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Responses of Thyme (*Thymus vulgaris* L.) to Magnesium Applications

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ABSTRACT

The effects of soil and foliar applications of Mg^{2+} ($MgSO_4$) on *Thymus vulgaris* L. plants were investigated in sandy soil during two successive seasons, 2007 and 2008. 20 g L^{-1} $MgSO_4$ was most effective, resulting in a significant increase in vegetative growth characters, essential oil (EO) content, main components of EO, photosynthesis pigments, total sugars, protein and most nutrient contents.

Keywords: essential oil, growth, magnesium sulphate ($MgSO_4$), mineral, photosynthesis pigment, protein, total sugar
Abbreviations: Chl, chlorophyll; **DW**, dry weight; **EO**, essential oil; **FW**, fresh weight

INTRODUCTION

The main objective of the present investigation was to study the effects of soil and foliar applications of $MgSO_4$ (Mg^{2+}) levels on the yield, essential oil (EO) and some biochemical changes of *Thymus vulgaris* L. plants.

The genus *Thymus* includes numerous species with very different botanical characteristics and a large chemical heterogeneity that have achieved economic importance (Stahl-Biskup 1991). *T. vulgaris* (family: Labiatae/Lamiaceae) is considered the principal species for its uses, fresh and dried as a culinary herb. Its EO is also employed in perfumery and in the food industry. The EO possesses antiseptic and antifungal properties and is used for medicinal purposes (Aureli 1992; Hammer 1999; Dorman and Deans 2000; Bisset 2001). The pharmacological action of thyme, due mainly to the presence of phenolic compounds (Bisset 2001; Martínez-Pérez *et al*. 2007) is strictly dependent on the volatile oil composition; differences in the chemical composition arise from the existence of different chemotypes (De Bouchberg *et al*. 1976; Adze *et al*. 1977; Rhyu 1977; Lemordan 1986).

Sandy soils in Egypt are characterized by poor nutrients and unfavorable environmental conditions which negatively affect growth and productivity of medicinal and aromatic plants such as thyme plants. On the other hand, thyme is a hardy perennial requiring a minimal amount of care, but mulch and the right amount of fertilizer can assist it in remaining healthy for a long time.

Magnesium is required by a large number of enzymes involved in energy transfer, particularly those utilizing ATP (Evans 1966). It is a constituent of the Chlorophyll (Chl) molecule and is required for the normal structural development of the chloroplast (Hall *et al*. 1972; Thoaison and Weier 1962), as well as other organelles such as the mitochondrion (Marinos 1963). Thus, it is to be expected that Mg^{2+} deficiency would have damaging effects on photosynthesis and respiration (Bottrill 1970; Peaslee and Moss 1966). Mg has an influence not only on the ribosome structure but also on the biosynthesis of some hormones (gibberellines, auxins, cytokinins) involved in protein synthesis. The activity of catalase is also increased by the rising level of Mg, which has a protective effect on auxins. It can thus be established that Mg exercises a direct influence on juvenility by stabilizing the polyribosome structure and an indirect effect by increasing hormone and enzyme activity (Kiss 1988). Biomass production of marjoram plant was higher at 0.75-1.5 range of Mg^{2+} (Cheol *et al*. 2001); however, the dry weight (dw) ratio showed different results. In particular, 1.5 mmol/L treatments showed a high dw value. Chl contents were connected with the increasing level of Mg^{2+} concentration at an early growth stage. EO contents also increased with increasing level of Mg^{2+} concentration. Mg^{2+} contents increased in response to the increasing rate of Mg^{2+} concentration in nutrient solution. Total nitrogen content decreased with the increasing concentration of Mg^{2+} treatment. Mg has a positive effect on the quality and quantity of chamomile EO production (Eva *et al*. 2004). El-Wahab and Mohamed (2007) indicated that *Trachyspermum ammi* L. EO constituents were not largely affected by the applied Mg while total nitrogen, phosphorus, potassium and Mg percentages in the leaves in additional to leaf pigments showed enhanced response to Mg application. Mg fertilizer increased the dry matter yield of Guinea grass, the crude protein content, and the Mg uptake of the grass (Fajemilehin *et al*. 2008).

MATERIALS AND METHODS

Experiments were carried out in sandy soil at the Experimental Farm of National Research Centre (NRC) in Nubaria region, Egypt, during two successive seasons, 2007 and 2008. Physical and chemical properties of the soil used in this study were determined according to Jackson (1973) and Cottenie *et al.* (1982) and are presented in **Table 1**.

Seedlings of *T. vulgaris*, which were kindly provided by the Department of Medicinal and Aromatic Plants, Ministry of Agriculture, Giza, Egypt, were transplanted into the open field. The experimental design was a complete randomized block with four replicates. The experimental area (plot) was 4 m² containing 4 rows (each plot contained 32 plants); the distance between hills was 25 cm and 50 cm apart. Thinning for two plants per hill was made 45 days after transplanting. All agriculture practices operations other than experimental treatments were performed according to the recommendations of the Ministry of Agriculture, Egypt. Plots were divided into three main groups. The first group

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Table 1 Physical and chemical properties of the soil.

Texture	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})
Sand	858	117.9	22.3

Available (mg g^{-2})		Total (mg g^{-2})	Soluble anions (Cmol$_c$)				Soluble cations (Cmol$_c$)			EC (dS m^{-1})	pH 1. 2.5
P	K	N	CO_3	HCO_3	Cl	SO_4	Na	Mg	Ca	1.11	8.15
9.30	16	45	-	2.79	5.81	2.50	5.10	1.57	4.03		

divided into 3 subgroups subjected to soil application of magnesium (Mg^{2+}) as magnesium sulphate ($MgSO_4$) with the rates of 59.5, 119 and 178.6 kg ha^{-1} for the first, second and third subgroup, respectively. The second group was divided into 3 subgroups subjected to foliar application of $MgSO_4$ with the rates of 10, 20 and 30 g L^{-1} for the first, second and third subgroup, respectively. The plants of the third group were not treated with $MgSO_4$ (control treatment). The soil and foliar applications have very different concentrations because magnesium resupplied through the roots passed preferentially to the upper leaves, by passing those leaves with the largest deficit while foliar application has the advantage that magnesium can be supplied directly to all leaves. We selected the rates of both soil and foliar application according to published literature.

Harvesting

At the full bloom stage, plants were harvested twice (first and second harvest) during the two seasons by cutting the plants 5 cm above the soil surface. Total mass production (fresh and dry weights (fw and dw, respectively) of the herbs) as g plant^{-1} and kg m^{-2} were recorded.

EO isolation

Fresh herbs were collected from each treatment during the first and second harvest of both first and second seasons, and then 300 g from each replicate of all treatments was subjected to hydrodistillation for 3 h using a Clevenger type apparatus (Clevenger 1928). The EO content was calculated as a percentage. In addition, total EO per plant was calculated by using the fresh weight of the herbs.

Gas Chromatography-Mass Spectrophotometry (GC-MS)

An ADELSIGLC MS system, equipped with a BPX5 capillary column (0.22 mm id × 25 m, film thickness 0.25 µm) was used. Analysis was carried out using helium as the carrier gas, with the flow rate at 1.0 ml/min. The column temperature was programmed from 60 to 240°C at 3°C/min. The sample size was 2 µl, the split ratio 1: 20. The injector temperature was 250°C. The ionization voltage applied was 70 eV, mass range m/z 41-400 amu. Kovat's indices were determined by co-injection of the sample with a solution containing a homologous series of *n*-hydrocarbons in a temperature run identical to that described above.

Identification of EO components

The separated components of the EO were identified by matching with the National Institute of Standards and Technology (NIST) mass spectral library data, comparison of the Kovat's indices with those of authentic components and with published data (Adams 2001). Quantitative determination was carried out based on peak area integration.

Photosynthesis pigments determination

Chl *a*, *b* and total carotenoids in leaves collected at the first and second harvests of both seasons of each treatment were determined using the methods described by the Association of Official Agricultural Chemists (AOAC) (1970).

Total sugars

Total soluble sugars contents were determined from plant material (leaves) collected at the first and second season of each treatment. The method of Dubois *et al*. (1956) was used.

Nutrients and protein determination

The leaf samples in the first and second harvest of both seasons were dried, ground and Mg, Fe, Zn and Mn extracted by acid digestion (Cottenie *et al.* 1982). Concentrations were determined by an atomic absorption spectrophotometer (Perkin-Elmer) (Gonzalez *et al.* 1973).

Total nitrogen, protein, phosphorus, potassium and calcium in the leaves at the first and second harvest of both seasons of each treatment were determined using the methods described by the AOAC (1970).

Statistical analysis

The averages of data from each season were statistically analyzed using analysis of variance (ANOVA) and the values of least significant difference (L.S.D.) at 1% and 5% according to Snedecor and Cochran (1990).

RESULTS AND DISCUSSION

Effect of Mg^{2+} on growth characters

Data in **Table 2** shows the response of growth characters (fw and dw of herb g plant^{-1}) in *T. vulgaris* plants to the different rates of $MgSO_4$. All $MgSO_4$ treatments, i.e. both soil and foliar application were superior to the control treatment and significantly improved the vegetative growth characters. The highest values of vegetative growth characters were recorded when plants were sprayed with 20 g L^{-1} $MgSO_4$ – resulting in 59.8 and 65 g plant^{-1} (for herb fw) and 18.9 and

Table 2 Effect of soil and foliar application of Mg^{2+} on the growth characters of *Thymus vulgaris* L. plant.

Mg treatments		Fresh mass production				Dry mass production			
		(g plant^{-1})		(kg m^{-2})		(g plant^{-1})		(kg m^{-2})	
		1st season	2nd Season	1st Season	2nd Season	1st season	2nd Season	1st Season	2nd Season
	Control	20.2	25.2	0.32	0.40	7.6	7.9	0.12	0.13
Soil application (kg ha^{-1})	59.5	28.6	32.0	0.46	0.51	9.8	11.6	0.16	0.19
	119.0	52.3	58.3	0.84	0.93	13.9	15.6	0.22	0.25
	178.6	34.6	35.3	0.55	0.57	10.0	12.3	0.16	0.20
Foliar application (g L^{-1})	10.0	30.5	34.2	0.49	0.55	17.3	19.1	0.28	0.31
	20.0	59.8	65.1	0.96	1.04	18.9	24.9	0.30	0.40
	30.0	37.2	37.0	0.60	0.59	12.3	15.6	0.20	0.25
L. S. D.									
at: 0.05		3.57	2.98	0.05	0.04	1.23	2.18	0.02	0.03
at: 0.01		4.01	3.25	0.07	0.05	1.98	3.56	0.03	0.04

Table 3 Effect of soil and foliar application of Mg^{2+} on the essential oil extracted from *Thymus vulgaris* L. plant.

Mg treatments		**Essential oil content**			
		Percentage		**ml per plant**	
		1st Season	**2nd Season**	**1st Season**	**2nd Season**
	Control	0.41	0.39	0.083	0.098
Soil application (kg ha^{-1})	59.5	0.42	0.41	0.120	0.131
	119.0	0.45	0.46	0.235	0.268
	178.6	0.44	0.43	0.152	0.152
Foliar application (g L^{-1})	10.0	0.46	0.48	0.140	0.164
	20.0	0.53	0.55	0.317	0.358
	30.0	0.47	0.52	0.175	0.192
L. S. D.					
at: 0.05		0.006	0.004	0.008	0.006
at: 0.01		0.008	0.006	0.009	0.009

Table 4 Effect of soil and foliar application of Mg^{2+} on the chemical constituents of essential oil extracted from *Thymus vulgaris* L. plant.

No.	**Components (percentage)**	**KI**	**control**	**Soil application (kg ha^{-1})**			**Foliar application (g L^{-1})**		
				59.5	119	178.6	10.0	20.0	30.0
1	α-Pinene	932	1.52	1.23	1.89	1.12	1.58	1.02	1.26
2	Camphene	945	2.23	2.13	1.15	1.56	1.24	0.29	1.23
3	Sabinene	972	0.19	0.21	0.11	0.16	0.09	0.14	1.11
4	β-Pinene	973	0.26	0.15	0.10	0.13	0.11	0.12	0.36
5	Myrcene	993	1.15	1.12	1.10	0.14	0.16	0.19	1.17
6	α- Phellandrene	1001	1.32	1.52	1.15	1.23	1.00	0.15	1.36
7	α-Terpinene	1014	4.31	4.37	4.89	4.96	4.39	5.42	4.89
8	*p*-Cymene	1023	15.63	16.3	16.9	15.98	16.23	17.56	16.53
9	Limonene	1028	4.23	4.13	4.59	4.26	4.24	5.20	4.26
10	1,8-Cineol	1030	0.16	0.19	0.11	0.10	0.09	0.03	0.26
11	γ--Terpinene	1059	18.68	19.36	20.13	19.55	20.98	22.14	19.98
12	Terpinolene	1089	2.13	2.03	2.00	2.01	2.04	0.02	1.23
13	Linalool	1102	2.31	1.96	1.39	1.36	2.28	1.03	1.26
14	Camphor	1144	2.56	1.14	1.12	1.14	2.89	0.56	0.58
15	Borneol	1165	0.23	0.36	0.26	0.29	0.12	0.11	0.26
16	α-Terpineol	1191	0.56	1.45	1.56	1.52	1.02	1.91	1.25
17	Thymol	1292	38.85	39.22	40.23	38.99	40.01	42.02	39.68
18	Carvacrol	1300	2.03	2.13	0.11	1.12	0.04	0.16	0.19
19	α-Copaene	1377	0.13	0.14	0.19	1.13	0.15	0.26	0.26
20	β-Bourbonene	1386	0.18	0.19	0.26	0.22	0.26	0.36	0.46
21	β-Caryophyllene	1416	0.19	0.22	0.12	1.15	0.26	0.23	0.65
22	α-Humulene	1449	0.18	0.15	0.19	0.21	0.11	0.15	0.65
23	Germacrene *D*	1481	0.23	0.12	0.25	1.12	0.16	0.24	0.46
Total identified:			99.26	99.82	99.80	99.45	99.45	99.31	99.34
Monoterpene hydrocarbons			51.65	52.55	54.01	51.10	52.06	52.25	53.38
Oxygenated Monoterpene			46.70	46.45	44.78	44.52	46.45	45.82	43.48
Sesquiterpene hydrocarbons			0.73	0.67	0.82	3.62	0.83	1.09	1.83
Oxygenated Sesquiterpene			0.18	0.15	0.19	0.21	0.11	0.15	0.65

KI*= Confirmed by comparison with Kovats indices on DB5 column (Adams 2001).

24.9 g plant^{-1} (for herb dw) during the first and second season, respectively – compared with the control and other treatments such as soil or foliar application of $MgSO_4$. The positive effects of Mg^{2+} fertilization may be due to the important physiological role of Mg^{2+} on molecule structure, enzyme activity and protein synthesis (Jones *et al.* 1991) that reflected on an increase in growth parameters of *T. vulgaris* plants. Also, these results are in accordance with those obtained by Thoaison and Weier (1962), Peaslee and Moss (1966), Bottrill (1970), Hall *et al*. (1972) and El-Wahab and Mohamed (2007), all of whom reported that Mg^{2+} could increase the Chl content and growth characters in *Phaseolus vulgaris*, spinach, maize and *Trachyspermum ammi* and, consequently, photosynthetic efficiency.

Effect of Mg^{2+} on EO contents

The effects of different treatments of Mg So_4 on the EO content (percentage or ml plant^{-1}) extracted from *T. vulgaris* plants are represented in **Table 3**. Generally, all levels of $MgSO_4$ as soil or foliar application progressively increased the EO of *T. vulgaris* plants compared with the control. The intermediate level (20 g L^{-1}) of $MgSO_4$ as foliar spray seemed to be the optimal level for obtaining a higher concentration of EO, 0.53 to 0.55% and 0.317 to 0.358 ml plant^{-1} for both seasons. These results parallel those of Eva *et al.* (2004) and El-Wahab and Mohamed (2007) who reported that Mg has a positive effect on the quantity of chamomile and *Trachyspermum ammi* EO production.

Effect of Mg^{2+} on EO constituents

A qualitative and quantitative comparison of the constituents present with the different $MgSO_4$ treatments in the hydro-distilled *T. vulgaris* EO was studied. A total of 23 compounds, amounting for 99.26-99.82% of the EO, were identified. The effect of soil and foliar application of $MgSO_4$ levels on the chemical composition of EO extracted from *T. vulgaris* is shown in **Table 4**. The main components were thymol, γ-terpinene, *p*-cymene and α-terpinene. Moreover, the highest percentages of the main components resulted from the treatment of 20 g L^{-1} $MgSO_4$ (as foliar application). The highest percentage of monoterpene hydrocarbons compounds (54.01%) resulted from the treatment of 119 kg ha^{-1} of $MgSO_4$ as soil application, of oxygenated monoterpene compounds (46.70%) from the control, of sesquiterpene hydrocarbons compounds (3.62%) from the treatment of 178.6 $MgSO_4$ ha^{-1} (as soil application), and of oxygenated sesquiterpene compounds (0.65%) from the treatment of 30 g L^{-1} $MgSO_4$ (as foliar application). The effect of dif-

Table 5 Effect of soil and foliar application of Mg^{2+}on the photosynthesis pigments of *Thymus vulgaris* L. plant.

Mg treatments		Chlorophyll a (mg g^{-1})		Chlorophyll a (mg g^{-1})		Total carotenoids(mg g^{-1})	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
	Control	0.034	0.026	0.076	0.081	1.09	1.46
Soil application (kg ha^{-1})	59.5	0.039	0.041	0.079	0.086	1.28	1.52
	119.0	0.045	0.047	0.086	0.095	1.35	1.59
	178.6	0.041	0.036	0.075	0.085	1.29	1.47
Foliar application (g L^{-1})	10.0	0.049	0.052	0.077	0.092	1.10	1.78
	20.0	0.059	0.057	0.099	0.098	1.56	1.89
	30.0	0.047	0.049	0.087	0.085	1.42	1.75
L. S. D.							
at: 0.05		0.001	0.002	0.001	0.003	0.004	0.005
at: 0.01		0.003	0.003	0.002	0.004	0.006	0.007

Table 6 Effect of soil and foliar application of Mg^{2+} on the total sugars and protein contents of *Thymus vulgaris* L. plant.

Mg treatments		Total sugars (percentage)		Protein (percentage)	
		1st Season	2nd Season	1st Season	2nd Season
	Control	7.85	6.89	8.44	8.94
Soil application (kg ha^{-1})	59.5	8.56	8.16	10.25	10.69
	119.0	10.23	9.78	11.75	12.10
	178.6	11.14	12.03	10.81	11.25
Foliar application (g L^{-1})	10.0	11.12	10.32	10.63	10.63
	20.0	14.52	12.45	12.31	13.13
	30.0	16.35	14.69	11.25	12.10
L. S. D.					
at: 0.05		0.96	1.01	N. S	N. S
at: 0.01		1.02	1.12	N. S	N. S

ferent $MgSO_4$ treatments on EO and its constituents may be due to its effect on enzyme activity and metabolism (Burbott and Loomis 1969). Also these results may be due to $MgSO_4$ increase chlorophyll content and, consequently, photosynthesis efficiency, so the results showed that EO content was increased with the application of $MgSO_4$ (referring to Mostafa *et al.* 2007 on banana plant).

Effect of Mg^{2+} on the photosynthesis pigments

Data presented in **Table 5** shows that the application of $MgSO_4$ as either a soil or foliar application produced a significant increase in the accumulation of photosynthetic pigments (Chl *a*, Chl *b* and total carotenoids) during both seasons. The highest values of photosynthetic pigments were obtained when $MgSO_4$ was applied as a foliar spray at 20 g L^{-1} resulting in 0.059 and 0.57 mg g^{-1} for Chl *a*, 0.099 and 0.098 mg g^{-1} for Chl *b*, as well as 1.56 and 1.89 for total carotenoids during the first and second season, respectively. On the other hand the lowest contents resulted from control treatments. These results may be due to magnesium applications made by chloroplast activation and the amount of Photosynthetic pigments elevation (Hall *et al.* 1972; Thoaison and Weier 1962). In addition these results paralleled those of other authors (Peaslee and Moss 1966; Bottrill 1970; El-Wahab and Mohamed 2007; Fajemilehin *et al.* 2008), who indicated that leaf pigments showed enhanced response to $MgSO_4$ application of some plants such as *Phaseolus vulgaris*, maize, spinach, *Trachyspermum ammi* and *Panicum maximum*.

Effect of Mg^{2+} on the total sugars content

Table 6 shows that total sugars content increased with soil and foliar application of $MgSO_4$ during both seasons. However the highest content of total sugars was recorded when plants were sprayed with 20 g L^{-1} compared with the control or other treatments. The increment increased to 185 and 181% over control treatment for the first and second season, respectively. These results may be due to an increase in Mg and Chl content and consequently, photosynthesis efficiency. So the results showed that total sugars content was increased with application of $MgSO_4$ (referring to Mostafa *et al.* 2007 on banana plant).

Effect of Mg^{2+} on the protein content

Protein contents were not significantly affected by soil and foliar application of $MgSO_4$ (**Table 6**). The treatment of 20 g L^{-1} $MgSO_4$ as foliar application recorded the highest protein content with the values of 12.31 and 13.13 % during the first and second seasons respectively. These results may be due to Mg which has an influence on the ribosome structure and the biosynthesis of some hormones (gibberellines, auxins, cytokinins) involved in protein synthesis (Kiss 1988, Jones *et al.* 1991 and El-Wahab and Mohamed 2007).

Effect of Mg^{2+} on mineral content and its uptake

It is evident from **Tables 7** and **8** that all mineral (N, P, K, Ca, Mg, Fe, Zn and Mn) contents and uptake under investigation gradually increased in all treatments as compared with the control treatment in both seasons. Soil or foliar applications of $MgSO_4$ increased the nutrient content compared with untreated plants. With respect to the effect of the methods of $MgSO_4$ application, data indicated that spraying $MgSO_4$ increased most nutrients compared with soil dressing. By applying 119 kg ha^{-1} $MgSO_4$ as dressing gave high values of N, P, K, Ca, Mg, Fe, Zn and Mn as compared with 59.5 and 119 kg ha^{-1} $MgSO_4$. In addition, foliar application of Mg at 20 g L^{-1} recorded high values of all minerals compared with 10 and 30 g L^{-1}. In addition, 20 g L^{-1} $MgSO_4$ as a foliar application recorded the highest values of mineral content and their uptake. Mg may regulated by uptake of essential elements. Increasing the essential minerals and their uptake may be due to an increase in the dry matter of plant materials. These results are in agreement with those of Na *et al.* (2001), El-Wahab and Mohamed (2007) and Fajemilehin *et al.* (2008), they repored that nutrient contents showed enhanced response to Mg application of *Trachyspermum ammi* L. as well as Mg fertilizer increased the dry matter yield, essential minerals and their uptake of Guinea grass.

CONCLUSION

Mg^{2+} treatment resulted in a significant increase in thyme vegetative growth characters, EO content, main components of EO, photosynthesis pigments, total sugars, protein and most of nutrient contents.

Table 7 Effect of soil and foliar application of Mg^{2+} on the nutrient contents of *Thymus vulgaris* L. plant.

Mg treatments		N	P	K	Ca	Mg	Fe	Zn	Mn
		Percentage					ppm		
1st season	Control	1.35	0.15	1.38	1.63	0.44	80	35	48
Soil application (kg ha^{-1})	59.5	1.64	0.18	2.06	1.80	0.63	98	43	64
	119.0	1.88	0.24	2.24	1.90	0.76	105	48	77
	178.6	1.73	0.22	2.18	2.00	0.60	97	47	70
Foliar application (g L^{-1})	10.0	1.71	0.20	2.23	1.67	0.74	94	44	73
	20.0	1.97	0.28	2.32	1.74	0.81	111	51	79
	30.0	1.80	0.25	2.27	1.44	0.78	98	48	71
L. S. D.									
at: 0.05		NS	0.004	0.003	0.003	0.005	3.1	2.9	5.1
at: 0.01		NS	0.008	0.005	0.004	0.009	3.8	3.3	6.2
2nd season									
	Control	1.43	0.16	1.44	1.66	0.41	85	35	50
Soil application (kg ha $^{-1}$)	59.5	1.71	0.20	2.12	1.83	0.66	101	45	63
	119.0	1.93	0.26	2.24	1.99	0.79	117	50	79
	178.6	1.80	0.25	2.20	2.04	0.62	98	46	69
Foliar application (g L^{-1})	10.0	1.70	0.22	2.28	1.69	0.74	96	48	75
	20.0	2.01	0.26	2.38	1.80	0.85	118	51	80
	30.0	1.93	0.28	2.33	1.60	0.80	103	51	73
L. S. D.									
at: 0.05		NS	0.002	0.005	0.004	0.003	3.6	4.2	6.2
at: 0.01		NS	0.004	0.007	0.007	0.009	4.2	5.1	6.9

Table 8 Effect of soil and foliar application of Mg^{2+} on the nutrient uptake of *Thymus vulgaris* L. plant.

Mg treatments		N	P	K	Ca	Mg	Fe	Zn	Mn
					mg plant^{-1}				
1st season	Control	102.6	11.40	104.9	121.6	33.4	0.60	0.26	0.36
Soil application (kg ha^{-1})	59.5	160.1	17.64	201.9	176.4	61.7	0.95	0.42	0.62
	119.0	261.3	33.4	311.4	264.1	105.6	1.45	0.66	1.07
	178.6	173.3	22.0	218.0	200.0	60.0	0.97	0.47	0.70
Foliar application (g L^{-1})	10.0	227.4	26.6	296.6	222.1	98.4	1.25	0.58	0.97
	20.0	372.3	47.2	438.5	328.8	153.1	2.09	0.96	1.049
	30.0	221.1	34.4	279.2	177.1	95.9	1.20	0.59	0.87
L. S. D.									
at: 0.05		6.2	3.2	5.6	7.9	5.8	0.002	0.002	0.003
at: 0.01		7.9	4.5	7.4	10.2	7.3	0.004	0.003	0.004
2nd season									
	Control	112.9	12.6	113.8	131.1	32.4	0.67	0.27	0.39
Soil application (kg ha^{-1})	59.5	197.2	23.2	245.9	212.3	76.6	1.17	0.52	0.73
	119.0	301.1	40.6	349.4	310.4	123.2	1.82	0.78	1.23
	178.6	221.4	30.8	270.6	250.9	76.3	1.20	0.56	0.85
Foliar application (g L^{-1})	10.0	324.7	42.0	435.5	322.8	141.3	1.83	0.92	1.43
	20.0	500.5	64.7	592.6	448.2	211.6	2.93	1.26	1.99
	30.0	301.1	43.7	363.5	249.6	124.8	1.61	0.79	1.14
L. S. D.									
at: 0.05		5.4	2.8	4.8	8.8	4.5	0.006	0.004	0.003
at: 0.01		6.2	3.3	6.5	9.2	4.9	0.008	0.005	0.005

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