by the plants grown on soils contained 3% and40% gypsum content.

Zinc:

Zinc behaved almost as iron, where the highest uptake values were obtained by barley plants grown under the gypsum content of 3% in both 1 st and 2 nd years (422.0 and 563.0 ug Zn/pot, respectively).There were significant differences between the uptake values at least for three groups of data, namely 3% as a group, 10 and 20% as a second group and 30 and 40% as a third group.

General Conclusion

As a result of this experiment it could be stated that the soil that contained 10% of gypsum showed the best germination % and plant growth as well as the highest uptake of macronutrients and suitable uptake of micronutrients. It is also found that the conditions were improved in the second year due to the decrease of salts through successive irrigation.

Comparing the growth parameters between wheat and barley under the same conditions in these experiments, it is clear that barley seedlings gave higher values (about double) regarding germination %, dry weight and nutrients uptake.

These findings indicate the good stability of barley to gypsum content as tolerant crop more than wheat. These results were approved by **Mardoud (1996)** who investigated the productivity, fertilization and irrigation of the main crops grown on some gypsiferous soils of Euphrates basin. In the same respect **Verhey and Boyadgiev (1997)** stated that soils with high gypsum accumulation (> 25%) are only useful for tolerant crops as barley, tomato and onions.

4.5.2- Effect of soil gypsum content on plant growth:

The second greenhouse experiment was to assess the cultivation of soils that have various natural gypsum conducted in the light of the primary experimental results, where cultivated soils were provided with differenet levels of pure gypsum. The sown plants were wheat and barley for two years. In the first year the soils were sown as they were collected from the field and only of the required portions of macronutrient fertilizers were applied. However, in the second year organic manure was added and salt leaching was conducted before sowing the soils. The obtained results from these experiments can be discussed in the following:

4.5.2.1- Wheat :

Data of the conducted greenhouse experiment for wheat are presented in Table no.12. These data reveal that in the first year wheat succeeded to survive only in two soils namely Wadi El-Farigh (0-20) profil no.4 and El-Minya profil no.2 (photo no. 15) . Moreover, the growth conditions of wheat were much better in El-Minya soil than in Wadi El-Farigh. Statistically, Table (12) Effect of gypsum on the germination, dry weight and uptake of nutrients by wheat plants after 6 weeks of sowing

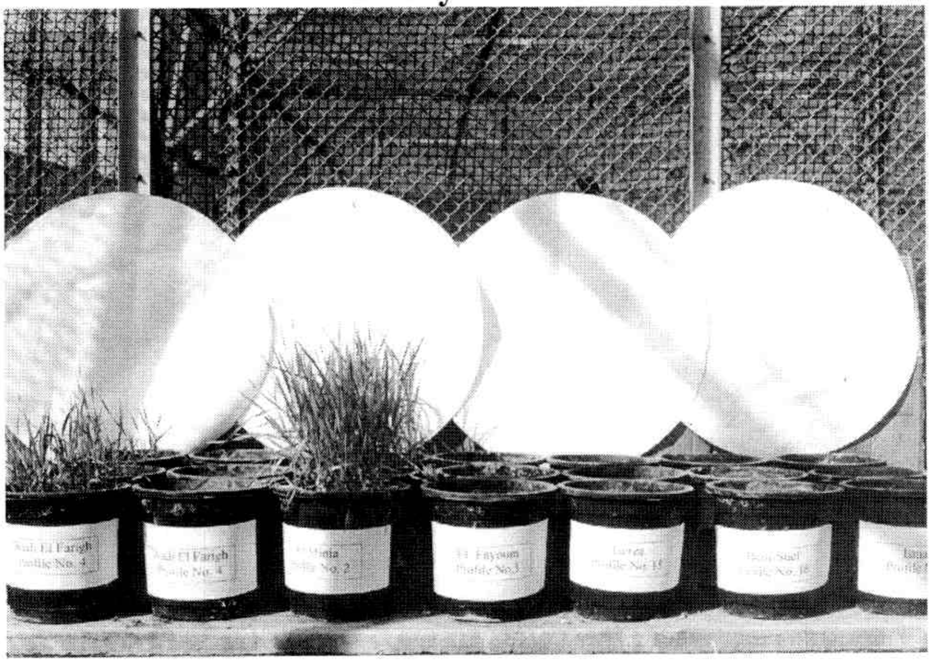
First year

Location of samples	Germination %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
Wadi El Farigh	36.3	5.34	98.16	7.77	51.47	1339.8	195.5
El Minya	90.8	9.89	179.89	15.71	96.77	2237.7	224.1
LSD 0.05	15.5	1.97	51.22	4.14	21.86	544.7	106.4
LSD 0.01	35.7	3.27	84.93	6.86	36.25	903.3	176.4

Second year

Location of samples	Germination %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
Wadi El Farigh	84.4	34.95	810.20	91.10	806.43	10578.4	836.6
Wadi El Farigh	87.8	37.51	926.63	95.13	328.80	11630.6	968.7
El Minia	92.2	42.19	1052.78	109.96	350.65	20428.2	1750.6
El Fayoum	80.0	34.41	919.55	81.13	300.00	10429.5	410.8
Gerza	78.9	34.07	666.60	79.85	300.50	10741.8	415.5
Beni Suef	90.0	38.41	969.31	100.43	345.76	18159.6	1116.9
Ismailia	32.2	15.72	211.29	25.23	97.11	4570.8	146.5
LSD 0.05	7.53	1.81	174.25	5.63	18.65	1422.6	112.5
LSD 0.01	10.45	2.51	251.85	7.81	25.89	1974.6	156.2

First year



Second year

Photos (15), Effect of soil gypsum content on the wheat growth

significant differences are obtained between the results of the two soils. It is worth to mention that El-Minya soil contained 12.8% gypsum and had an EC value of 3.8 dS/m^3, whereas Wadi El-Farigh soil had 3.1% of gypsum and EC value of 14.7 dS/m^3. The profile description of El Minya (appendix) refers that this soil was cultivated for10 years with different field crops and characterized by medium texture originated from shale deposits.

These results indicate that gypsum content in soil is not the only factor that limit the growth of wheat seedlings. Evidently the total soluble salts (14.7 dS/m) greatly inhibit germination in the soil of Wadi El Farigh.

In the second year, however, the plants have grown in all soils but much variation between the results was occurred. Generally, El-Minya soil gave the highest results above all other soils. Germination percentage of wheat plants varied between 92.2% for El-Minya, which contained 12.8% of gypsum and 32.2% for Ismailia soil that had 81.7% of gypsum, (Fig. no.6). These results are matching with the obtained results of the first experiment, where the soil that contained 10% of gypsum gave the best plant conditions.

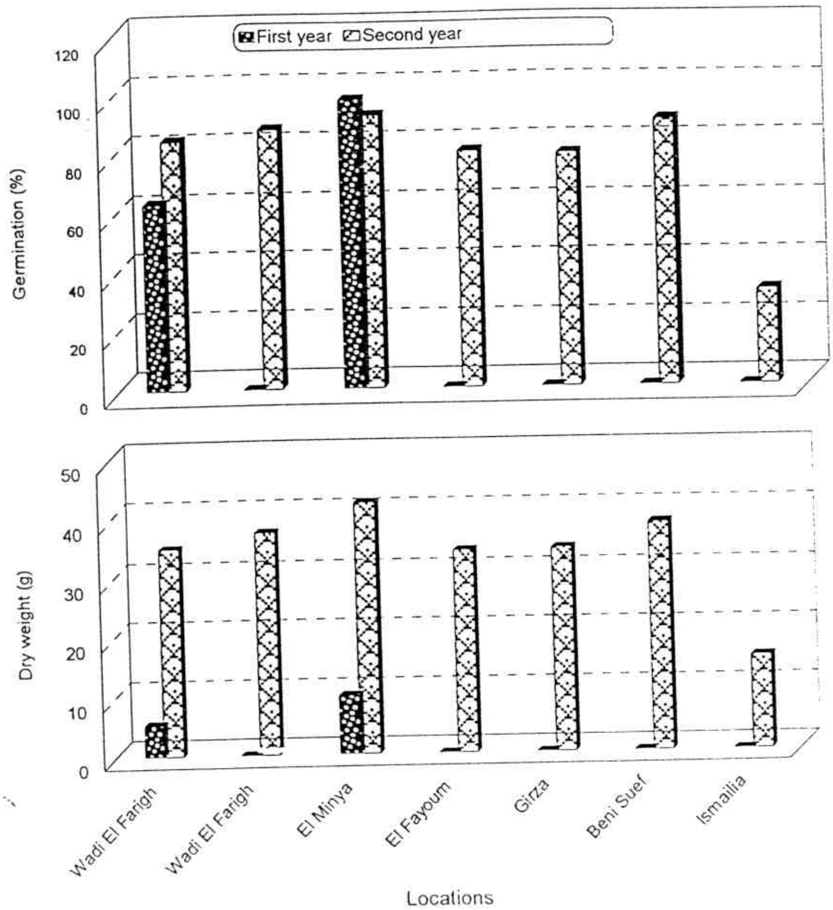


Fig. (6): The germination % of wheat and its dry weight in the investigated soils

The highest value of wheat was achieved in dry matter for El-Minia soil (42.19 g/pot) and the lowest are was obtained in Ismailia soil (15.72 g/pot). Although, the soil of Beni Suef had 31.11% of gypsum, it gave very good results just after those of El-Minya soil. The germination percentage of this soil reached 90% and the dry weight of wheat amounted to 38.41 g/pot. Nutrients as N, P, K, Fe and Zn uptake (Fig 7) were found to be the highest for wheat plants under El-Minya soil followed by Beni Suef, Wadi El-Farigh 2 and 1, El-Fayoum, Girza and Ismailia soils which corresponded to gypsum content of 12.80, 31.11, 8.30, 3.10, 20.70, 27.52 and 81.70%, respectively. The obtained results for different soils were significantly different as shown in Table (12).

The figures of dry matter and the nutrient content of the wheat plants in the second year prove that growth conditions in all soil samples are improved due to leaching of salts through successive irrigations and the increase of nutrients from the residues of previous plantation. The variations in growth parameters between the soils under

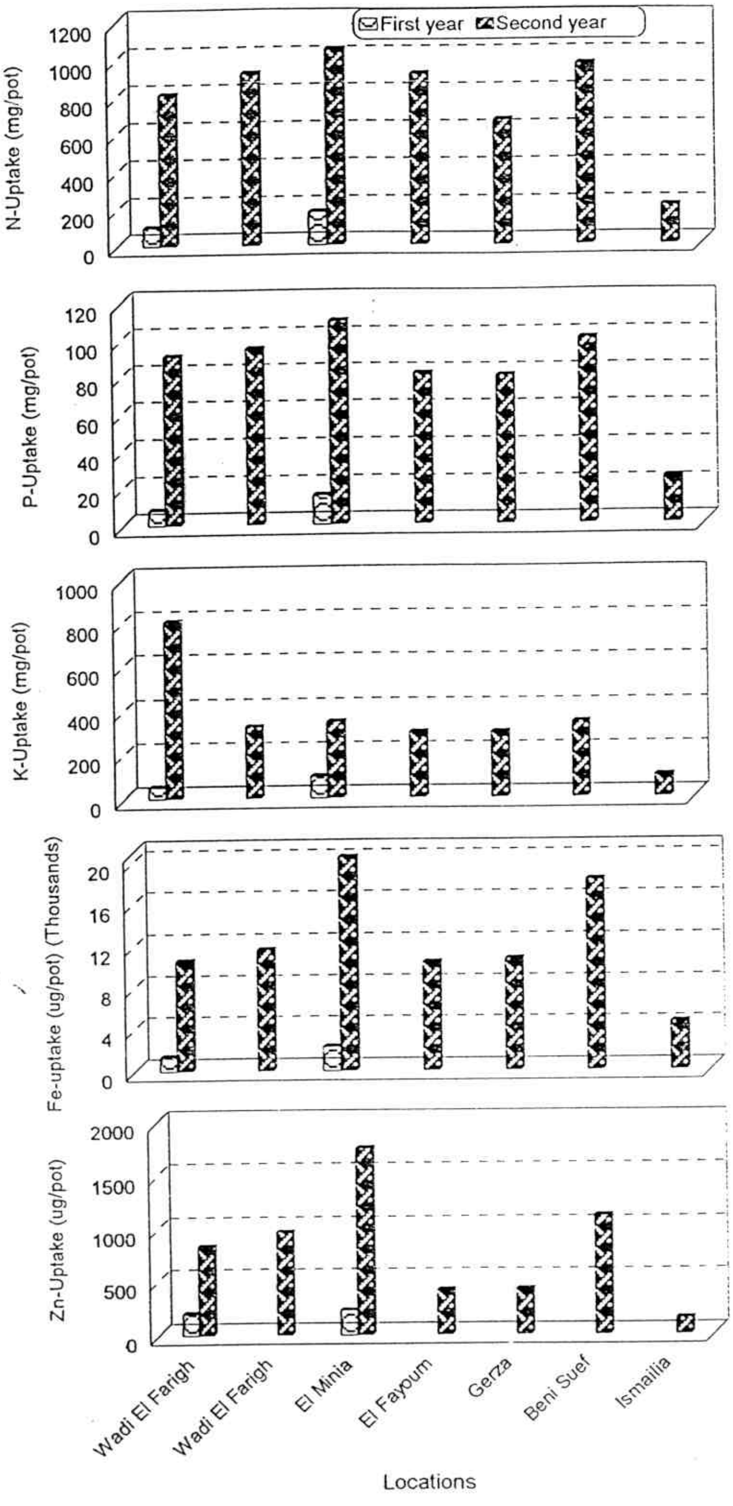
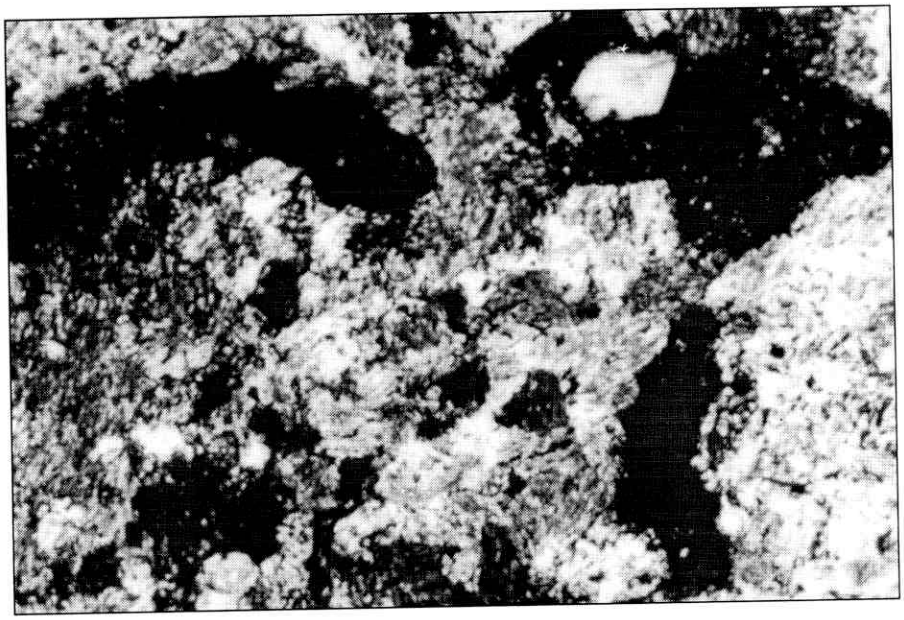


Fig. (7): The uptake of N, P, K, Fe and Zn by wheat plants in the investigated soils.

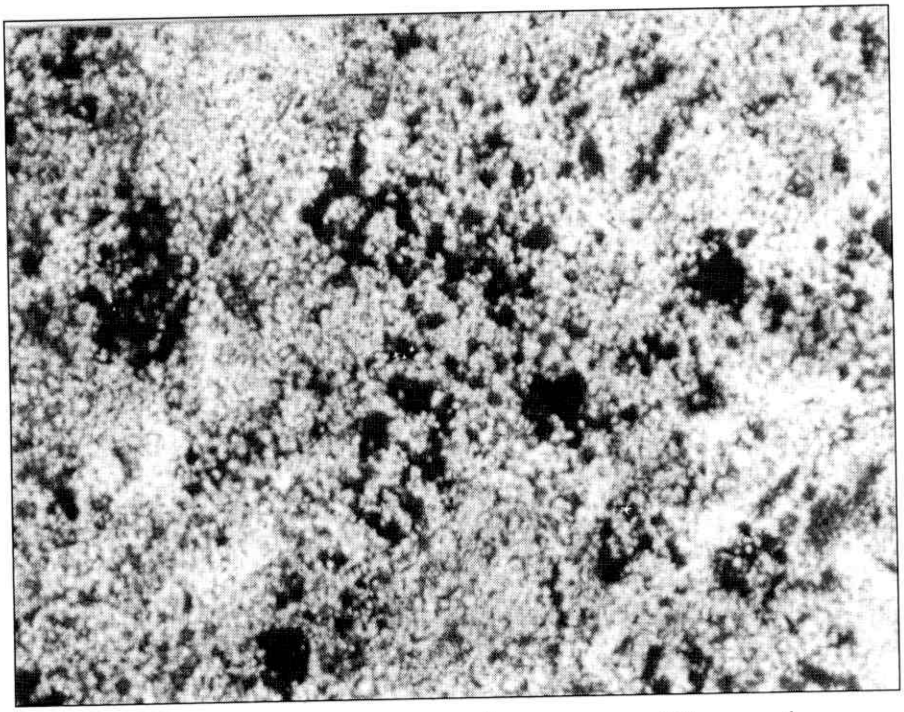
consideration can be attributed to the form of gypsum accumulation in these soils. The soils of Beni Suef which gave high germination % (90%) and dry matter 38.41 g/pot, has 31.11% gypsum in the form of intercalary gypsum crystal and very small granules besides some intergrowth grains (photos 16). These forms of gypsum besides the 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. Comparing the results of Wadi El Farigh (profile no 4) with low gypsum (3.1%) and $CaCO_3$ (1.90%) contents which gave lower germination than El Minya and Beni Suef due to the influence of small crystallites of gypsum scattered in the groundmass forming the chitonic related distribution, besides the influence of salinity (residual after leaching) (Table no.1, and photo no. 3 appendix).

4.5.2.2 Barley

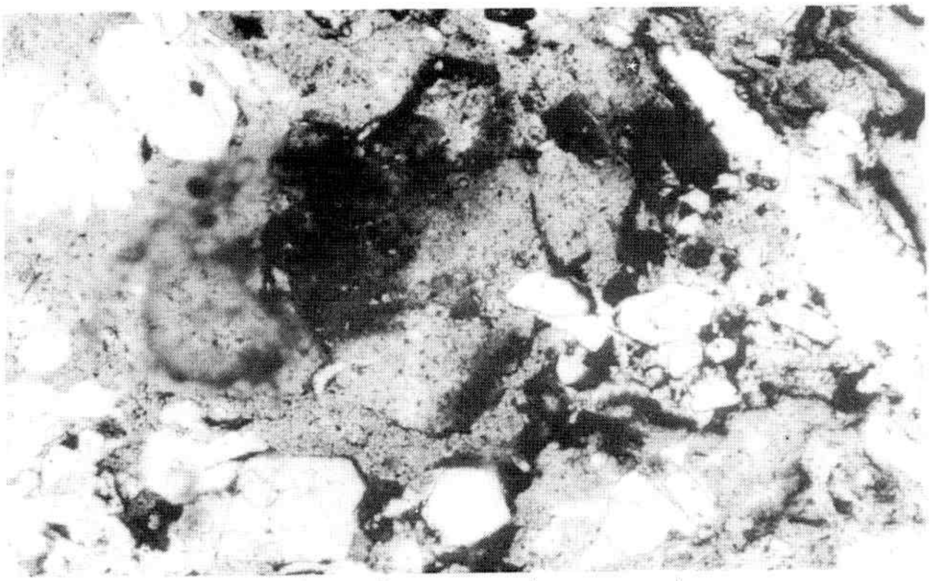
Germination of Barley showed more adaptation to gypsic soils than wheat, where barley grew in all soils starting from the first year, (Table no. 13 and photo 17). However, the soils exhibted



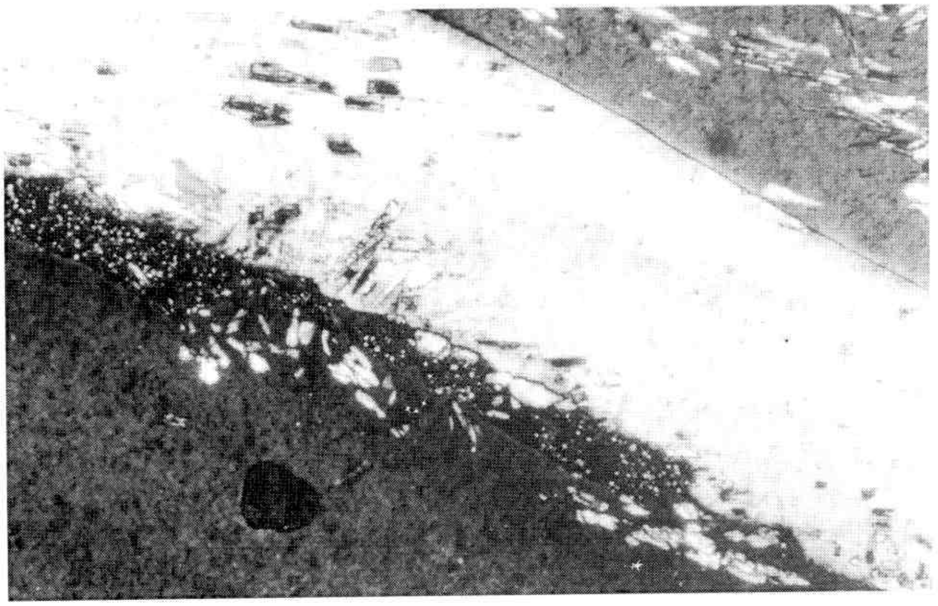
Interblocking networks of euhedral gypsum crystals , profile no. 3, North of EL Minya , depth of (0 – 85 cm) X 4



Gypsum scattered in groundmass , profile no. 4 , Wadi EL Farigh , depthof (20 – 60 cm) X 10, Photos (16)



Isolated single grains of gypsum in groundmass, Profile no. 2, El Minya, depth of (20-40cm) X10



Large intergrowth comented gypsum, some acicular small gypsum crystals, profile no. 2, EL Minya, depth of (40-70cm) X4, Photos (16) cont.

Table (13) Effect of gypsum on the dry weight and uptake of N, P, K, Fe and Zn by barely plants after 6 weeks of sowing

First year

Location	Germi-nation %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
Wadi El Farigh	94.4	29.5	535.3	67.9	235.2	1734.0	315.0
Wadi El Farigh	86.7	24.8	384.2	42.0	160.7	4568.0	234.0
El Minia	87.8	27.9	450.8	59.7	161.3	8196.0	500.0
El Fayoum	90.0	28.8	529.6	66.5	180.6	11523.0	698.0
Gerza	87.8	25.9	400.9	51.1	161.3	7355.0	390.0
Beni Suef	97.8	37.9	752.7	90.1	274.3	18918.0	969.0
Ismailia	42.2	12.3	116.0	24.6	95.7	2715.0	119.0
LSD 0.05	8.73	2.1	88.59	8.07	37.71	1011.7	180.2
LSD 0.01	12.12	2.92	122.95	11.21	52.34	1404.2	250.0

Second year

Location	Germi-nation %	Dry weight (g/pot)	N (mg/pot)	P (mg/pot)	K (mg/pot)	Fe (ug/pot)	Zn (ug/pot)
Wadi El Farigh	76.7	24.41	508.5	51.9	176.3	4220.0	395.0
Wadi El Farigh	83.3	28.8	601.2	68.5	208.0	8340.0	396.0
El Minia	90.0	35.05	674.3	83.4	251.5	11033.0	660.0
El Fayoum	96.7	42.7	925.6	107.0	356.6	21466.0	1303.0
Gerza	93.3	37.3	784.8	88.8	266.0	16874.0	1060.0
Beni Suef	96.7	39.9	804.1	101.3	351.5	18388.0	1253.0
Ismailia	36.7	15.2	195.1	27.3	114.2	4311.0	197.0
LSD 0.05	7.33	1.96	83.7	4.39	19.59	1841.0	97.4
LSD 0.01	10.18	2.72	116.1	6.10	27.19	2555.0	135.2

First year

Second year

Photos (17), Effect of soil gypsum content on the barley growth

different responses for the barley cultivation. Beni Suef soil (31.11% gypsum) was the best for barley in both first and second year experiments, followed by Wadi El-Farigh 1 (3.1% gypsum) in the first year and El-Fayoum (20.7% gypsum) in the second year. On the other hand, the least soil for barley remained the Ismailia soil (81.7% gypsum) in both first and second year experiments as well for wheat.

Germination percentage was the highest for barley that grow under Beni Suef soil (97.8 and 96.7% in the first and second years, respectively). It was the lowest for barley plants that planted under Ismailia soil (42.2 and 36.7% in the first and second years, respectively) (Fig.no.8). The dry matter content had similar trend where it was found to be the highest of (37.88 and 42.70 g/pot) under the soil of Beni Suef in the first and second years, respectively. The lowest values of dry weight were recorded for Ismailia soil where they reached 12.33 and 15.21 g/pot in the first and second years, respectively. Values of N, P, K, Fe and Zn uptake (Fig.no.9) were the highest for barley under Beni Suef soil followed by El-Fayoum, Girza, El-Minya,

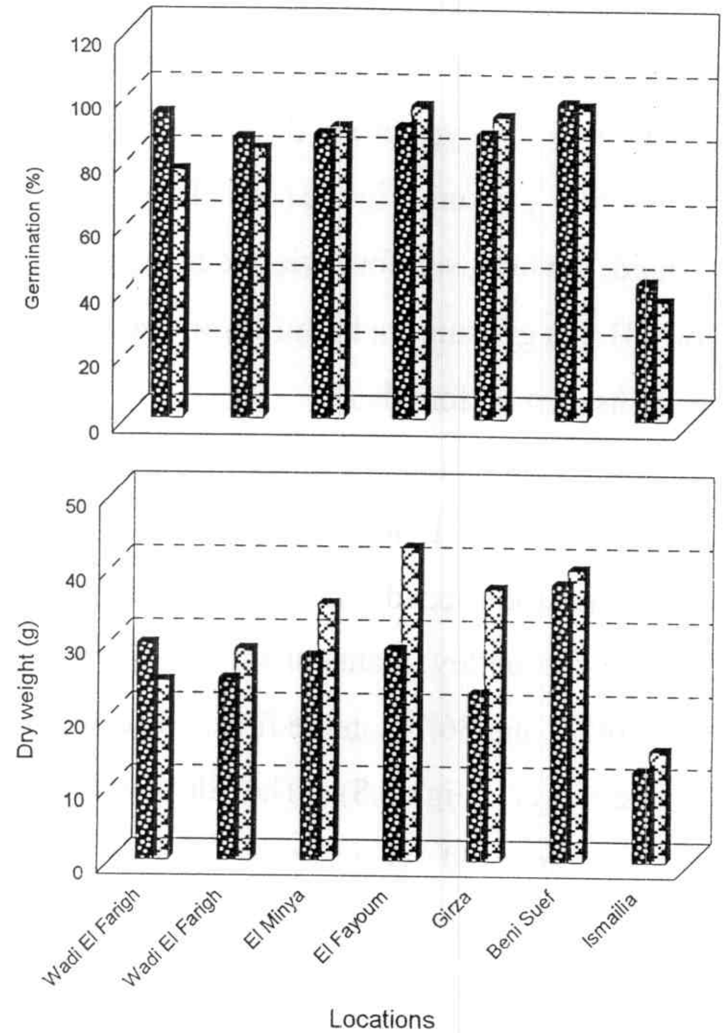


Fig. (9): The germination % of barley and its dry weight in the investigated soils.

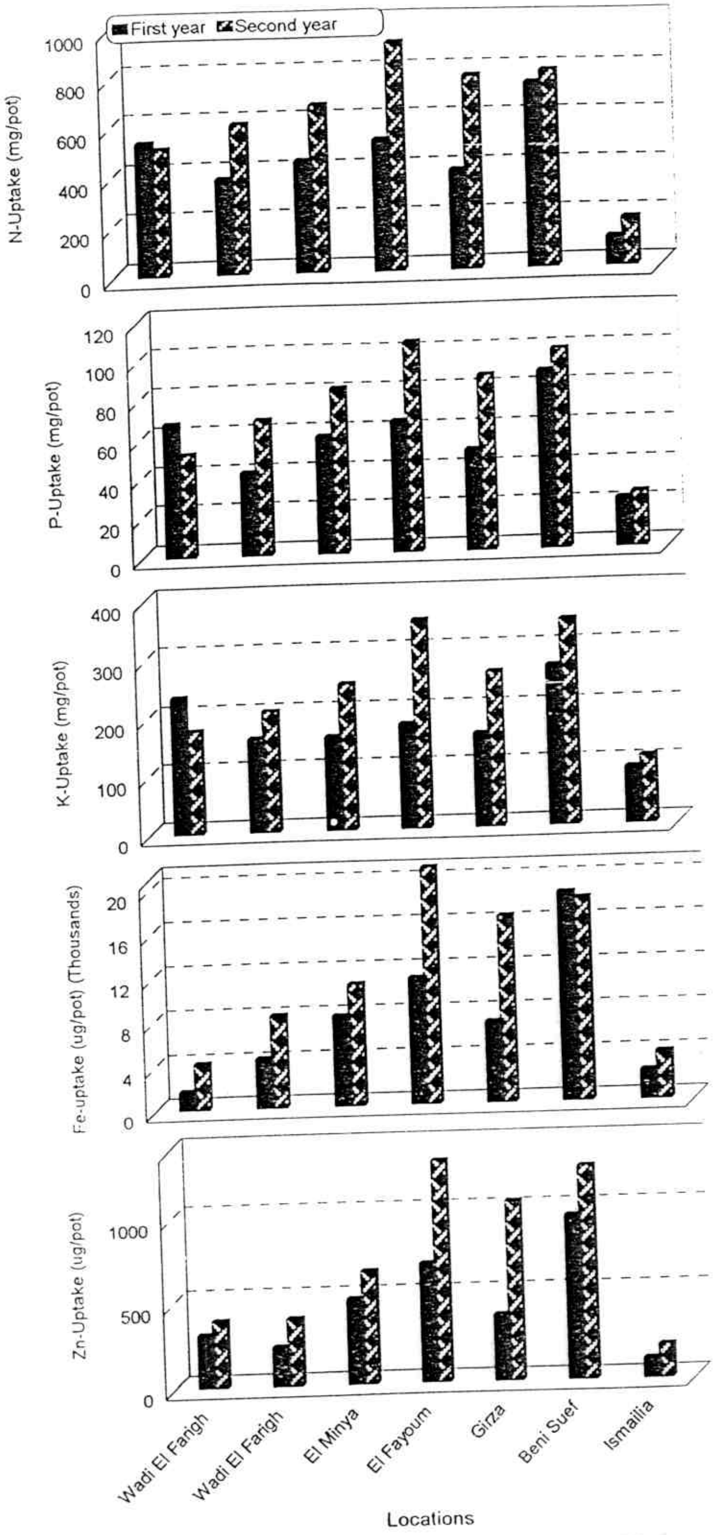


Fig. (9): The uptake of N, P, K, Fe and Zn by barley plants after 6 weeks from sowing.

Wadi El-Farigh 2,1 and Ismailia soils, corresponding to soil gypsum content of 31.11, 20.70, 27.52, 12.80, 8.30, 3.10 and 81.70%, respectively.

Highly significant differences between the obtained results were statistically found.

General Conclusions

The greenhouse experiments, which were conducted to assess cultivation of gypsiferous soils of Egypt, revealed some conclusions.

1- The soils that contain gypsum contents up to 30% could be used for agricultural purposes with satisfactory output.

2- The use of these soils improves their capabilities for agricultural production, as it is indicated in the second year experiment.

3- Barley showed more adaptation to the soils contain gypsum than wheat, especially in the first year of cultivation.

4- The obtained results were so variable and statistically significant due to many factors. The total content of gypsum and the form of crystals whether they are fine crystallites scattered in the groundmass or large cemented intergrowth grains. The associated salts and the sort of these salts are very important factors. Also the calcium carbonate accumulations which fix many of the nutrients and inhibit their uptake by plants are limiting factor as well.

5- More investigations should be conducted specially under field conditions in order to establish a management program and get better investment of these soils.