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THE ROLE OF MAGNESIUM IN INCREASING OF PHOSPHORUS FERTILIZER EFFICIENCY AND WHEAT YIELD

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ABSTRACT

The study was conducted during the growing season 2003 to study the influence of four levels of P (0, 60, 100 and 140 kg ha^{-1}) and four levels of Mg (0, 40, 80 and 120 kg ha^{-1}) at two locations (Bakrajow and Kalar) on growth and yield of wheat and phosphorus fertilizer efficiency. The results indicated to the response of wheat to phosphorous fertilizer at Bakrajow location only. While the application of 40 kg Mg ha^{-1} caused significant increase in wheat yield at Bakrajow location only. The highest phosphorus fertilizer efficiency was 34.44% and 55.24% at Bakrajow and Kalar respectively while the Mg fertilizer efficiency was 7.6% and 22.8% at Kalar and Bakrajow respectively.

INTRODUCTION

There are many factors influencing phosphorus availability, efficiency and recovery of phosphorus 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 (Foth, *et al*., 2000; Al- Akrawi, 2002). Magnesium plays a positive role in phosphorus availability and recovery of phosphorus by crops in calcareous soil like magnesium concentration in soil solution. Magnesium can alter the formation of calcium phosphate precipitates and apatite formation (Marin and Babcok, 1977). On the other hand Kuo and Milkkelsen (1977) showed that magnesium may interfere with phosphorus adsorption on $CaCO_3$ surface by one of the following mechanisms:

1-Magnesium that alters some of adsorption sites on $CaCO_3$ surface, due to lower affinity of phosphate to Mg^{2+} in comparing with Ca^{2+} which causes the decrease in phosphorus adsorption by $CaCO_3$.

2-The extend to which magnesium will affect the availability of phosphorus depends on the mole ratio of P/Mg, if the ratio is equal or less than 2:1 the efficiency of phosphorus will increase due to the reduction in adsorption of phosphorus by $CaCO_3$ which causes increase of available phosphorus in calcareous soil, since the solubility of magnesium orthophosphate slightly higher than the solubility of calcium orthophosphate. Dawood (1982) indicated that the application of three levels (0,120 and 240kg $MgSO_4.7H_2O$ ha^{-1}) caused a significant increase in phosphorus uptake by plant. Al-Lami (1999) showed that the increase in adding of $MgSO_4.7H_2O$ from 0 to 80 kg ha^{-1} caused a significant increase in available phosphorus in the soil from 0.23 to 0.25 $cmol_c$ kg^{-1}.

On the other hand the Mg/Ca ratio plays an important role in phosphorus availability. Madrid, *et al.*(1977) showed that the increase in utilization efficiency

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of phosphorus fertilizer by rye grass as the ratio of Mg/Ca increased by the incorporation of $MgSO_4.7H_2O$ with dicalocium phosphate and octacalcium phosphate. Al-Khatteb *et al.*(1986) found the formation of higher amount of dimagnesium phosphate and trimagnesium phosphate, if the ratio of Mg/Ca higher than 1.5 which caused the increase in phosphorus availability. Al-Kaysi and Saleem (1990) applied different ratios (0/0, 0/200, 50/150, 100/100, 150/50, 200/0 meq L^{-1}) 0f Mg/Ca they indicated that the increase in the ratio of applied Mg/Ca caused an increase in phosphorus availability for plants. Esmail (1992); Dohuki (1997); Abbod (1998) and 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 phosphorus in the soil and its recovery by plant. Al-Akrawi (2002) studied the influence of four levels (0, 40, 80, 120 kg Mg ha^{-1}) of Mg on the efficiency of phosphorus fertilizer by using three levels of triple superphosphate (0, 100, 200 kg P ha^{-1}) she found that the application of 120 kg ha^{-1} of Mg-fertilizer caused the conversion of phosphorus phase to more soluble from (DCPD) in comparing with control treatment (above OCP). For the mentioned reason the purpose of this study includes the role of Mg-fertilizer in P-availability, growth and yield of wheat at two different locations.

MATERIALS AND METHODS

The experiment was conducted at two different locations (Bakrajow and Kalar) under rain-fed condition during the winter growing season 2003 to study the influence of four levels of Mg as $MgSO_4.7H_2O$ (0, 40, 80, 120 kg ha $^{-1}$) and four levels of P as TSP (0, 60, 100 and 140 kg ha^{-1}) and their interaction on wheat yield ,availability of phosphorus and the efficiency of phosphorus and magnesium fertilizers using Randomized Complete Block Design (RCBD) with three replicates. 100kg N ha^{-1} as urea fertilizer was added at the sowing time. On 20 and 24 November 2003 seeds of wheat variety Acsad were planted at Bakrajow and Kalar respectively. The plants from Kalar location were harvested on 26 may 2004 while at Bakrajow the harvesting was conducted on 1 June 2004. Soil samples were taken from all experimental units at (0 to 30 cm) depth before sowing and after harvesting, then air dried thoroughly mixed, ground passed through a 2 mm sieve, and stored in plastic bottles prior to analysis. Some physical and chemical properties of the soils are given in (table 1). Electrical conductivity (EC) was measured for the soil saturation extract using EC-meter, model (WTW 82362 Weilheim, Germany). pH was measured in a saturated peaste using a pH-meter, model (Microprocessor pH meter, Hanna pH 211).Organic matter was determined by dichromate oxidation (Walkley and Black method) as described in Jackson (1973).The total calcium carbonate equivalent $CaCO_3$ was determined by a rapid titration method (Rayment and Higginson, 1992).Cation Exchange Capacity (CEC) was determined by saturation with 1*M* NH_4OAc at pH 8.1.Soluble HCO_3^-, Cl^- and Ca^{2+} + Mg^{2+} were determined using titration methods (Page *et al.*, 1982).Na^+ and K^+ were determined by using (Flame Photometer). $SO_4^{2-}$was indirectly determined from combined Ca and Mg by titration with (0.02*M*) EDTA di-sodium salt according to Jackson (1958). Available P was determined by extracting the samples with 0.5*M* $NaHCO_3$ (Olsen *et al.*, 1954). The particle size was determined according to international pipette method as described by Day (1965).

Table (1): some physical and chemical properties of soil used in field experiments.

Properties		Location	
		Bakrajow	Kalar
Particle Size Distribution(PSD) g kg^{-1}	Sand	115.4	234
	Silt	523.6	572
	Clay	361	196
Texture Class		SiCL	SiL
pH		7.90	7.60
EC_e dS m^{-1} at 25°C		0.40	2.60
Soluble ions $mmol_c$ L^{-1}	Ca^{2+}	1.70	12.0
	Mg^{2+}	0.31	4.60
	Na^+	0.48	4.20
	K^+	0.19	6.10
	HCO_3^-	2.95	3.20
	Cl^-	0.21	16.10
	SO_4^{2-}	0.81	20.10
Cation Exchange capacity $cmol_c$ kg^{-1}		29.76	22.10
O. M. g kg^{-1}		17.6	7.57
Available P mg kg^{-1}		6.5	9
$CaCO_3$ equivalent g kg^{-1}	Total	328.00	370.3

Plant analysis: The representative harvested wheat shoots were dried at 65°C for 72 hr dried plant material were grinded then digested according to Schuffelen and Schouwenburg(1961) using (1:1 conc.H_2SO_4 and H_2O_2)mixture to determination the concentration of phosphorus in digested plant samples according to colorimetric method as described by Rowell (1996).

Biological parameters were calculated using the following models:

Relative yield = (yield of control / yield of fertilized treatment) x 100…………. (1)

Response %=(yield fertilized – yield control) / yield fertilized x 100………..… (2)

FUS = [{P-uptake (fertilized) – P-uptake (control)} / P-added] x 100……….…..(3)

According to Westerman, 1990 and Tisdale, *et al*., 1997.

RESULTS AND DISCUSSION

Influence of different levels of Mg and P fertilizer and their interaction on grain weight: Table (2) shows the significant effect of Mg, P and their interaction on grain yield at Bakrajow location, the highest values 5142.6, 5113.3 and 5605.2 kg ha^{-1} were recorded from treatments, Mg_1, P_1 and Mg_2P_3 respectively. The above results indicated that the combination between Mg and P caused the decrease in P-fertilizer requirement for the highest yield.Table (3) indicated that the Mg, P-fertilizer and their interaction were no affected significantly on grain yield this may be due to the high concentration of Mg in Kalar soil (4.20 $mmol_c$ kg^{-1}) and high 1.2 ratio of Na/Ca ratio this may causes the increase in phosphorus availability the similar results were obtained by Esmail (1992).

Table (2): Influence of different rates of Mg, P and their interaction on wheat grain yield (kg ha^{-1}) at Bakrajow location.

P / Mg	P_0	P_1	P_2	P_3	mean	%Fertilizer efficiency
Mg_0	4690.0	4680.0	5085.2	5005.2	4865.1	0
Mg_1	5205.2	5545.2	4930.0	4890.0	5142.6	22.8
Mg_2	4650.0	4980.0	4805.2	5605.2	5010.1	12.0
Mg_3	4440.0	5248.0	4920.0	5120.0	4932.0	5.6
mean	4746.0	5113.3	4935.2	4985.2		
%Fertilizer efficiency		30.92	15.88	34.44		

$RLSD_{0.05}$ P = 101.2 $RLSD_{0.05}$ Mg = 101.2 $RLSD_{0.05}$ Mg x P = 212.8

Table (3): Influence of different rates of Mg, P and their interaction on wheat grain yield (kg ha^{-1}) at Kalar location.

P / Mg	P_0	P_1	P_2	P_3	mean	%Fertilizer efficiency
Mg_0	2351.2	3117.2	3150.0	2592.0	2802.6	0
Mg_1	2738.4	2655.2	2680.0	2565.2	2659.7	0
Mg_2	2600.0	2798.4	2870	2558.4	2706.7	0
Mg_3	2668.4	2983.2	3088.4	2675.2	2853.8	7.6
mean	2589.5	2888.5	2947.1	2597.7		
%Fertilizer efficiency		45.72	55.24	1.24		

$RLSD_{0.05}$ P = n.s. $RLSD_{0.05}$ Mg = n. s. $RLSD_{0.05}$ Mg x P = 273.2

Influence of different rates of Mg, P fertilizer and their interaction on P concentration and P uptake of wheat grain at Bakrajow location (kg ha^{-1}):

Table (4 and 5) indicated to significant effect of Mg, P rates and their interaction on phosphorus concentration and uptake at level of significant 0.05.

The highest values of phosphorus concentration (4.65, 4.18 and 5.00 mg g^{-1}) were recorded from Mg_3, P1 and Mg_3P_3 respectively, but the highest wheat yield were not recorded from the above treatments as mentioned before (table 2) since the concentration of nutrients are not responsible for limiting the yield but the nutrient balance index is responsible for limiting the yield or increasing in nutrient balance in plant causes increase in yield as mentioned by Darwesh (2007). He indicated to the highest wheat yield in treatment or treatment combination which has the highest nutrient balance (low nutrient balance index NBI). On the other hand the highest P uptakes (2256.43, 2164.78 and 2717.20 kg ha^{-1}) were recorded from $Mg_{3,}$ P_1, and Mg_1P_1 treatments, this means the increase in P uptake to a certain level caused increase in wheat yield due to the role of phosphorus in seed formation and increase in weight of 1000 seeds (Salih,2008).

Table (4): Influence of different rates of Mg, P and their interaction on phosphorus concentration (mg g^{-1}) at Bakrajow location.

Mg \ P	P_0	P_1	P_2	P_3	mean
Mg_0	2.20	2.23	2.22	3.00	2.41
Mg_1	3.21	4.87	3.31	3.50	3.72
Mg_2	3.80	4.70	4.20	3.70	3.93
Mg_3	4.21	4.90	4.49	5.00	4.65
mean	3.36	4.18	3.56	3.80	

$RLSD_{0.05}$ P = 0.80 $RLSD_{0.05}$ Mg = 0.80 $RLSD_{0.05}$ Mg x P = 1.41

Table (5): Influence of different rates of Mg, P and their interaction on phosphorus uptake (kg ha^{-1}) at Bakrajow location.

Mg \ P	P_0	P_1	P_2	P_3	mean
Mg_0	938.00	1029.60	1102.20	1525.56	1148.84
Mg_1	533.20	2717.20	1724.60	1725.52	1675.13
Mg_2	1767.00	2340.80	2249.20	1441.56	1949.64
Mg_3	1864.80	2571.52	2129.40	2460.00	2256.43
mean	1275.75	2164.78	1801.35	1788.16	

$RLSD_{0.05}$ P = 437.2 $RLSD_{0.05}$ Mg = 437.2 $RLSD_{0.05}$ Mg x P = 750

Influence of different rates of Mg, P fertilizer and their interaction on P concentration and P uptake of wheat grain at Kalar location (kg ha^{-1}): Table (6 and 7) shows the increase in rates of Mg and P to a certain level caused a significant increase in phosphorus content of grains at level of significant 0.05, the highest values (4.50, 4.20 and 4.80 mg g^{-1}) were recorded from the treatments Mg_3, P_2 and $Mg_3P_{3,}$ but the highest yield were not recorded from the mentioned treatments this may be due to role of nutrient balance in limiting wheat yield instate of nutrient concentration and uptake. On the other hand the highest P uptakes (1199.38, 1241.05 and 1480.52 kg ha^{-1}) were obtained from treatments $Mg_{3,}$ P_2 and Mg_0P_2 respectively. It is clear that the yield of wheat at Bakrajow location is twice to its yield at Kalar location this may be due to the following reasons:

1-The amount of rainfall was 320 and 570 mm year^{-1} at Kalar and Bakrajow respectively.

2-The chemical composition and EC of the soil solutions were differ (table 1). The similar results were recorded by Esmail and Darwesh (2007).

3-The soil organic matter content and CEC of Bakrajow soil were higher than their values in Kalar soil while the calcium carbonate content of the Bakrajow soil was lower than its content in Kalar soil(table,1). Which caused the increase in wheat yield at Bakrajow location in comparing with Kalar location .These results agree with those recorded by Salih (2008).He indicated to the influence of soil chemical and physical properties on wheat yield.

Table (6):Influence of different rates of Mg, P and their interaction on phosphorus concentration (mg g^{-1}) at Kalar location.

P / Mg	P_0	P_1	P_2	P_3	mean
Mg_0	2.20	2.70	4.70	3.00	3.00
Mg_1	3.40	3.70	3.20	3.50	2.60
Mg_2	3.60	4.50	4.20	4.00	4.10
Mg_3	3.80	4.60	4.60	4.80	4.50
mean	3.30	3.90	4.20	3.80	

$RLSD_{0.05}$ P = 0.82 $RLSD_{0.05}$ Mg = 0.82 $RLSD_{0.05}$ Mg x P = 1.33

Table (7):Influence of different rates of Mg, P and their interaction on phosphorus uptake (kg ha^{-1}) at Kalar locations.

P / Mg	P_0	P_1	P_2	P_3	mean
Mg_0	517.28	838.40	1480.52	777.60	903.45
Mg_1	931.04	982.44	857.60	897.84	917.23
Mg_2	936.00	1259.28	1205.40	1023.36	1106.01
Mg_3	720.48	1372.28	1420.68	1284.08	1199.38
mean	776.20	1113.10	1241.05	995.72	

$RLSD_{0.05}$ P = 205 $RLSD_{0.05}$ Mg = 205 $RLSD_{0.05}$ Mg x P = 372.6

دور المغنيسيوم في زيادة كفاءة الأسمدة الفوسفاتية و حاصل الحنطة

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الخلاصة

أجريت هذه الدراسة خلال الموسم الزراعي ٢٠٠٣ لدراسة تأثير أربعة مستويات من الفسفور (صفر ، ٦٠، ١٠٠، ١٤٠ كغم/هكتار) و أربعة مستويات من المغنيسيوم (صفر، ٤٠، ٨٠، ١٢٠ كغم/هكتار) في موقعي بكرةجو و كلار في نمو و حاصل الحنطة و كفاءة السماد. تشير النتائج إلى إستجابة الحنطة للسماد الفوسفاتي في بكرةجو فقط، كذلك إضافة ٤٠كغم Mg/هكتار أدت إلى زيادة

معنوية لإنتاج الحنطة في بكرةجو و سجلت أعلى كفاءة للسماد الفوسفاتي ٣٤.٤٤ و ٥٥.٢٤% في بكرةجو و كلار على التوالي، ولكن سجلت أعلى كفاءة للسماد المغنيسيوم ٢٢.٨% و ٧.٦% في بكرةجو وكلار على التوالي.

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