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Wheat and Faba Bean Plants as Responded to Magnesium Nitrate Foliar Fertilization

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PREVIOUS studies have shown that liquid fertilizers significantly improve crop morphology and productivity. Pot experiment was conducted in the greenhouse of the Micronutrient Project, Fertilization Technology Department, National Research Centre, Dokki, Cairo, Egypt with wheat (*Triticum aestivum* L. var. Sids 6) and faba bean (*Vicia faba* L. var. Giza 716) grown on clay loam soil to study the plants response to magnesium nitrate foliar fertilization. The experiment followed the Randomized Complete Block Design (RCBD) with six treatments in three replicates. The plants sprayed two times with the concentrations 0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 $ml.l^{-1}$ from 28.76% $Mg(NO_3)_2$ stock solution. Results showed that $MgNO_3$ foliar fertilization significantly increased fresh weight, dry weight, plant height and root volume of the treated plants. The superior doses were 7.5-10.0 $ml.l^{-1}$ for wheat and 5.0$ml.l^{-1}$ for faba bean plants. Magnesium nitrate foliar fertilization found also to significantly increase both concentrations and uptake of almost all determined macro and micronutrients by wheat and faba bean plant organs. Magnesium nitrate foliar application is highly recommended for wheat and faba bean crop plants grown under low soil magnesium levels.

Keywords: Winter crops, Foliar feeding, Secondary elements

Wheat (*Triticum aestivum* L.) is the first strategic commodity in Egypt because of it's highly demand in the daily diet. It provides more than one-third of daily caloric intake and 45 percent of total daily protein consumption. A huge gape between production and consumption still there (FAO, 2011), which mandates vertical increase of crop productivity.

Faba bean (*Vicia faba* L.) is one of the major winter-sown legume crops grown in the Mediterranean region. As a low-cost food rich in proteins and carbohydrates, vitamin C and minerals (Sepetoğlu, 2002), it has considerable importance as a main dish in the breakfast meals for most of Egyptians. Faba bean production is also not sufficient for the population consumption because of the relatively small area cultivated with faba bean compared to wheat and clover in the winter season.

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Magnesium is an essential nutrient for plant growth and development (Marshcner, 1995). Available Mg levels in some Egyptian soils are relatively low because of continuous crop removal and farm management practices (El-Fouly *et al.*, 2010). Cereals typically remove 5-13 kg $Mg.ha^{-1}$ depending on the crops grown. Chalmers *et al.* (1999) reported that the new high yielding wheat crop varieties could remove 15kg $Mg.ha^{-1}$ by the grain and straw. In a study on 12 faba bean genotypes, Daur *et al*. (2010) found that the average removal of magnesium is 23.9kg.ha^{-1}. Cakmak & Kirkby (2008) concluded that maintenance of a high Mg nutritional status of plants is essential in the avoidance of highly reactive O_2 species (ROS) generation, which occurs at the expense of inhibited phloem export of sugars and impairment of CO_2 fixation. Abou El-Nour & Shaaban (2012) found that magnesium sulphate foliar fertilization increased macro and micronutrients concentrations and uptake and dry biomass accumulation in wheat plants grown in loamy soil deficient in magnesium.

The present work aimed at studying the effect of supplying wheat and faba bean plants with magnesium nitrate as foliar spray on the growth, nutrient uptake and balance within the plant tissues.

Materials and Methods

Pot experiment was conducted in the greenhouse of the "Micronutrient Project", Fertilization Technology Department, National Research Centre, Dokki, Cairo, Egypt with Wheat (*Triticum aestivum* L. var. Sids 6) and faba bean (*Vicia faba* L. var. Giza 716) grown on clay loam soil to study the plants response to magnesium nitrate {$Mg(NO_3)_2$} foliar fertilization. Fertilizer analysis is shown in Table 1 and physical and chemical characteristics of the used soil are shown in Table 2.

TABLE 1. Chemical and physical characteristics of the used soil.

Physical characteristics			Nutrient concentrations		
			Exchangeable Macronutrients ($mg.100g^{-1}$ soil)		
pH	8.2	H			
E.C. ($dS.m^{-1}$)	0.32	M	P	2.5	M
$CaCO_3$ (%)	1.34	L	K	8.9	L
O.M. (%)	2.17	M	Mg	22.0	L
			Available Micronutrients ($mg.kg^{-1}$ soil)		
Sand (%)	15.0				
Silt (%)	28.0		Fe	3.4	L
Clay (%)	57.0		Mn	10.2	M
Texture	Clay loam		Zn	1.6	M
			Cu	1.4	M

H= High, M= Medium, L= Low , VL= Very low (Ankerman & Large, 1974).

The experiment followed the Randomized Complete Block Design (RCBD) with six treatments in three replicates. The plants were sown on Mid-November, 2010 in Mitscherlich pots contained 7.0 kg clay loam soil. Before sowing, each pot received 2.0 g ammonium sulphate (20.5% N), 2.0 g super mono-phosphate

(15.5% P_2O_5) and 1.0 g potassium sulphate (48-50 % K_2O) as basic fertilization. At the seedling age, the plants were thinned to leave 10 plants per pot.

TABLE 2. Effect of $MgNO_3$ on macro and micronutrient concentrations of wheat tissues .

Treatment ($ml.l^{-1}$)	**Macronutrients**				**Micronutrients**		
	N	**P**	**K**	**Mg**	**Fe**	**Mn**	Zn
	% Dry weight basis				**$mg.kg^{-1}$ Dry weight basis**		
	Shoots						
Control (0)	2.91	0.38	4.26	0.20	175	51	52
2.5	3.30	0.38	4.48	0.25	200	52	53
5.0	3.31	0.38	4.48	0.27	222	53	52
7.5	2.92	0.36	4.50	0.29	219	54	52
10.0	3.01	0.38	4.40	0.33	222	51	53
12.5	3.01	0.41	4.19	0.36	194	51	56
$LSD_{0.05}$	0.21	N.S.	0.15	0.075	13	N.S.	2
	Roots						
Control (0)	1.61	0.17	0.35	0.22	287	190	43
2.5	1.77	0.21	0.37	0.27	319	153	48
5.0	1.75	0.20	0.35	0.25	313	135	42
7.5	1.75	0.22	0.43	0.25	238	133	44
10.0	1.75	0.21	0.35	0.25	305	127	40
12.5	1.56	0.22	0.43	0.25	301	130	44
$LSD_{0.05}$	0.05	0.02	0.02	0.02	N.S.	4	3

Treatments

A stock solution contains 28.76% $Mg(NO_3)_2$ prepared by Heliopilis Company for Chemicals was used and concentrations of 0.0, 2.5, 5.0, 7.5, 10.0 and 12.5$ml.l^{-1}$ from which were two times sprayed. The first spray was 25 days after sowing and the second was 10 days after the first one. Every pot received 15 ml as a spray solution volume and tap water was used for preparing spray solutions and for spraying control plants.

Harvest

Ten days after the second spray, wheat and faba bean plants were harvested to measure plant height and determine root volume and fresh and dry weights. The plant tissues, then analyzed for nutrient concentrations and nutrient uptake was calculated.

Determinations and measurements

Soil

A 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 & Black (1934). Soil P was extracted using sodium bicarbonate ($NaHCO_3$) (Olsen *et al*., 1954). Magnesium and potassium were extracted using ammonium acetate ($C_3H_3O_2NH_4$) (Chapman & Pratt, 1978). Iron, Mn, Zn and Cu were extracted using DTPA-solution (Lindsay & Norvell, 1978).

Vegetative tissue

Arial parts and roots of wheat plants and leaves, stems and roots of faba bean plants were washed with tap water, 0.01 N HCl and bi-distilled water, respectively, dried at 70°C for 24 hr, weighed and ground. A part of the dry parts was wet-digested according to the method of Chapman & Pratt (1978).

Nutrient measurements

Nitrogen was determined using Micro-Kjeldahl method digestion and titration method (Ma & Zauzage, 1942). Phosphorus was photometrical determined using the molybdate-vanadate method. Potassium was measured using Dr. Lang -M8D Flame-photometer. Magnesium, Fe, Mn and Zn 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 & Large (1974) and shoot tissue nutrient concentration ratios were based upon the values of Rueter (1986).

Statistical analysis

Data were subjected to statistical analysis as specified by Snedecor & 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

Effect of $MgNO_3$ on fresh and dry weights

Fresh weights of wheat and faba bean plant parts as affected by different concentrations of $MgNO_3$ are shown in Fig. 1& 2, respectively. The highest fresh weight of wheat plants was achieved by the concentration 10mg.l^{-1}, while the highest fresh weight of faba bean plants was achieved by the concentration 5mg.l^{-1} $MgNO_3$ in the spray solution. On the other hand, $MgNO_3$ supplement appeared to be effective on the fresh weight of all plant parts. Dry weights of both wheat (Fig.3) and faba bean (Fig. 4) plants were significantly affected by $MgNO_3$ foliar fertilization. The most effective dose on wheat was also 10mg.l^{-1}, while it was 5.0mg.l^{-1} on faba bean plants. Lower doses were less effective because of their insufficient and higher doses may cause disturbance in the nutrient balance because of the antagonism between magnesium and other nutrients (Cao & Tibbitts, 1992 and Lasa *et al*., 2000). A high correlation was found between dry biomass accumulation and N-concentration. Similar results were obtained by Sabo *et al.* (2002). Shoot/root ratio in wheat plants was increased as $MgNO_3$ foliar fertilization dose was increased. This was clearly related to the increase in dry weight accumulation of the shoots and decline of dry weight accumulation in the roots. The same was true for faba bean plants, where dry biomass accumulation in leaves and stems was increased and decreased in the roots which led to shoot/root ratio increment. While Mg level is low in the soil and as the sprayed $MgNO_3$ contains nitrogen and Mg, it is likely to increase the vegetative growth of the aerial plant parts (Marschner, 1995; El-Metwally *et al*., 2010 and Daur *et al*., 2010).Positive significant effects on the fresh and dry weights of both crop plants may be attributed to the synergetic effect of Mg with other nutrients especially phosphorus (Fageria *et al*., 1995) rather than the direct effect of both Mg and N on photosynthesis, sugar synthesis, starch translocation and protein synthesis (Marschner, 1995). Daur *et al*. (2008) concluded that adequate N rate is one of the possible strategies to improve shoot dry weight. Root development inhibition occurred with the increase of foliar fertilizer doses may be related to carbohydrate depletion in the roots due to the higher photosynthetic rates and carbohydrate translocation took place by Mg and N sufficient rates (Ericsson, 1995).

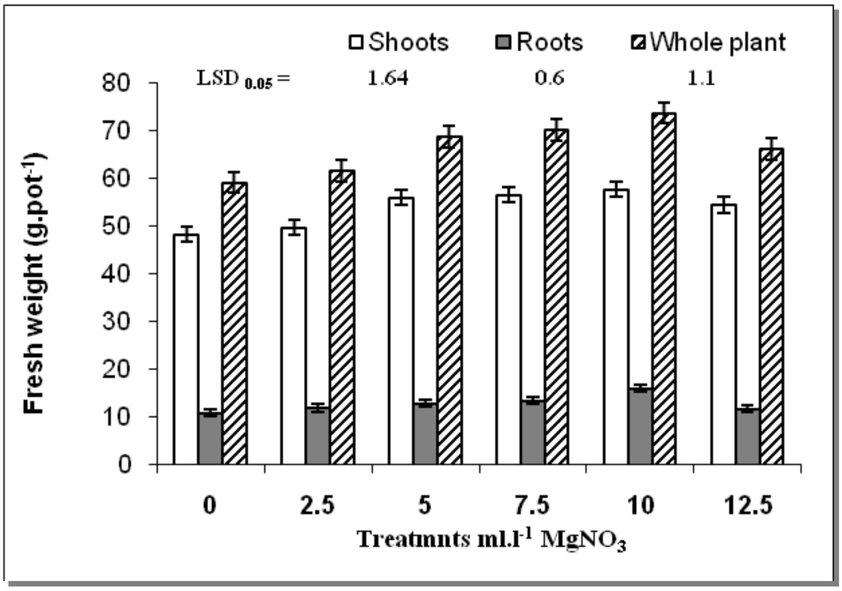

Fig.1. Fresh weight of wheat plant organs as responded to $MgNO_3$ foliar fertilization.

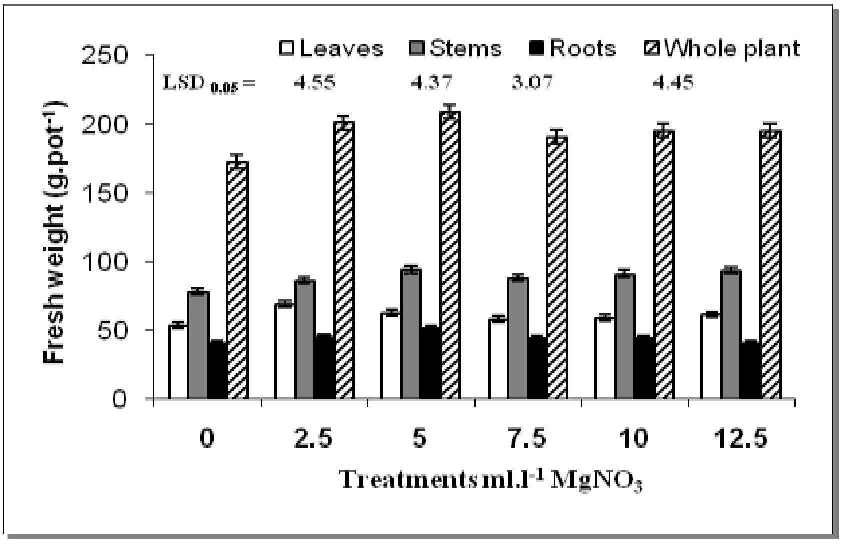

Fig. 2. Fresh weight of faba bean plant organs as responded to $MgNO_3$ foliar fertilization.

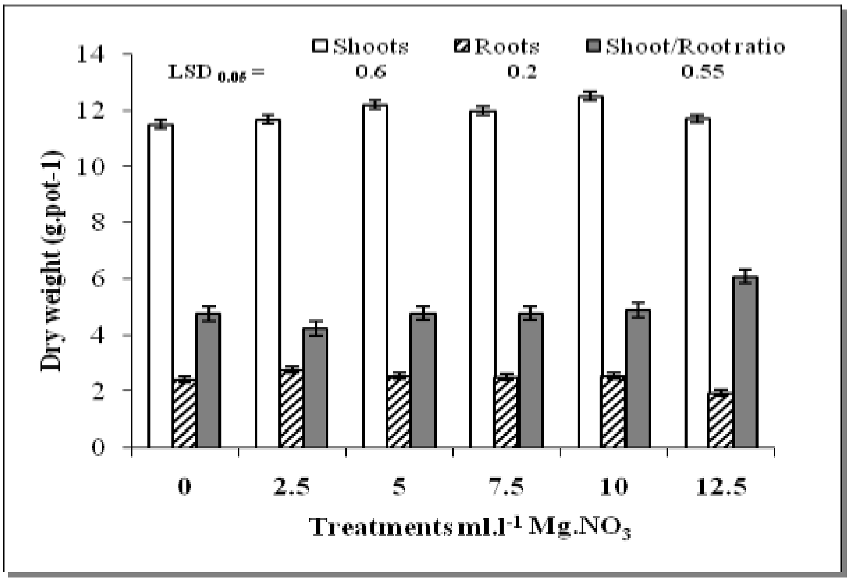

Fig. 3. Dry weight of wheat plant organs as responded to $MgNO_3$ foliar fertilization.

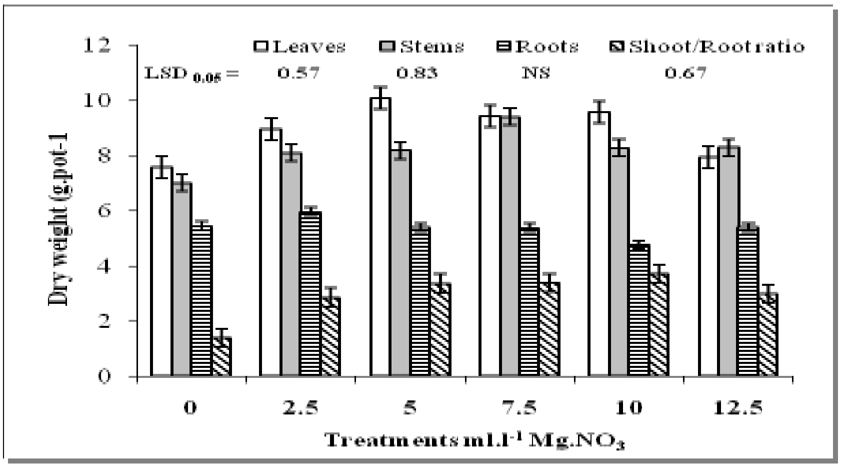

Fig. 4. Dry weight of faba bean plant organs as responded to $MgNO_3$ foliar fertilization.

Effect of $MgNO_3$ on plant height and root volume

Magnesium nitrate foliar fertilization significantly affected both plant height and root volume of wheat (Fig.5) and faba bean plants (Fig.6). Superior doses were 7.5g.l^{-1} for wheat and 5g.l^{-1} for faba bean. Sufficient Mg doses beside nitrate anions absorbed by the aerial parts may promote synthesis of growth regulators such as IAA, GA and cytokinin (Ibrahim *et al*., 2007). Ibrahim *et al*. (2001) stated that growth regulators modify morphological and physiological characteristics of plant and induce cell division and organogenesis in plant cell cultures. Kiss *et al.* (2004) reported that Mg nutrition treatment increased the number of *Rhizobium* nodules in legume roots and their Mg-content, resulting in increased N_2-fixation, root volume and yield.

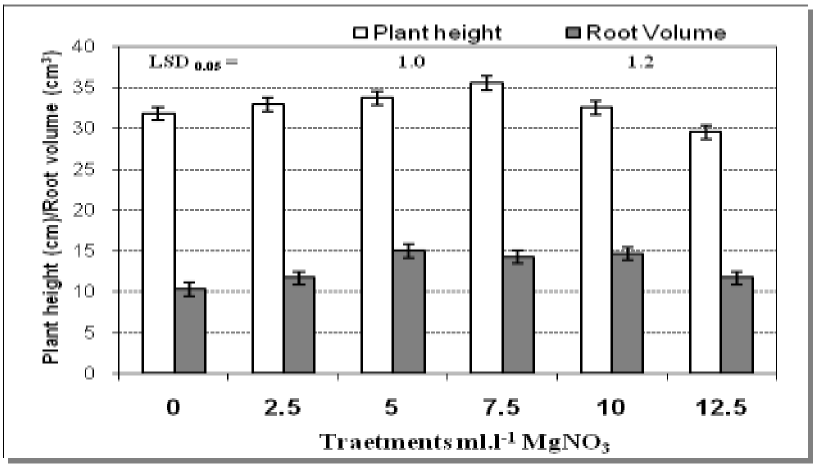

Fig. 5. Plant height and root volume of wheat plants as responded to $MgNO_3$ foliar fertilization.

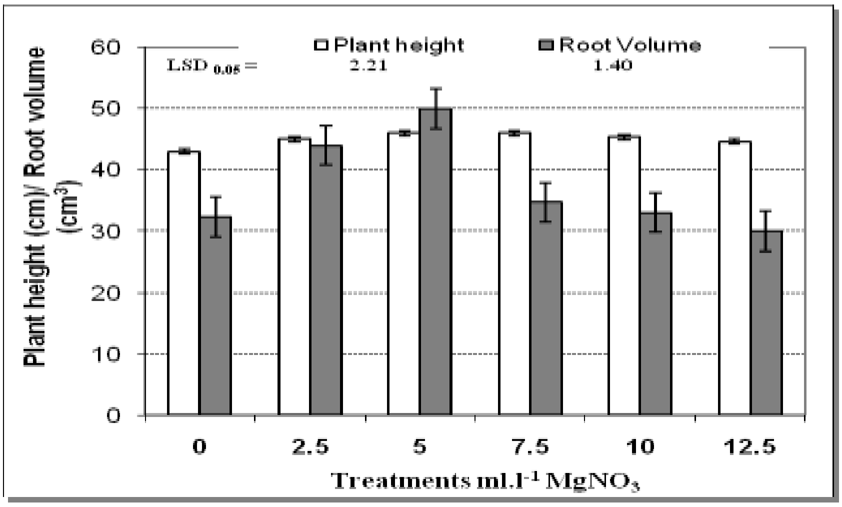

Fig. 6. Plant height and root volume of faba bean plants as responded to $MgNO_3$ foliar fertilization.

Effect of $MgNO_3$ on nutrient concentrations and content

Effect of $MgNO_3$ doses on nutrient concentrations of wheat and faba bean plant tissues is shown in Tables 2 & 3, respectively. Nitrogen, Mg and K-concentrations in both wheat and faba bean shoots and roots were significantly increased. However, P concentration in the shoots was not significantly affected. The micronutrients: Fe, Mn and zinc concentrations were also significantly increased in the plant tissues as a response to $MgNO_3$ foliar fertilization with the exception that Fe in wheat roots, Mn in wheat shoots and Zn in all faba bean plant parts were not significantly affected. Meanwhile, the content of almost all determined nutrients in wheat (Table 4) and faba bean (Table 5) plant tissues was significantly increased with $MgNO_3$ dose increment. Less increment and/or uptake reduction with the high $MgNO_3$ doses may be related to the reduction of root volume occurred by the application of these doses (Fig. 5 & 6). As the fertilizer contains N and Mg, it is likely to increase both elements concentration and content of plant tissues. Similarly, Craighead & Martin (2001) found that Mg treatments increased Mg-levels in winter wheat tissues. Despite Mg has a synergetic effect on P-uptake (Lasa *et al*., 2000), there was no significant effect of Mg treatments on P-uptake by wheat shoots. This may be attributed to the higher photosynthetic rates occurred by Mg treatments that consumed higher amounts of phosphate molecules than untreated plants. High doses of $MgNO_3$ noticed to inhibit K-uptake by the roots of both wheat and faba bean plants. Leggett & Gilbert (1969) found also that potassium and calcium contents of soybean plant roots were depressed with increasing rates of magnesium fertilization. Non significance of Mg treatments on concentrations and/or uptake of some divalent cations such as Mn^{++}, Zn^{++} and Fe^{++} can be explained by the antagonistic effect between these cations and Mg (Davis, 1996 and Gunes *et al*., 1998). On the other hand, El-Metwally *et al*. (2010) concluded that Mg treatments increased all macro and micronutrients content in wheat plants.

TABLE 3. Effect of $MgNO_3$ on macro and micronutrient concentrations of faba bean plant tissues .

Treatment ($ml.l^{-1}$)	Macronutrients				Micronutrients		
	N	P	K	Mg	Fe	Mn	Zn
	% Dry weight basis				$mg.kg^{-1}$ Dry weight basis		
	Leaves						
Control (0)	5.56	0.49	2.67	0.52	321	86	40
2.5	5.68	0.52	2.84	0.55	422	95	53
5.0	5.70	0.53	3.34	0.59	416	93	43
7.5	5.70	0.50	3.34	0.58	409	91	41
10.0	5.85	0.51	3.17	0.58	402	92	40
12.5	5.98	0.50	2.65	0.57	388	93	40
$LSD_{0.05}$	0.13	N.S.	0.05	0.02	16	6	N.S.
	Stems						
Control (0)	2.22	0.27	4.35	o.24	220	20	26
2.5	2.45	0.27	4.45	0.24	215	21	24
5.0	2.47	0.26	5.62	0.28	213	21	25
7.5	2.35	0.28	5.60	0.27	200	19	25
10.0	2.41	0.30	5.04	0.26	205	19	25
12.5	2.25	0.25	5.02	0.26	196	18	24
$LSD_{0.05}$	0.07	N.S.	0.10	0.02	7	N.S.	N.S.
	Roots						
Control (0)	3.76	0.37	2.99	0.30	303	112	52
2.5	3.57	0.37	3.01	0.34	427	119	53
5.0	3.22	0.37	2.88	0.34	503	113	52
7.5	3.18	0.36	2.89	0.35	527	113	53
10.0	2.88	0.36	2.80	0.46	482	150	52
12.5	2.98	0.34	2.40	0.46	423	156	51
$LSD_{0.05}$	0.18	0.01	0.17	0.03	12	6	N.S.

TABLE 4. Effect of $MgNO_3$ on macro and micronutrients content of wheat tissues .

Treatment ($ml.l^{-1}$)	Macronutrients				Micronutrients		
	N	P	K	Mg	Fe	Mn	Zn
	($mg.pot^{-1}$)				($\mu g.pot^{-1}$)		
	Shoots						
Control (0)	334	44	489	24.4	2005	596	597
2.5	385	44	523	31.6	2330	606	618
5.0	402	46	545	32.8	2697	645	633
7.5	351	43	542	32.4	2640	650	626
10.0	376	47	550	35.0	2772	637	663
12.5	353	45	491	31.6	2401	594	654
$LSD_{0.05}$	23	N.S.	23	5.3	268	87	N.S.
	Roots						
Control (0)	39	4.1	8.5	5.1	693	459	104
2.5	49	8.5	10.2	7.4	880	422	132
5.0	45	5.1	8.9	6.4	797	344	107
7.5	44	5.5	10.8	6.2	856	347	111
10.0	45	5.4	8.9	6.4	779	324	102
12.5	30	4.3	8.4	4.9	587	254	86
$LSD_{0.05}$	4	0.6	0.9	0.5	59	30	9
	Whole						
Control (0)	373	47.8	497	29.5	2699	156	704
2.5	434	52.7	533	39.0	3211	1027	751
5.0	447	51.4	554	39.2	3494	985	739
7.5	396	48.8	553	38.6	3496	985	737
10.0	421	52.7	559	41.4	3551	962	764
12.5	383	48.6	499	36.2	2988	847	742
$LSD_{0.05}$	20	N.S.	22	5.0	247	83	N.S.

TABLE 5. Effect of $MgNO_3$ on macro and micronutrients content of faba bean tissues .

Treatment ($ml.l^{-1}$)	Macronutrients				Micronutrients		
	N	P	K	Mg	Fe	Mn	Zn
	($mg.pot^{-1}$)				($\mu g.pot^{-1}$)		
	Leaves						
Control (0)	422	37	203	40	2435	656	303
2.5	509	47	255	49	3787	852	383
5.0	575	54	337	60	4203	938	430
7.5	539	47	316	55	3865	860	387
10.0	561	49	304	56	3859	883	387
12.5	475	40	210	45	3080	738	320
$LSD_{0.05}$	28	5	17	4	345	71	27
	Stems						
Control (0)	156	19.0	306	16.8	1544	140	183
2.5	199	21.9	361	19.4	1743	170	195
5.0	203	21.3	461	23.0	1751	172	206
7.5	221	26.3	526	25.7	1885	177	239
10.0	199	24.8	417	21.3	1696	157	207
12.5	187	20.7	417	21.6	1628	150	199
$LSD_{0.05}$	20	3.1	45	3.2	195	21	34
	Roots						
Control (0)	163	16.2	131	13.2	1327	491	228
2.5	213	22.1	180	20.4	2551	710	317
5.0	174	20.0	156	18.3	2716	610	281
7.5	161	18.1	147	17.7	2615	572	269
10.0	139	17.5	135	22.2	2320	722	250
12.5	135	15.4	109	20.8	1913	707	229
$LSD_{0.05}$	16	1.7	15	2.3	216	44	29
	Whole						
Control (0)	740	72	639	70	5307	1287	713
2.5	921	91	794	78	8080	1732	895
5.0	951	95	954	101	8670	1720	917
7.5	921	92	989	98	8365	1609	895
10.0	900	91	956	99	7875	1762	844
12.5	797	76	742	87	6622	1595	749
$LSD_{0.05}$	42	6	55	16	426	79	58

Conclusions

Supplementation of magnesium nitrate as foliar fertilization has positively affected growth and development of wheat and faba bean plants through increasing concentration and uptake of macro and micronutrients by the plant tissues. Whenever magnesium level of the soil is low, foliar fertilization to such short staying crops with magnesium compounds is highly recommended to achieve good growth and higher yields. Further research is required to determine the suitable Mg-source for different wheat and faba bean varieties grown under different environmental conditions.

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استجابة نباتات القمح والفول البلدى للرش الورقى بنترات المغنسيوم

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أوضحت النتائج السابقة أن الأسمدة السائلة يكون لها تاثيرا معنويا ايجابيا على الشكل العام للنبات وانتاجيته. أجريت تجربة اصص بصوبة مشروع العناصر المغذية الصغرى بقسم تكنولوجيا التسميد بالمركز القومى للبحوث- الدقى- القاهره- مصر على نباتات القمح الصنف سدس ٦ والفول البلدى الصنف جيزه ٧١٦ النامية على تربة طينية طميية وذلك لدراسة استجابة النباتات للرش الورقى بنترات المغنسيوم. ولقد كان تصميم التجربة طبقا للقطاعات كاملة العشوائية واحتوت على ٦ معاملات واحتوت كل معاملة على ثلاثة مكررات. ولقد تم رش النباتات مرتين بتركيزات صفر، ٢،٥ ، ٥،٠ ، ٧،٥ ، ١٠،٠ ، ١٢،٥ مل/لتر من مركز يحتوى على ٢٨،٧٦% نترات مغنسيوم. واوضحت النتائج أن الرش بنترات المغنسيوم كان له اثرا معنويا بالزيادة على الوزن الرطب والوزن الجاف وطول النبات وحجم الجذور. وكانت أفضل جرعة مستخدمة هى ٧،٥ و١٠,٠ مل/لتر بالنسبة لنباتات القمح بينما كانت الجرعة الأفضل هى ٥ مل/لتر لنباتات الفول البلدى. كما وجد أن للرش الورقى بنترات المغنسيوم أثر معنويا بالزيادة على تركيز وامتصاص كل العناصر التى تم تقديرها تقريبا. لذا فان التسميد الورقى بنترات المغنسيوم يعد ضروريا لنباتات القمح والفول البلدى النامية فى تربة منخفضة المحتوى من المغنسيوم.