Zagazig J. Agric. Res., Vol. 46 No. (5) 2019 1467-1478

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

THE ROLE OF MAGNESIUM IN PHOSPHORUS AVIALABILITY IN SOIL

Eman I. El-Nagar*, **I.R. Mohamed, Atyat E. Nasralla and A.S. Elrys**

Soil Sci. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 01/07/2019; Accepted: 04/08/2019

ABSTRACT: An experiment was carried out under laboratory conditions to study the change in available phosphorus (P), magnesium (Mg), calcium (Ca), pH value and EC value during 336 hours of incubation as affected by three levels of each of P and Mg and all possible combination between them in clayey and sandy soils. Ordinary superphosphate fertilizer as a P-source at rates of 0 (P_0), 13.1 (P_1) and 26.2 (P_2) mg P kg^{-1}, the rates of Mg were 0 (Mg_0), 20 (Mg_1) and 40 (Mg_2) mg Mg kg^{-1} as magnesium sulphate. The results indicated that available P, Mg and Ca as well as EC were increased with increasing P fertilizers rates, while pH was decreased in the two tested soils. Available P, Mg and EC were increased with increasing Mg fertilizers rates, while available Ca and pH were decreased in the two tested soils. Available P increased up to 12 hours and then decreased with increasing incubation time. Available Mg, available Ca and EC increased until 72 hours and then decreased until the end of the experiment, while pH decreased until 72 hours and then increased until the end of the experiment.

Key words: Super phosphate, magnesium fertilizers, sandy and clay soils.

INTRODUCTION

Phosphorus (P) is an essential element for plant growth, crop production and quality. With increasing demand of agricultural production and as the peak in global production will occur in the next decades, P is receiving more attention as a nonrenewable resource (**Cordell *et al.*, 2009; Gilbert, 2009**). One unique characteristic of P is low availability due to slow diffusion and high fixation in soils. Plants up take only 10-20% of the P applied with fertilizers in the year of application because the majority of applied P is rapidly fixed or precipitated into poorly available forms (**Nassar *et al.*, 2006**). Due to low P availability in soil and low fertilizer use efficiency, farmers often apply P fertilizers in excess of plant requirements. Phosphorus is essential for cell division because it is a constituent element of nucleoproteins which are involved in the cell reproduction processes. It also affects the quality of the grains and it may increase the plant resistance to diseases (**Camargo *et al.*, 2000**). It is essential for good vegetative growth and grain development in maize production. **Amanullah and Khalil (2009)** found that P fertilizers application have a significant effect on wheat crops production.

There are many factors influencing P availability, efficiency and recovery of P fertilizer by plants like soil pH, texture, type of clay minerals, calcium carbonate content of the soil, organic matter content of the soil and Mg/Ca ratio of irrigation water or soil solution in additional to mycorhizal activity **(Al-Akrawi, 2002)**. Magnesium (Mg) plays a positive role in P availability and recovery of P by crops in calcareous soil like Mg concentration in soil solution. **Al-Kaysi and Saleem (1990)** applied different ratios (0/0, 0/200, 50/150, 100/100, 150/50, 200/0 meq L^{-1}) of Mg/Ca and they indicated that the increase in the ratio of applied Mg/Ca caused an increase in P availability for plants. **Esmail *et al.* (1999)** indicated that the increase in Mg/Ca to 1.5 in soil solution and irrigation water caused a significant increase in available P in the soil and its recovery by plant. **Al-Akrawi (2002)** studied the influence of four levels (0, 40, 80, 120 kg Mg fad^{-1}) of Mg on the

***Corresponding author: Tel. :** +201060726441
E-mail address: emanelnagar82@.com

efficiency of P fertilizer by using three levels of triple superphosphate (0, 100, 200 kg P fad^{-1}). He found that the application of 120 kg fad^{-1} of Mg-fertilizer caused the conversion of P phase to more soluble form in comparing with control treatment. Applications of chemical P fertilizers and $MgSO_4$ to agricultural land have improved soil P fertility and crop production.

A little information is handy regarding the effects of Mg fertilization on the availability of P fertilizer under different soil types. Therefore, the present work aims to study the effect of Mg fertilization on P availability in clay and sandy soils.

MATERIALS AND METHODS

Soil Sampling

Two different soil samples were collected from the top surface up to 30 cm depth as follows: i) A clay, soil samples from Hihia District, Sharkia Governorate, and ii) A sandy soil from the farm of the faculty of agriculture at El-Khattara county, Sharkia Governorate. Soil samples were air dried, crushed, sieved through 2 mm plastic screen, thoroughly mixed and stored in plastic bags for analysis and experimental work. Table 1 shows some physical and chemical characteristics of the studied soils.

Soil analysis were done according to the methods described by **Black *et al.* (1965)**.

Mineral Fertilizers

Mineral fertilizers which used in this work were ordinary superphosphate (P) (67.6 g P kg^{-1}) as source of P, and magnesium sulphate (Mg) (98.0g Mg kg^{-1}) as a source of Mg.

Incubation Experiment

An incubation experiment was conducted to study the changes of available P, Mg and Ca as well as the change in soil pH and EC at various intervals (6, 12, 24, 48, 72, 168 and 336 hour) as affected by ordinary superphosphate (P) added either singly at the rates of zero (P_0), 13.1 (P_1) and 26.2 (P_2) mg kg^{-1} or combined with magnesium sulphate (Mg) at the rates of zero (Mg_0), 20 (Mg_1) and 60 (Mg_2) mg Mg kg^{-1} . 200 g of each soil type was placed in small plastic containers. Treatments were replicated three-times and containers were kept under laboratory condition. The experimental treatments were as follows: 1) P_0Mg_0, 2) P_1Mg_0, 3) P_2Mg_0, 4) P_oMg_1, 5) P_1Mg_1, 6) P_2Mg_1, 7) P_oMg_2, 8) P_1Mg_2, and 9) P_2Mg_2. The soil moisture content was adjusted at the field capacity through the experimental period. The plastic contains were covered through the experimental time and incubated at room temperature (30ºC approximately). Soil samples were taken at intervals of (6, 12, 24, 48, 72, 168 and 336 hour), where available P, Mg and Ca as well as soil pH and EC were determined.

Soil Analysis

The methods used for different analysis conducted could be described briefly as follows: The electrical conductivity (EC) of soil paste extract was determined using the method as described by **Jackson (1973)**. Soil pH was measured using glass electrode pH meter in a 1 : 2.5 soil water suspension (**Cottenie *et al.*, 1982**). Available P was determined using the method of **Watanabe and Olsen (1965)**. Available Ca and Mg were determined following the Versenate method (**Jackson, 1973**).

RESULTS AND DISCAUSSION

Available Phosphorus

Results in Table 2 demonstrate the effect of P and Mg fertilizers on P availability in clay and sandy soils during incubation of successive intervals. Obtained results can be discussed under following headings:

Effect of P fertilizer rates

Results revealed that values of P availability in the untreated clayey soil during oven the different incubation periods, ranged from 18.2 to 19.8 mg P kg^{-1} with an average of 19 mg P kg^{-1} soil. The corresponding range in sandy soil was 9.9 to 10.9 mg P kg^{-1} with an average 10.4 mg P kg^{-1} soil. In the treated clayey soil with 13.1 mg kg^{-1} (P_1) ranged from 18.3 to 27.1 mg P kg^{-1} with an average of 23.1 mg P kg^{-1} soil. While in sandy soil it ranged from 13.0 to 17.9 mg P kg^{-1} with an average of 16.1 mg P Kg^{-1} soil. In the treated clayey soil with 26.2 mg kg^{-1} (P_2) ranged from 21.5 to 31.3 mg P kg^{-1} with an average of 27.1 mg P kg^{-1} soil. For corresponding range in sandy soil, the values ranged from 15.3 to 21.5 mg p kg^{-1} with an average of 19 mg P kg^{-1} soil.

Table 1. Some physical and chemical properties of the investigated soils

Soil characteristic	Soil location	
	Hihia	El-khattara
Soil particles size distribution (%)		
Sand	36.1	92.2
Silt	17.0	6.69
Clay	46.9	1.11
Textural class	Clay	Sand
Field capacity (%)	35.3	10.2
$CaCO_3$ (g kg^{-1})	8.30	3.00
Organic matter (g kg^{-1})	17.3	3.44
pH	7.74	8.07
EC (µS cm^{-1})	213	78
Soluble cations and anions ($mmol_c$ L^{-1})**		
Ca^{2+}	5.70	2.46
Mg^{2+}	2.15	1.04
Na^+	12.3	3.35
K^+	1.10	0.95
CO_3^{2-}	Nil	Nil
HCO_3^-	1.51	2.04
Cl^-	7.20	4.13
SO_4^{2-}	12.54	1.63
Available nutrient (mg kg^{-1} soil)		
N	64.3	44.2
P	22.7	14.7
K	135	182
Ca	22.5	12.6
Mg	15.6	7.3

pH: in soil- water suspension 1: 2.5 EC: in soil paste extract

Table 2. Effect of phosphatic and magnesium fertilization on available phosphorus (mg P kg^{-1}) in clayey and sandy soils during incubation periods

Soil type	Mineral fertilizer (mg kg^{-1} soil)		Incubation period (hr.)							Average
	P	Mg	6	12	24	48	72	168	336	
Clayey soil	P_0	Mg_0	19.4	19.8	19.5	19.0	18.5	18.4	18.2	19.0
		Mg_1	20.9	21.2	21.0	20.1	19.6	19.7	19.1	20.2
		Mg_2	21.3	21.6	20.9	20.5	20.3	19.7	19.3	20.5
	P_1	Mg_o	25.9	27.1	24.7	22.9	21.8	20.8	18.3	23.1
		Mg_1	27.1	27.9	26.5	25.1	23.6	22.3	19.6	24.6
		Mg_2	28.8	29.4	28.6	26.0	25.3	24.0	21.1	26.2
	P_2	Mg_o	30.5	31.3	29.1	26.8	25.8	24.4	21.5	27.1
		Mg_1	31.8	32.4	30.2	28.0	26.8	25.3	22.3	28.1
		Mg_2	34.0	34.1	31.7	29.8	28.3	26.7	23.5	29.7
Sandy soil	P_0	Mg_o	10.8	10.9	10.5	10.3	10.2	10.1	9.9	10.4
		Mg_1	11.5	11.7	11.1	11.0	10.7	10.6	10.4	11.0
		Mg_2	11.7	11.9	11.5	11.3	11.1	10.6	10.6	11.3
	P_1	Mg_o	17.9	18.0	17.2	17.0	15.4	14.2	13.0	16.1
		Mg_1	19.6	19.7	18.6	18.3	16.3	14.7	13.7	17.3
		Mg_2	20.3	20.5	19.9	19.7	17.6	15.4	14.7	18.3
	P_2	Mgo	21.0	21.5	20.3	20.0	18.2	16.4	15.3	19.0
		Mg_1	21.9	22.0	21.1	20.8	19.2	17.0	15.7	19.7
		Mg_2	23.3	23.5	22.3	21.9	20.9	17.9	17.1	21.0

P_0: without phosphorus P_1: 13.1 mg P kg.$^{-1}$ P_2:26.2 mg P kg.$^{-1}$
Mg_0: without magnesium Mg_1: 20 mg Mg kg.$^{-1}$ Mg_2: 40 mg Mg kg.$^{-1}$

The average values of available phosphorus were increased with increasing the application rate of ordinary super phosphate (P) to each tested soil. This finding is in agreement with that obtained by each of **Nassar *et al.* (2000) Merwad (2013) and Abd El-Satar (2018).** The average values of available P in untreated clayey soil were greatest than those in untreated sandy soil. This result could be due to the great native content of available P in clayey soil (Table 1).

Effect of Mg fertilization rates

Results presented in Table 2 show that in absence of P fertilizer (P_0), the values of available-P in a clay soil treated with (Mg_1) and (Mg_2) during the various incubation periods ranged from 19.1 to 21.2 mg P kg^{-1} and 19.3 to 21.6 mg P kg^{-1} with an average of 20.2 and 20.5 mg P kg^{-1} soil, respectively. The corresponding ranges in a sandy soil were 10.4 to 11.7 mg P kg^{-1} and 10.6 to 11.9 with an average of 11 and 11.3 mg P kg^{-1} soil, respectively. Corresponding ranges of the same treatments under the application of P fertilizer at the rate of (13.1 mg P kg^{-1}) (P_1) to clayey soil were 19.6 to 27.9 mg P kg^{-1} and 21.1 to 29.4 mg P kg^{-1} with an average of 24.6 and 26.2 mg P kg^{-1} soil , respectively. While in sandy soil were 13.7 to 19.7 mg P kg^{-1} and 14.7 to 20.6 mg P kg^{-1} with an average of 17.3 and 18.3 mg P kg^{-1} soil, respectively .On the other hand, the addition of P fertilizer at the rate of (26.2 mg P kg^{-1}) (P_2) gave the corresponding values in clayey soil ranged from 22.3 to 32.4 mg P kg^{-1} and 23.5 to 34.1 mg P kg^{-1}, with an average of 28.1 and 29.7 mg P Kg^{-1}, respectively. While in the sandy soil ranged from 15.7 to 22.0 mg P kg^{-1} and 17.1 to 23.5 mg P kg^{-1} with an average of 19.7 and 21.0 mg P kg^{-1}, respectively. The average values of available P in the studied soils were increased with the addition of Mg fertilizer rates. This finding is in agreement with that obtained by **Marion and Babcock (1977), Kuo and Mikkelsen (1979) and Al-Akrawi (2002)**.

Effect of incubation time

After 6, 12, 24, 48, 72, 168 and 336 hours of incubation, the greatest values of available P

(23.3 and 34.0), (23.5 and 34.1), (22.3 and 31.7), (21.9 and 29.8), (20.9 and 28.3), (17.9 and 26.7) and (17.1 and 23.5) mg P kg^{-1} soil were found with the treatment of (P_2 + Mg_2) in the sandy and clayey soils, respectively. While the lowest ones (10.8 and 19.4), (10.9 and 19.8), (10.5 and 19.5), (10.3 and 19.0), (10.2 and 18.5), (10.1 and 18.4) and (9.9 and 18.2) mg P kg^{-1} soil were observed with the treatment of P_0 + Mg_0 in the sandy and clayey soils, respectively.

As a general result, the available P was increased after 12 hours of incubation for the clay and sandy soils after that the available P level gradually decreased in the tested soils for all studied treatments. The first slightly increase may lie interpreted in terms of the work of **Barea *et al.* (1970)**, who reported that the microbial activity have the ability to affect soil reaction in soil microenvironment leading to solubilizing of inorganic P. The gradually reduction in available P level after 24 hours until the end of incubation periods could lie due to assimilation by microorganisms. This result is in a good agreement with those obtained by **Stevenson (1982), Mohamed *et al.* (1991), Merwad (2013) and Abd El-Satar (2018)**.

Available Mg

Results in Table 3 show the effect of P and Mg fertilizers on Mg availability in clayey and sandy soils during incubation of successive intervals.

Effect of P fertilizer rates

Results revealed that values of available Mg in the untreated clayey soil, over the different periods of incubation, ranged from 1.01 to 1.08 mg Mg kg^{-1} with an average of 1.05 mg Mg kg^{-1}. The corresponding range in sandy soil was 0.30 to 0.34 mg Mg kg^{-1} with an average of 0.32 mg Mg kg^{-1}. In the treated clay soil with only 13.1 mg P kg^{-1} (P_1) ranged from 1.13 to 1.38 mg Mg kg^{-1} with an average of 1.29 mg Mg kg^{-1}. While in sandy soil ranged from 0.33 to 0.42 mg Mg kg^{-1} with an average of 0.38 mg Mg kg^{-1}. In the treated clay soil with only 26.2 mg P kg^{-1} (P_2), available Mg ranged from 1.13 to 1.45 mg Mg kg^{-1} with an average of 1.29 mg Mg kg^{-1}. For corresponding range in sandy soil, the values ranged from0.34 to 0.40 mg Mg kg^{-1} with an average of 0.37mg Mg kg^{-1}. The average values of available Mg were increased with increasing P fertilizer rates in absence or presence of Mg fertilization in two investigated soils, this finding is in agreement with that obtained by **Sutcliffe and Baker (1983)**.

Effect of Mg fertilization rates

Results presented in Table 3 show that in absence of P fertilizers (P_0), the values of available-Mg in a clay soil treated with (Mg_1) and (Mg_2), during the various incubation periods ranged from 1.40 to 1.70 mg Mg kg^{-1} and 1.48 to 1.80 mg Mg kg^{-1} with an average of 1.56 and 1.69 mg Mg kg^{-1} soil, respectively. The corresponding ranges in a sandy soil were 0.39 to 0.49 mg Mg kg^{-1} and 0.43 to 0.52 with an average of 0.45 and 0.49 mg Mg kg^{-1}, respectively. In presence of P fertilizer at the rate of (13.1 mg P kg^{-1}) the corresponding ranges to clayey soil with (Mg_2) were 1.57 to 1.87 mg Mg kg^{-1} and 1.99 to 2.38 mg Mg kg^{-1} with an average 1.72 and 2.22 mg Mg Kg^{-1}, respectively, while in sandy soil were 0.46 to 0.54 mg Mg kg^{-1} and 0.59 to 0.70 mg Mg kg^{-1} with an average 0.50 and 0.66 mg Mg kg^{-1} soil, respectively. On the other hand, the addition of P fertilizers at the rate of (P_2) gave the corresponding values in clayey soil ranged from 1.74 to 2.09 mg Mg kg^{-1} and 2.11 to 2.50 mg Mg kg^{-1}, with an average of 1.90 and 2.31 mg Mg kg^{-1} soil, respectively. While in sandy soil ranged from 0.50 to 0.61 mg Mg kg^{-1} and 0.63 to 0.72 mg Mg kg^{-1} with an average of 0.56 and 0.68 mg Mg kg^{-1} soil, respectively. The average values of available Mg were increased with increasing Mg fertilizers rates in absence or presence of P fertilization in the two soils under study. This finding is in agreement with that obtained by **Sutcliffe and Baker (1983)**.

Effect of incubation time

After 6, 12, 24, 48, 72, 168 and 336 hours of incubation, the highest values of available magnesium (0.63 and 2.11), (0.67 and 2.29), (0.71 and 2.37), (0.72 and 2.46), (0.71 and 2.50), (0.70 and 2.33) and (0.64 and 2.13) mg Mg kg^{-1} soil were found with the treatment of (P_2 + Mg_2). The lowest ones (0.31 and 1.08), (0.31 and 1.05), (0.31 and 1.06), (0.34 and 1.07), (0.33 and 1.07), (0.33 and 1.06) and (0.30 and 1.01) mg Mg kg^{-1} soil were observed with the treatment of P_0+ Mg_0 in the sandy and clayey soils, respectively.

Table 3. Effect of phosphatic and magnesium fertilization on soil available magnesium (mg Mg kg^{-1}) in clayey and sandy soils during incubation periods

Soil type	Mineral fertilizer (mg kg^{-1} soil)		Incubation period (hr.)							Average
	P	Mg	6	12	24	48	72	168	336	
Clayey soil	P_0	Mg_0	1.08	1.05	1.06	1.07	1.07	1.06	1.01	1.05
		Mg_1	1.43	1.54	1.58	1.68	1.70	1.62	1.40	1.56
		Mg_2	1.65	1.69	1.76	1.79	1.80	1.69	1.48	1.69
	P_1	Mg_0	1.13	1.19	1.31	1.38	1.41	1.35	1.28	1.29
		Mg_1	1.57	1.69	1.77	1.85	1.87	1.70	1.57	1.72
		Mg_2	2.09	2.15	2.30	2.38	2.38	2.26	1.99	2.22
	P_2	Mg_0	1.16	1.25	1.33	1.42	1.45	1.29	1.13	1.29
		Mg_1	1.74	1.77	1.89	2.07	2.09	1.97	1.81	1.90
		Mg_2	2.11	2.29	2.37	2.46	2.50	2.33	2.13	2.31
Sandy soil	P_0	Mg_0	0.31	0.31	0.31	0.34	0.33	0.33	0.30	0.32
		Mg_1	0.44	0.45	0.47	0.48	0.49	0.47	0.39	0.45
		Mg_2	0.49	0.48	0.49	0.52	0.52	0.49	0.43	0.49
	P_1	Mg_0	0.33	0.36	0.39	0.41	0.42	0.39	0.36	0.38
		Mg_1	0.47	0.50	0.52	0.54	0.55	0.50	0.46	0.50
		Mg_2	0.63	0.64	0.68	0.69	0.70	0.68	0.59	0.66
	P_2	Mg_0	0.35	0.38	0.39	0.40	0.38	0.36	0.34	0.37
		Mg_1	0.50	0.53	0.58	0.61	0.61	0.60	0.55	0.56
		Mg_2	0.63	0.67	0.71	0.72	0.71	0.70	0.64	0.68

P_0: without phosphorus P_1: 13.1 mg P kg.$^{-1}$ P_2:26.2 mg P kg.$^{-1}$
Mg_0: without magnesium Mg_1: 20 mg Mg kg.$^{-1}$ Mg_2: 40 mg Mg kg.$^{-1}$

In general, the available Mg was gradually increased with increasing time up to 72 hours of incubation for the clayey and sandy soils after that the available Mg level decreased in the tested soils for all studied treatments. The decrease in available Mg level after 168 hours until the end of incubation time could be due to assimilation by microorganism or perspiration of Mg in from of insoluble compounds. This finding is in agreement with that obtained by **Mohamed *et al.* (1991) and Abd El-Satar (2018)**.

Available Ca

Results in Table 4 show the effect of P and Mg fertilization rates on Ca availability in clayey and sandy soils during incubation of successive intervals.

Effect of P fertilizer rates

Results revealed that values of available calcium in the untreated clay soil, over the different periods of incubation, ranged from 17.8 to 18.9 mg Ca kg^{-1} with an average of 18.5 mg Ca kg^{-1}. The corresponding range in sandy soil was 7.83 to 8.79 mg Ca kg^{-1} with an average of 8.51 mg Ca kg^{-1}. While in the treated clay soil with only (P_1) ranged from 21.2 to 28.5 g Ca kg^{-1} with an average of 25.22 mg Ca kg^{-1}. While in sandy soil ranged from 11.1 to 15.9 mg Ca kg^{-1} with an average of 13.0 mg Ca kg^{-1}. In the treated clayey, soil with (P_2) ranged from 28.1 to 37.7 mg Ca kg^{-1} with an average of 31.8 mg Ca kg^{-1}.

Table 4. Effect of phosphatic and magnesium fertilization on soil available calcium (mg Ca kg^{-1}) in sandy and clayey soils during incubation periods

Soil type	Mineral fertilizer (mg kg^{-1} soil)		Incubation period (hr.)							Average
	P	Mg	6	12	24	48	72	168	336	
Clay soil	P_0	Mg_o	18.5	18.6	18.9	18.9	18.8	18.1	17.8	18.49
		Mg_1	16.9	16.6	15.9	15.2	14.8	14.1	13.8	15.31
		Mg_2	15.9	15.5	15.1	14.9	14.6	13.8	13.0	14.69
	P_1	Mg_o	23.3	25.1	26.2	27.4	28.5	24.9	21.2	25.22
		Mg_1	22.5	22.5	23.7	24.9	25.9	22.7	18.8	23.00
		Mg_2	21.2	21.2	22.5	23.9	25.3	19.1	17.1	21.48
	P_2	Mg_o	27.9	30.5	32.7	34.7	37.7	30.9	28.1	31.78
		Mg_1	26.0	27.2	28.9	30.6	32.3	26.9	23.2	27.86
		Mg_2	23.8	24.9	26.2	27.6	29.0	22.7	19.7	24.84
Sandy soil	P_0	Mg_o	8.72	8.88	8.72	8.79	8.69	7.94	7.83	8.51
		Mg_1	7.78	7.05	6.82	6.60	6.41	6.06	5.83	6.65
		Mg_2	7.51	6.50	5.90	5.83	5.70	4.36	4.10	5.70
	P_1	Mg_o	10.1	12.0	13.7	15.6	15.9	12.4	11.1	12.96
		Mg_1	9.57	11.7	11.6	14.0	14.2	10.2	9.81	11.58
		Mg_2	9.23	9.31	9.06	13.0	12.6	9.65	8.80	10.24
	P_2	Mg_o	13.6	15.5	17.9	19.2	19.7	16.4	15.4	16.81
		Mg_1	12.5	13.5	14.2	16.9	17.2	14.3	12.9	14.49
		Mg_2	11.5	12.0	13.0	15.2	15.6	13.0	12.1	13.19

P_0: without phosphorus P_1: 13.1 mg P $kg.^{-1}$ P_2:26.2 mg P $kg.^{-1}$
Mg_0: without magnesium Mg_1: 20 mg Mg $kg.^{-1}$ Mg_2: 40 mg Mg $kg.^{-1}$

For the corresponding range in sandy soil, the values ranged from 15.4 to 19.7 mg Ca kg^{-1} with an average of 16.81 g Ca kg^{-1}. Average values of available Ca in untreated clay soil were greater than those in untraded sandy one. This result may be due to the great native content of available Ca in clay soil (Table 1).

Effect of Mg fertilization rate

Results presented in Table 4 show that in absence of phosphate fertilizers (P_0) , the values of available-Ca in a clayey soil treated with (Mg_1) and (Mg_2)rates , during the various incubation periods ranged from 13.8 to 16.9 mg Ca Kg^{-1} soil and 13.0 to 15.9 mg Ca kg^{-1} soil with an average of 15.31 and 14.69 mg Ca kg^{-1} soil, respectively. The corresponding ranges in a sandy soil were 5.83 to 7.78 mg Ca kg^{-1} soil and 4.10 to 7.51mg Ca kg^{-1} soil with an average of 6.65 and 5.70 mg Ca kg^{-1} soil, respectively. The corresponding ranges of P fertilizer at the rate of (13.1 mg P kg^{-1}) to clayey soil were 18.8 to 25.9 mg Ca kg^{-1} soil and 17.1 to 25.3 mg Ca kg^{-1} soil with an average 23.00 and 21.48 mg Ca kg^{-1} soil, respectively, while in sandy soil were 9.57 to 14.2 mg Ca kg^{-1} soil and 8.80 to 13.0 mg Ca kg^{-1} soil with an average of 11.6 and 10.2 mg Ca kg^{-1} soil, respectively. On the other hand, the addition of P fertilizers at the rate of (26.2 mg P kg^{-1}) gave the corresponding values in clayey soil ranged from 23.2 to 32.3 mg Ca kg^{-1} soil and 19.7 to 29.0 g Ca Kg^{-1} soil with an average of 27.9 and 24.8 mg Ca Kg^{-1} soil, respectively, while in the sandy soil ranged from 12.5 to 17.2 mg Ca kg^{-1} soil 11.5 to 15.6 mg Ca kg^{-1} soil with an average of 14.5 and 13.2 mg Ca kg^{-1} soil, respectively. The addition of Mg fertilizers reduce the amount of available Ca in the soils. This finding is in agreement with that obtained by **Scharrer and Jung (1955)**.

Effect of incubation time

After 6, 12, 24, 48, 72, 168 and 336 hours of incubation, the greatest values of available Ca (11.5 and 23.8), (12.0 and 24.9), (13.0 and 26.2), (15.2 and 27.6), (15.6 and 29.0), (13.0 and 22.7) and (12.1 and 19.7) mg Ca kg^{-1} soil were found with the treatment of P_2 + Mg_2, while the lowest ones (8.72 and 18.5), (8.88 and 18.6), (8.72 and 18.9), (8.79 and 18.9), (8.69

and 18.8), (7.94 and 18.1) and (7.83 and 17.8) mg Ca kg^{-1}soil were observed with the treatment of P_0 + Mg_0 in the sandy and clay soils, respectively. As a general result, the available Ca was gradually increased with increasing incubation up to 72 hours of incubation time for the clay and sandy soils. The reduction in available Ca level after 168 hours until the end of incubation time could be due to assimilation by microorganism or perspiration of calcium in form of insoluble compounds. This finding is in agreement with that obtained by **Mohamed *et al.* (1991) and Abd El-Satar (2018)**.

Soil pH

Results in Table 5 demonstrate the effect of P and Mg fertilizer rates on soil pH in the clayey and sandy soils during incubation of successive intervals.

Effect of P fertilizer rates

Results presented in Table 5 reveal that values of soil pH in the untreated clayey soil, at the different periods of incubation, ranged from 7.52 to 7.70 with an average of 7.58. The corresponding range in sandy soil was 7.90 to 8.04 with an average of 7.99. While in the treated clayey soil with only 13.1 mg P kg^{-1} ranged from 7.46 to 7.67 with an average of 7.54. While in sandy soil ranged from 7.87 to 8.03 with an average of 7.93. In the treated clayey, soil with 26.2 mg P kg^{-1} ranged from 7.39 to 7.56 with an average of 7.47. The corresponding range in sandy soil, the values ranged from 7.79 to 7.94 with an average of 7.87. The values of pH were slightly decreased with increasing P fertilizer rates in presence or absence of Mg fertilization in both soils under study. This finding is in agreement with that obtained by **Abd El-Satar (2018)**. Average values of pH in untreated sandy soil were greater than those in untreated clayey soil. This result could be attributed due to the low buffering capacity of the sandy soil having the less organic matter and clay content if compared to the clay one (Table 1).

Effect of Mg fertilization rate

Results presented in Table 5 show that in absence of P fertilizers (P_0), the values of available-Mg in a clayey soil treated with (20 mg Mg kg^{-1}) and (40 mg Mg kg^{-1}), during the various incubation periods ranged from 7.45 to 7.86 and 7.28 to 7.56 with an average of 7.53 and 7.38, respectively. The corresponding ranges in a sandy soil were 7.86 to 8.03 and 7.68 to 7.91 with an average of 7.93 and 7.77, respectively. The corresponding ranges at the rate of (13.1 mg P kg^{-1}) in clayey soil were 7.28 to 7.58 and 7.21 to 7.47 with an average 7.39 and 7.32, respectively, while in sandy soil were 7.68 to 7.96 and 7.60 to 7.84 with an average 7.78 and 7.70, respectively. On the other hand, the addition of P fertilizers at the rate of (26.2 mg P kg^{-1}) gave the corresponding values in clayey soil ranged from 7.21 to 7.48 and 7.15 to 7.42, with an average of 7.31 and 7.28, respectively. While in sandy soil ranged from 7.60 to 7.84 and 7.55 to 7.79 with an average of 7.70 and 7.66, respectively. The values of soil pH were gradually decreased with increasing Mg fertilizer levels in two tested soils (Table 5).

Effect of incubation time

After 6, 12, 24, 48, 72, 168 and 336 hours of incubation, the greatest values of pH (7.79 and 7.42), (7.76 and 7.39), (7.57 and 7.21), (7.55 and 7.17), (7.53 and 7.15), (7.69 and 7.30) and (7.74 and 7.35) were found with the treatment of (26.2 kg P $fad.^{-1}$ + 40 kg Mg $fad.^{-1}$) while the lowest ones (8.04 and 7.70), (8.04 and 7.49), (8.01 and 7.63), (8.0 and 7.60), (7.90 and 7.52), (7.95 and 7.94) and (7.79 and 7.57) were observed with the treatment of (zero mg P kg^{-1} + zero mg Mg kg^{-1}) in the sandy and clayey soils, respectively. As a general result, soil pH values were decreased during incubation periods up to 72 hours after that pH value increased with time until of the end experiment under the studied soil conditions. In general, the reduction in soil pH values during incubation periods in the two tested soils may be due to features of the soil type, microbial activity and rate of phosphorus and magnesium fertilization. This finding is in agreement with that obtained by **El-Fahham (1997), Merwad (2009) and (2013), Silber *et al.* (2010) and Abd El-Satar (2018)**.

Soil EC

Results in Table 6 demonstrate the effect of P and Mg fertilization rates on soil EC values in the clayey and sandy soils during incubation of successive intervals.

Table 5. Effect of phosphatic and magnesium fertilization on soil pH in clayey and sandy soils during incubation periods

Soil type	Mineral fertilizer mg kg^{-1} soil)		Incubation period (hr.)							Average
	P	Mg	6	12	24	48	72	168	336	
Clayey soil	P_0	Mg_0	7.70	7.49	7.63	7.60	7.52	7.54	7.57	7.58
		Mg_1	7.68	7.54	7.53	7.49	7.45	7.49	7.51	7.53
		Mg_2	7.56	7.48	7.31	7.32	7.28	7.32	7.37	7.38
	P_1	Mg_o	7.67	7.63	7.51	7.48	7.46	7.51	7.54	7.54
		Mg_1	7.58	7.54	7.31	7.31	7.28	7.35	7.39	7.39
		Mg_2	7.47	7.43	7.24	7.23	7.21	7.29	7.34	7.32
	P_2	Mg_o	7.56	7.51	7.44	7.43	7.39	7.48	7.51	7.47
		Mg_1	7.48	7.43	7.23	7.22	7.21	7.27	7.36	7.31
		Mg_2	7.42	7.39	7.21	7.17	7.15	7.30	7.35	7.28
Sandy soil	P_0	Mg_0	8.04	8.04	8.01	8.00	7.90	7.95	7.97	7.99
		Mg_1	8.03	8.03	7.90	7.88	7.86	7.89	7.90	7.93
		Mg_2	7.91	7.90	7.72	7.70	7.68	7.73	7.76	7.77
	P_1	Mg_o	8.03	8.02	7.89	7.87	7.87	7.91	7.94	7.93
		Mg_1	7.96	7.92	7.72	7.69	7.68	7.74	7.78	7.78
		Mg_2	7.84	7.80	7.64	7.62	7.60	7.68	7.73	7.70
	P_2	Mg_o	7.94	7.92	7.85	7.82	7.79	7.89	7.91	7.87
		Mg_1	7.84	7.82	7.62	7.60	7.60	7.66	7.75	7.70
		Mg_2	7.79	7.76	7.57	7.55	7.53	7.69	7.74	7.66

P_0: without phosphorus P_1: 13.1 mg P kg.$^{-1}$ P_2:26.2 mg P kg.$^{-1}$
Mg_0: without magnesium Mg_1: 20 mg Mg kg.$^{-1}$ Mg_2: 40 mg Mg kg.$^{-1}$

Effect of phosphorus fertilizer rates

Results revealed that values of soil EC in the untreated clayey soil, over the different periods of incubation, ranged from 705 to 721 µS cm^{-1} with an average of 716 µS cm^{-1}. The corresponding range in sandy soil was 280 to 297 µS cm^{-1} with an average of 289 µS cm^{-1}. While in the treated clayey soil with 13.1 mg P kg^{-1} ranged from 800 to 1092 µS cm^{-1} with an average of 1045 µS cm^{-1}. While in sandy soil ranged from 307 to 330 µS cm^{-1} with an average of 321 µS cm^{-1}. In the treated clayey, soil with 26.2 mg P kg^{-1} ranged from 870 to 1136 µS cm^{-1} with an average of 1093 µS cm^{-1}. The corresponding range in sandy soil, the values ranged from 328 to 390 µS cm^{-1} with an average of 372 µS cm^{-1}. Average values of EC in the two investigated soils were increased with increasing P fertilization rates in absence or presence of Mg fertilization. This finding is acceptance with that obtained by **Abd El-Satar (2018)**. Average values of EC in untreated clay soil were greater than in untreated sandy one. This result could be due to the high EC values in the clay soil (Table 1).

Effect of Mg fertilization rates

Results presented in Table 6 show that in absence of P fertilizers (P_0) , the values of soil EC in a clayey soil treated with (20 mg Mg kg^{-1}) and (40 mg Mg kg^{-1}), during the various incubation periods ranged from 730 to 808 µS cm^{-1} and 905 to 1084 µS cm^{-1} with an average of 782 and 1053 µS cm^{-1}, respectively. The corresponding ranges in a sandy soil were 295 to 314 µS cm^{-1} and 323 to 380 µS cm^{-1} with an average of 304 and 366 µS cm^{-1}, respectively. The corresponding ranges of P fertilizer at the rate of (13.1 mg P kg^{-1}) to clayey soil were 857 to 1125µ cm^{-1} and 923 to 1151 µS cm^{-1} with an average 1078 and 1111 µS cm^{-1}, respectively, while in sandy soil were 314 to 337 µS cm^{-1} and 561 to 629 µS cm^{-1} with an average 326 and 612 µS cm^{-1}, respectively. On the other hand, the addition of P fertilizers at the rate of (26.2 mg P kg^{-1}) gave

Table 6. Effect of phosphatic and magnesium fertilization on soil EC (µS cm^{-1}) in clayey and sandy soils during incubation periods

Soil type	Mineral fertilizer mg kg^{-1} soil)		Incubation period (hr.)							Average
	p	Mg	6	12	24	48	72	168	336	
Clayey soil	P_0	Mg_0	715	719	717	721	720	712	705	716
		Mg_1	730	785	798	808	792	786	780	782
		Mg_2	905	1074	1079	1081	1084	1078	1069	1053
	P_1	Mg_o	800	1081	1084	1089	1092	1088	1081	1045
		Mg_1	857	1107	1112	1122	1125	1117	1109	1078
		Mg_2	923	1137	1142	1151	1146	1142	1135	1111
	P_2	Mg_o	870	1134	1129	1136	1135	1131	1120	1093
		Mg_1	1112	1181	1186	1193	1196	1192	1179	1177
		Mg_2	1285	1295	1299	1302	1308	1301	1289	1297
Sandy soil	P_0	Mg_0	282	294	295	297	293	287	280	289
		Mg_1	295	302	304	310	314	309	297	304
		Mg_2	323	370	375	380	378	374	366	366
	P_1	Mg_o	307	317	319	328	330	327	319	321
		Mg_1	314	331	330	337	333	324	315	326
		Mg_2	561	616	621	627	629	622	608	612
	P_2	Mg_o	328	375	380	386	390	382	364	372
		Mg_1	709	747	751	764	765	754	740	747
		Mg_2	804	869	877	916	918	909	898	884

P_0: without phosphorus P_1: 13.1 mg P $kg.^{-1}$ P_2:26.2 mg P $kg.^{-1}$
Mg_0: without magnesium Mg_1: 20 mg Mg $kg.^{-1}$ Mg_2: 40 mg Mg $kg.^{-1}$

the corresponding values in clayey soil ranged from 1112 to 1196 µS cm^{-1} and 1285 to1308 µS cm^{-1}, with an average of 1177 and 1297 µS cm^{-1}, respectively. While in sandy, soil ranged from 709 to 765 µS cm^{-1} and 804 to 918 µS cm^{-1} with an average of 747 and 884 µS cm^{-1}, respectively. Average values of EC in the two investigated soils were increased with increasing Mg fertilization rates in absence or presence of P fertilization. This result could be due to the high solubility product of other magnesium phosphate compound. The finding agree with that obtained by **Kuo and Mikkelsen (1979)**.

Effect of incubation time

After 6,12, 24, 48,72,168 and 336 hours of incubation, the greatest soil EC (µS cm^{-1}) values (804 and 1285), (869 and 1295), (877 and 1299), (916 and 1302), (918 and 1308), (909 and 1301) and (898 and 1289) were found with the treatment of P_2 + Mg_2 in both clayey and sandy soils. On the other hand, the lowest ones (282 and 715), (294 and 719), (295and 717), (297and 721), (293 and 720), (287 and 712) and (280 and 705) were observed with the treatment of P_0+Mg_0 in sandy and clay soils, respectively. In general, EC values were increased with incubation time up to 72 hours for the almost treatments after that the EC values decreased by time until the end of the experiment under in tested soils, except the treatments of P_0Mg_0 in the two tested soils, P_0Mg_1, P_1Mg_2 and P_2Mg_0 in clay soil and P_0Mg_2 and P_1Mg_1 in the sandy soil. The first increase of the EC values due to the increase of available Ca^{2+} and Mg^{2+} in the studied soils (Tables 3 and 4).

REFERENCES

Abd El-Satar, M. (2018). Phosphorus bioavailability in soils. M.Sc. Thesis, Soil Dept. Fac. Agric., Zagazig Univ., Egypt.

Al-Kaysi, S.C. and H.B. Saleem (1990). Influence of calcium and magnesium concentration in soil solution on phosphorus availability and transformation in soil. Iraqi J. of Agri. Sci. 21: 164-179. (In Arabic).

Al-Akrawi, H.S.Y. (2002). Interaction effect of phosphorus and magnesium on availability of phosphorus, Growth and yield of *Zea mayes* L. in a calcareous soil. M.Sc Thesis. Coll. Agric., Salahadden Univ.

Amanullah, R.A.K. and S.K. Khalil (2009). Effects of plant density and N on phenology and yield of maize. J. Plant Nutr., 32 (3): 245-259.

Barea, J.M., A. Ramos and V. Callac (1970). Contribution al studio *in vitro* de la mineralization bacteria and de fastafos. Microbiol. Espona. 23: 257-270.

Black, C.A., D.D. Evans, L.E. Ensminger, J.L White and F.E. Clarck (1965). Methods of Soil Analysis Ame. Soc. Agron., Madison, Wisconsin, USA.

Camargo, C., J.C. Felicio, J.G. Freitas and S. Paulo (2000). Evaluation of wheat cultivars for phosphorus efficiency on acid soil and nutrient solution. Eco. Agric. Sustain Dev., 2: 289-297.

Cordell, D., J.O. Drangert and S. White (2009). The story of phosphorus: global food security and food for thought. Glob Environ. Change, 19: 292–305.

Cottenie, A., M. Verloo, M. Velghe and R. Comerynck (1982). Chemical Analysis of Plant and Soil. Laboratory of analytical and Agro chemistry state Univ. Ghent. Belgium.

El-Fahham, M. (1997). Factors affecting transformation of some nutrients in soils. M.Sc. Thesis, Fac. Agric., Zagazig Univ.

Esmail, A.O., Kh.M. Kawa and M.F. Yadgar (1999). Effect of Mg/Ca ratio in irrigation water on the yield and quality of chickpea. Iraqi J. Agri. Sci. Zanco. 11: 1- 8 (in Arabic).

Gilbert, N. (2009). Environment: the disappearing nutrient. Nature, 461: 716–718.

Jackson, M.L. (1973). Soil Chemical Analysis. Pre Hail of Linda. Pvt. Ltd. New Delhi.

Kuo, S. and D. S. Mikkelsen (1979). Effect of magnesium phosphate adsorption by calcium carbonate. Soil Sci., 127: 65-69.

Marion, G.M. and K.L. Babcock (1977). The solubility of carbonates and phosphates in calcareous soil suspension. Soil Sci. Soc. Ame. J., 41: 724 – 728.

Merwad, A.M.A. (2013). Efficiency of phosphate fertilizers as influenced by soil amendments application in soils. Ph.D. Thesis, Soil Dept. Fac. Agric., Zagazig Univ., Egypt.

Merwad, A.M.A. (2009). Effect of some soil amendments on behavior of some nutrient in different soils. M.Sc. Thesis, Fac. Agric., Zagazig Univ., Egypt.

Mohamed, I.R., I.A. El-Garhi and N.N. Youssef (1991). The influence of organic-mineral fractions, Humic substances and Zinc availability of plants in sandy soil. Zagazig J. Agric. Res., 18 (1): 217-228.

Nassar, K.E., M.Y. Gebrail and K.M. Khail (2000). Efficiency of phosphate-Dissolving bacteria with different forms and rates of P-fertilization on the quantity of faba been (*Vicia faba* L.). Minufiya J. Agric. Res., 25: 1335-1349.

Nassar, K.E., A.M. Ewais and A.A. Mohmoud (2006). Raising of the quanty and quality of onion crop by foliar application of P and S. J. Adv. Agric., Res., Saba Basha Agric., 11 (2): 409-419.

Scharrer, K. and J. Jung (1955). Der Einelu Bder Ernα̋hrungauf das verhα̋ltnis von Kationen Zu Anionen inder P flanze. Z Pflanzenerα̋hr Dű́ngung Bodenkd, 71: 76-94.

Silber, A., B. Bar-Yosef, I. Levkovitch and S. Soryano (2010). pH-Dependent surface properties of perlite: Effects of plant growth. J. Geoderma, 158: 275-281.

Stevenson, F.J. (1982). Humus chemistry (Genesis, composition, reaction) John Wily, New York.

Sutcliffe, J.F. and D.A. Baker (1983). In: Suministros de Sales, Cuadernos de Biolog´ıa, Las Plantas ylas Sales Minerales (Sutcliffe, J.F. and Baker, D.A., Eds.), Barcelona, Omega SA.

Watanabe, F.S. and S.R. Olsen (1965). Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extractes from soil. Soil Sci. Ame. Proc., 29: 677-678.

دور المغنيسـيوم فـي تيسـر الفـوسـفور فـي التـربـة

إيمان إبراهيم النجار - إبراهيم رمضان محمد
عطيات السيد نصرالله – أحمـد صـلاح الريس

قسم علوم الأراضى - كلية الزراعة - جامعة الزقازيق - مصر

أجريت تجربة تحضين في ظل ظروف المعمل لدراسة التغير في قيمة الفسفور والمغنسيوم والكالسيوم ودرجة حموضة التربة وملوحة التربة خلال ٣٣٦ ساعة من التحضين وبدراسة ثلاث مستويات من كلا من الفسفور والمغنسيوم وتم الخلط بينهم بنسب معينه في التربة الطينية والرملية، تم استخدام السوبر فوسفات العادي كمصدر للفسفور بمعدلات صفر، ١٣,١، ٢٦,٢ ملليجرام فو كجم-١ واستخدمت كبريتات المغنسيوم كمصدر للمغنسيوم بمعدلات صفر، ٢٠، ٤٠ ملليجرام مغ كجم-١ وأظهرت النتائج أن زيادة كل من الفسفور والمغنسيوم والكالسيوم المتاح وكذلك ملوحة التربة بزيادة معدلات التسميد الفوسفاتى بينما انخفضت درجة حموضة التربة ، كماً زاد محتوى التربة من الفسفور والمغنسيوم الميسر وكذلك ملوحة التربة بزيادة التسميد المغنسيومي بينما انخفض تركيز الكالسيوم المتاح ودرجة حموضة التربة ، كما زاد محتوى التربة من الفسفور المتاح بعد ١٢ ساعة ثم تناقص محتواه تدريجياً بمرور الوقت، بينما إزداد تركيز الكالسيوم والمغنسيوم حتي ٧٢ ساعة ثم انخفض بعد ذلك حتى نهاية التجربة، بينما انخفضت درجة حموضة التربة حتي ٧٢ ساعة ثم زادت مرة أخرى حتي نهاية التجربة.

المحكمـــــون:

١- أ.د. فاطمـــة أحمـــد علي عثمان	أستاذ الأراضي – كلية التكنولوجيا والتنمية – جامعة الزقازيق.
٢- أ.د. صلاح الدين محمود دحدوح	أستاذ الأراضي المتفرغ – كلية الزراعة – جامعة الزقازيق