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Response of Wheat Plants to Magnesium Sulphate Fertilization

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ABSTRACT

Magnesium is an important fertilizer element in plant nutrition. Pot experiment was conducted at the greenhouse of the Micronutrients Project, Department of Fertilization Technology, National Research Centre, Dokki, Cairo, Egypt with wheat (*Triticum aestivum* L.) variety Sakha 93 grown on loamy sand soil to asses the plant response to magnesium sulphate as soil amendment and foliar fertilization. The experiment followed the Complete Randomized Block Design (CRBD) and contained eight treatments in four replicates. The obtained data showed that concentration and uptake of macro and micronutrients were increased with both soil and foliar fertilization. Superior treatments realized best concentrations; uptake, Mg/P, K/Mg and Ca/Mg ratios in the shoot tissues were 120 kg ha^{-1} $MgSO_4$ as soil addition or 5 g L^{-1} in the spray solution as foliar fertilization. However, the treatments achieved highest dry biomass accumulation and plant height were 60 kg ha^{-1} $MgSO_4$ or 5.0 g L^{-1} in the spray solution. Accordingly, wheat plants grown on the Egyptian and similar soils are recommended to be supplied with magnesium fertilizers in order to achieve good growth and higher production.

Key words: Secondary elements, cereal crop needs, nutrient balance

INTRODUCTION

Magnesium is related to the group "secondary elements" and involved in many metabolic processes in the plants. Magnesium ionic form (Mg^{++}) adhered to the colloidal particles in the soil is available to be taken up by the plant roots. Chlorotic or necrotic spots spread over the leaves indicate its deficiency. Magnesium deficiency was reported in some Egyptian soils (Attala *et al*., 1997; El-Safty and Rabii, 1998; Abou Aziz *et al*., 2000; Dawood *et al*., 2001). According to El-Fouly *et al*. (2010) available Mg decreases in the period 1998-2006 reached about 80% from the available Mg in 1998.

Wheat (*Triticum aestivum* L.) is the first food source in Egypt. According to FAO documents, production of wheat grains in Egypt reached 8.4 million tons in the year 2011. However, this production still far from covering the population needs, where Egypt imports of wheat grains in the same year reached about 15.7 million tons (FAO, 2011). This reflects the huge gap between consumption and production, which mandate supply of adequate and balanced nutrition for wheat crop plants in order to vertically increase crop production.

This study aimed at studying the response of wheat plants grown on sandy loam soil to magnesium sulphate as soil amendment and foliar fertilization.

MATERIALS AND METHODS

Pot experiment was conducted in the greenhouse of the project "Micronutrients", Department of Fertilization Technology, National Research Centre, Dokki, Cairo, Egypt with wheat

(*Triticum aestivum* L.) variety Sakha 93 to study the effect of magnesium sulphate as soil amendments and foliar feeding with magnesium sulphate diluted solutions on the dry weight accumulation, plant height and nutrient concentrations, uptake and balance within the shoot tissues.

The experiment followed the Completely Randomized Block Design (CRBD) with eight treatments in four replicates. The plants were sown on the end of October, 2011 in Mitscherlich pots contained 7.0 kg loamy sand soil. Before sowing, every pot was received 1.05 g urea (46% N), 1.4 g super mono-phosphate (15.5% P_2O_5) and 0.35 g potassium sulphate (50% K_2O) as basic fertilization.

Treatments

Soil amendments:

- Control plants received no magnesium fertilizers
- 0.179 g pot^{-1} equal 60 kg ha^{-1} $MgS_4.7H_2O$ (10% Mg+ 14% S)
- 0.350 g pot^{-1} equal 120 kg ha^{-1} $MgS^4.7H_2O$ (10% Mg+ 14% S)
- 0.529 g pot^{-1} equal 180 kg ha^{-1} $MgS_4.7H_2O$ (10% Mg+ 14% S)

Foliar fertilization: The plants were two times sprayed at 25 days after sowing and two weeks later as follows:

- Control plants received water only as a spray solution
- 5.0 g L^{-1} $MgS_4.7H_2O$ (10% Mg+ 14% S) in the spray solution
- 10.0 g L^{-1} $MgS_4.7H_2O$ (10% Mg+ 14% S) in the spray solution
- 15.0 g L^{-1} $MgS_4.7H_2O$ (10% Mg+ 14% S) in the spray solution

Harvest: Two months after sowing, the plant height was measured and the plants were harvested to determine dry matter accumulation in the shoots as well as macro and micronutrient concentrations. Then the nutrient uptake was accordingly calculated.

Determinations and measurements

Soil: Representative soil sample before fertilization was air-dried and passed through 2-mm sieve pores. Soil fractions were determined using the hydrometer method (Bauyoucos, 1954). E.C. and pH were determined in a soil/water extract (1:2.5) according to Jackson (1973). The $CaCO_3$ content was determined using the calcimeter method according to Black (1965). Organic matter was determined using the potassium dichromate method according to Walkely and Black (1934). Soil P was extracted using sodium bicarbonate ($NaHCO_3$) (Olsen *et al.*, 1954). K was extracted using ammonium acetate ($C_3H_3O_2NH_4$) (Chapman and Pratt, 1978). Fe, Mn, Zn and Cu were extracted using DTPA-solution (Lindsay and Norvell, 1978). Chemical and physical properties of the soil are shown in Table 1.

Vegetative tissue: Samples were washed with tap water, 0.01 N HCl and bi-distilled water, respectively, dried at 70°C for 24 h, weighed and ground. A part of the dry leaves was ashed in a Muffle furnace at 550°C for 6 h. The ash was digested in 3 N HNO_3 and the residue was then suspended in 0.3 N HCl (Chapman and Pratt, 1978).

Table 1: Chemical and physical characteristics of the used soil

		Nutrient	
Physical characteristics	Values	Name	Concentrations
pH	8.2 H	**Exchangeable macronutrients (mg/100 g soil)**	
E.C. (dS m^{-1})	0.33 M	P	0.4 VL
$CaCO_3$ (%)	1.6 L	K	2.0 VL
O.M. (%)	0.7 VL	Ca	164 VL
		Mg	8.4 VL
Sand (%)	80.8	**Available Micronutrients (mg kg^{-1} soil)**	
Silt (%)	6.0	Fe	5.0 M
Clay (%)	12.2	Mn	5.0 L
Texture loamy sand		Zn	8.0 L
		Cu	1.0 M

H: High, M: Medium, L: Low, VL: Very low Ankerman and Large (1974)

Nutrient measurements: Nitrogen was determined using Micro-Kjeldahl method digestion and titration method (Ma and Zauzage, 1942). Phosphorus was photometrical determined using the molybdate-vanadate method. Potassium, sodium and calcium were measured using Dr. Lang -M8D Flame-photometer. Magnesium, Fe, Mn, Zn and Cu were determined using the Atomic Absorption Spectrophotometer (Perkin-Elmer 100 B).

Evaluation of the nutrient status: Soil nutrient concentrations were evaluated according to the tentative values of Ankerman and Large (1974) and shoot tissue nutrient concentration ratios were based upon the values of Reuter (1986).

Statistical analysis: Data were subjected to statistical analysis as specified by Snedecor and Cochran (1990). Treatment means were calculated and subjected to the one-way ANOVA analysis and Student-Newman Keuls (SNK) and LSD ($p \leq 0.05$) tests-multiple comparison of means, using Costate 2 Program (Cohort software) for different treatments.

RESULTS AND DISCUSSION

The used soil (Table 1), as most of the Egyptian soils is characterized by high pH value, low organic matter content and poverty of macro and micronutrients. It is well known that magnesium is in competition with other major cations in the soil such as calcium (Ca^{++}), potassium (K^+), sodium (Na^+), ammonium (NH^+_4), iron (Fe^{++}) and aluminum (Al^{+++}) and potassium is the stronger competitor with Mg. So, Intensive agriculture used high rates of potassium and ammonium fertilizers and neglecting of Mg-fertilization led to Mg-unavailability which became a limiting growth factor (El-Fouly *et al*., 2010).

Magnesium sulphate effect on nutrient concentrations and balance: Data in Table 2 and 3 showed significant increase of N, Ca, Mg, Na, Fe and Cu concentrations in the shoot tissues due to $MgSO_4$ soil amendment or foliar fertilization. The best treatment was the rate 120 Kg ha^{-1} as soil amendment or 5 g L^{-1} in the spray solution as foliar fertilization. This may attributed to adjusting of the nutrient balance in the shoot tissues (Fig. 1). Nutrient ratios Mg/P, K/Mg and Ca/Mg of both treatments ranked to the middle of the ideal range which realized best assimilation of Mg to play its role in the control and uptake of nutrients and its role as activator for many

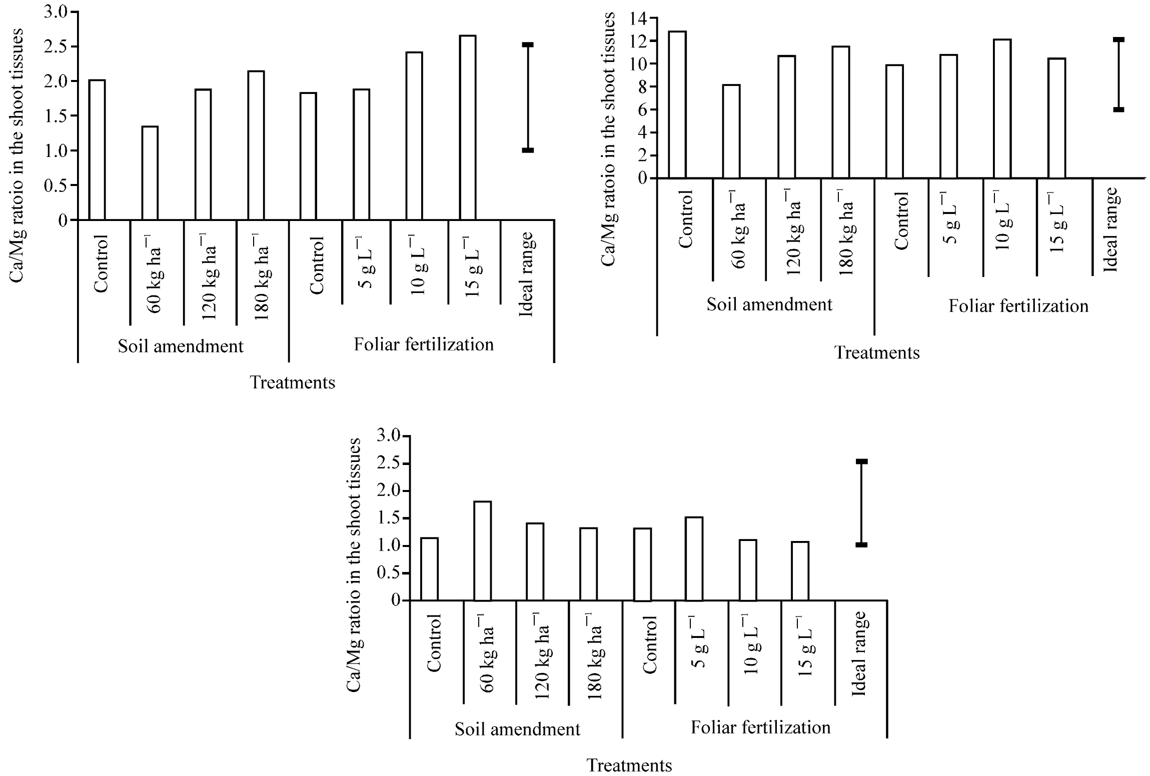

Fig. 1: Nutrient balance within shoot tissues treated with $MgSO_4$ soil amendment foliar fertilization

Table 2: Effect of $MgSO_4$ soil amendment or foliar fertilization on macronutrients concentration

	DW basis (%)					
Treatment	N	P	K	Ca	Mg	Na
Soil amendment (kg ha^{-1})						
Control	2.88^{bcd}	0.12^{a}	1.70^{a}	0.278^{a}	0.135^{a}	0.138^{d}
60	2.82^{bc}	0.12^{a}	1.76^{a}	0.290^{ab}	0.218^{d}	0.110^{bc}
120	3.07^{d}	0.12^{a}	1.79^{a}	0.313^{abc}	0.168^{c}	0.100^{abc}
180	3.00^{cd}	0.12^{a}	1.80^{a}	0.335^{abc}	0.158^{bc}	0.088^{a}
Foliar fertilization (g L^{-1})						
Control	2.57^{a}	0.13^{a}	1.62^{a}	0.300^{abc}	0.165^{c}	0.120^{c}
5	2.96^{cd}	0.11^{a}	1.81^{a}	0.280^{a}	0.168^{c}	0.098^{ab}
10	2.79^{bc}	0.13^{a}	1.76^{a}	0.352^{c}	0.145^{ab}	0.110^{c}
15	2.68^{ab}	0.12^{a}	1.87^{a}	0.345^{c}	0.130^{a}	0.108^{bc}
LSD $_{0.05}$	0.15	N.S	N.S	0.389	0.015	0.01^{4}

Columns with the same letters are not significantly different at LSD $_{0.05}$, N.S: Not significant

enzymatic processes in the plant tissues (Marschner, 1995). Magnesium found also to enhance stomatal width, length and transpiration rate which may encourage the passive uptake of nutrients (Putra *et al.*, 2012). Similar findings regarding the increase in the uptake of nutrients by wheat straw when sprayed with magnesium were also reported by El-Metwally *et al.* (2010).

Magnesium sulphate effect on nutrient uptake: Both $MgSO_4$ soil amendment and foliar fertilization had positive significant effects on the nutrient uptake of the determined macro

Table 3: Effect of $MgSO_4$ soil amendment or foliar fertilization on micronutrients Concentration

	(mg kg^{-1} dry matter)			
Treatment	Fe	Mn	Zn	Cu
Soil amendment (kg ha^{-1})				
Control	102^{b}	17^{a}	72^{a}	4.50^{a}
60	143^{c}	18^{a}	69^{a}	4.75^{ab}
120	163^{d}	17^{a}	71^{a}	5.00^{ab}
180	168^{d}	19^{a}	68^{a}	4.50^{a}
Foliar fertilization (g L^{-1})				
Control	72^{a}	17^{a}	75^{a}	4.75^{ab}
5	86^{b}	20^{a}	72^{a}	5.50^{ab}
10	89^{b}	19^{a}	76^{a}	5.75^{ab}
15	102^{b}	19^{a}	74^{a}	5.50^{ab}
LSD $_{0.05}$	13	NS	NS	0.74

Columns with the same letters are not significantly different at LSD $_{0.05}$ NS: Not significant

Table 4: Effect of $MgSO_4$ soil amendment or foliar fertilization on macronutrients uptake

	(mg plant^{-1})					
Treatment	N	P	K	Ca	Mg	Na
Soil amendment (kg ha^{-1})						
Control	23.85^{b}	0.98^{a}	14.03^{a}	2.30^{a}	1.12^{a}	1.14^{ab}
60	31.8^{cd}	1.39^{b}	19.90^{b}	3.28^{b}	2.46^{e}	1.25^{b}
120	35.75^{e}	1.38^{b}	20.18^{b}	3.52^{b}	1.87^{d}	1.13^{ab}
180	33.13^{d}	1.36^{b}	19.90^{b}	3.70^{b}	1.76^{d}	0.97^{a}
Foliar fertilization (g L^{-1})						
Control	20.58^{a}	1.02^{a}	14.48^{a}	2.29^{a}	1.32^{b}	0.96^{a}
5	31.5^{cd}	1.14^{ab}	19.35^{b}	2.99^{b}	1.79^{d}	1.04^{ab}
10	29.45^{c}	1.31^{b}	18.53^{b}	3.70^{b}	1.53^{c}	1.16^{ab}
15	29.63^{c}	1.33^{b}	20.65^{b}	3.54^{b}	1.44^{bc}	1.19^{ab}
LSD $_{0.05}$	2.01	0.19	1.68	0.49	0.16	0.14

Columns with the same letters are not significantly different at LSD $_{0.05}$

and micronutrients (Table 4 and 5). Superior treatments were also the rate 120 Kg ha^{-1} as soil amendment or 5 g L^{-1} in the spray solution as foliar fertilization. Same trend was found by Bohri *et al.* (2000) who determined the effect of Mg fertilization on the rice plants grown on artificial siltation soil. According to his results, the uptake of all nutrients in the straw was increased with Mg treatments. Magnesium positive effect on nutrients uptake may relate to its role in enzymatic processes activation and increase of nitrogen and iron utilization by the plants (Marschner, 1995).

Magnesium sulphate effect on plant growth: Growth of wheat plants interpreted as dry weight accumulation (g plant^{-1}) and plant height (cm) is shown in Fig. 2 and 3, respectively. The treatment equal 60 Kg ha^{-1} as soil amendment or 5.0 g L^{-1} in the spray solution as foliar fertilization were sufficient to realize most significant dry weight and plant height increases. Positive effect of Mg on dry biomass accumulation and plant height can be attributed to its role in photosynthesis, as a carrier of phosphorus, improvement of nutrient uptake, sugar synthesis and

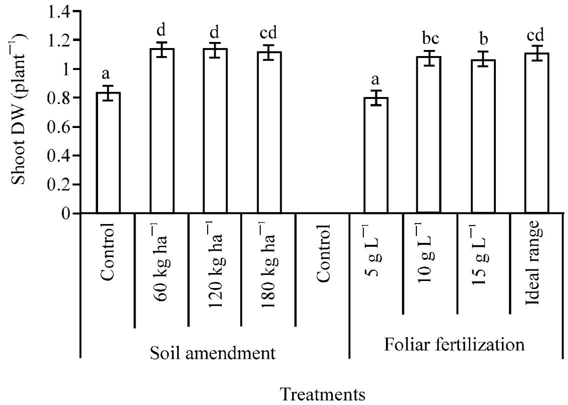

Fig. 2: Dry biomass accumulation in wheat shoots as affected by $MgSO_4$ soil amendment or foliar fertilization, Columns with same letters are not significantly different at $p = 0.05$

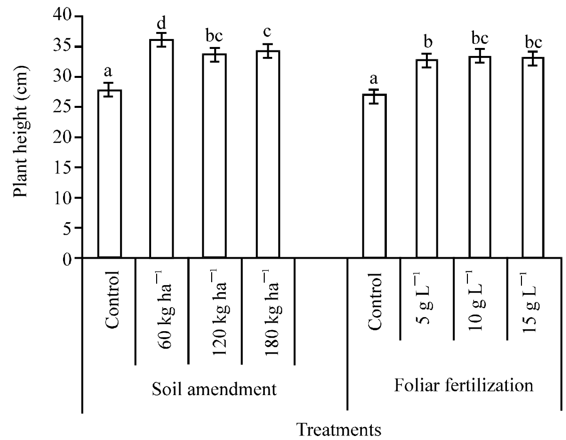

Fig. 3: Wheat plant height as affected by $MgSO_4$ soil amendment or foliar fertilization, Columns with same letters are not significantly different at $p = 0.05$

Table 5: Effect of $MgSO_4$ soil amendment or foliar fertilization on micronutrients uptake

	Nutrients (µg plant^{-1})			
Treatment	Fe	Mn	Zn	Cu
Soil amendment (kg ha^{-1})				
Control	84^{b}	14.1^{a}	59.6^{a}	3.75^{a}
60	160^{d}	20.3^{b}	78.0^{b}	5.38^{b}
120	183^{e}	19.4^{b}	79.7^{b}	5.65^{b}
180	186^{e}	20.4^{b}	75.5^{b}	4.98^{b}
Foliar fertilization (g L^{-1})				
Control	58^{a}	13.9^{a}	59.7^{a}	3.83^{a}
5	91^{b}	20.9^{b}	76.9^{b}	5.65^{b}
10	94^{b}	20.1^{b}	80.7^{b}	6.08^{b}
15	113^{c}	20.8^{b}	81.7^{b}	6.10^{b}
$LSD_{0.05}$	12	2.3	12.4	0.79

Columns with the same letters are not significantly different at $LSD_{0.05}$

starch translocation (Marschner, 1995). Sabo *et al.* (2002) concluded that winter wheat genotypes assimilated 80-130 kg ha^{-1} from the soil and thus Mg availability from the soil could significantly influence dry matter accumulation and crop productivity. Similar findings were also reported by Tan *et al.* (1992) with sorghum. Dhiraj and Kumar (2012) concluded that foliar nutrients increases crop quality and yield. Upadhyay and Patra (2011) found that 200 mg Mg pot^{-1} significantly increased plant height, number of branches per plant, width of flower, number of flower per plant, fresh weight and oil content of chamomile plants.

CONCLUSIONS

From the present findings it can be concluded that:

- Wheat plants grown on soils similar to that of Egypt should be fertilized with magnesium and the rate 60-120 kg ha^{-1} as magnesium sulphate is quite enough to satisfy the plant growth and realize the best nutrient concentrations, uptake and balance in the shoot tissues
- Soil amendment is better than foliar fertilization because it realizes the soil nutrient balance
- Foliar fertilization with magnesium is mandatory when its deficient symptoms are appeared and a concentration of 5.0 g L^{-1} $MgSO_4$ in the spray solution is sufficient to achieve good growth and nutrients uptake and balance in the shoot tissues

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