THE EFFECT OF LIQUID FERTILIZER MG-TITANIT ON CREATION OF WINTER WHEAT PHYTOMASS

Peter KOVÁČIK[1], Jozef HUDEC[1], Peter ONDRIŠÍK[2], Nora POLLÁKOVÁ[3]

Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources
[1]Department of Agrochemistry and Plant Nutrition, [2]Department of Environmental Science and Zoology, [3]Department of Soil Science and Geology, Slovak Republic
e-mail: *Peter.Kovacik@uniag.sk*

Abstract: *The effect of the application of liquid fertilizer Mg-Titanit (MgTi) containing titanium in the form of titanium ascorbate on creation of aboveground phytomass dynamics, total chlorophyll content in leaves and yield grain and straw of winter wheat was investigated in a small plot field trial (20 m^2 per one plot) realized on the haplic chernozem (48°42′ N, 17°70′ E – western Slovakia) during two farming years (2010/2011 and 2011/2012). The experiment consisted of 5 treatments (0; 2xTi0.2; 3xTi0.2; 2xTi0.4; 3xTi0.4). 0 – control treatment without MgTi fertilizer; 2xTi0.2 – two applications of MgTi in the dose of 0.2 $l.ha^{-1}$; 3xTi0.2 – three applications of MgTi in the dose of 0.2 $l.ha^{-1}$; 2xTi0.4 – two applications of MgTi in the dose of 0.4 $l.ha^{-1}$; 3xTi0.4 – three applications of MgTi in the dose of 0.4 $l. ha^{-1}$. The fertilizer was applied in the spring during two, or three different growth stages: BBCH 29, BBCH 32, BBCH 55. The plant sampling was carried out two or three weeks after spraying by the fertilizer (BBCH 32, BBCH 55, BBCH 65). The results show that both first and second (repeated) application of Mg-Titanit stimulated the formation of the aboveground phytomass of winter wheat and it tended to increase the content of the total chlorophyll in leaves. A higher one-off application dose (0.4 $l.ha^{-1}$) had more positive effect on the formation of the aboveground phytomass than a lower one-off dose (0.2 $l.ha^{-1}$). The effect of the third dose was not positive. The increased total dose of Mg-Titanit led to the increased yield of wheat grains up to the total dose 0.8 $l.ha^{-1}$. The highest yield of grain and straw was achieved with the total dose 0.8 $l.ha^{-1}$, i.e. after two applications of Mg-Titanit in the dose of 0.4 $l.ha^{-1}$. The dose of 1.2 $l.ha^{-1}$ (3 x 0.4 $l.ha^{-1}$) did not increase the grain and straw yield in comparison with the dose of 0.8 $l.ha^{-1}$. However, the grain and straw yield was higher with the given dose of Mg-Titanit than in the variants with the total doses of 0.4 and 0.6 $l.ha^{-1}$. From the aspect of the quantity of grain and straw yield and nitrogen content in the wheat grain the better parameters were achieved when the application dose of Mg-Titanit was 0.4 $l.ha^{-1}$ in comparison with the dose of 0.2 $l.ha^{-1}$, regardless there carried out two or three applications.*

Key words: *chlorophyll, fertilizer, titanium, winter wheat*

INTRODUCTION

Despite the profound knowledge on positive impact of titanium application on plants, recorded in the twentieth century, agricultural practice has not still made pressure on the producers of fertilizers, growth promoters (soil improvers), amendments and remediate substances to add titanium into all these products. Apart from the positive effects of titanium on plants (TRAETTA-MOSCA, 1913; PAIS 1983; TICHÝ and TÓTH, 1990; CARVAJAL et al., 1994; CARVAJAL and ALCARAZ, 1998), there were also recorded the cases of its negative impact (KUŽEL et al., 2007). There is significantly less knowledge of phytotoxic effects of titanium foliar applications than the amount of knowledge of their positive impact. The negative effects result from the disregard of the agrochemical application principles of fertilizers, growth promoters or soil remediate substances.

Titanium affects positively the growth of vertebrates (in small doses) and it also has bacteriostatic and bacteriocidal properties (DUFFY et al., 1998; YAGHOUBI et. al., 2000). Its presence on plant leaves and in soil acts as an antibiotic. The availability of titanium from soil to plants is very low, both in acid and the alkaline surroundings. This fact creates a presumption of a positive performance of its foliar application. The effect of titanium utilization (apart from dosage) is significantly determined by the selected form of compound ($TiCl_2$, $TiCl_3$, $TiCl_4$, Na_2TiO_3, $C_{30}H_{25}Na_3O_{35}Ti_3$, titanium citrate, titanium ascorbate, $C_{10}H_{10}CI_2Ti$, TiO_2, titanylsulphate chelated with tartaric acid).

On the basis of this information, the aim of experiment has been to investigate the effect of the application of liquid fertilizer Mg-Titanit (MgTi) containing titanium in the form of titanium ascorbate on creation of aboveground phytomass dynamics, total chlorophyll content in leaves and yield of winter wheat grain and straw.

MATERIAL AND METHODS

The effect of the application of liquid fertilizer Mg-Titanit (MgTi) on creation of aboveground phytomass dynamics, total chlorophyll content and yield grain of winter wheat was investigated in a small plot field trial (20 m^2 per one plot) realized on the haplic chernozem (48^{o}42´ N, 17^{o}70´ E – western Slovakia) during two farming years (2010/2011 and 2011/2012). The agrochemical parameters of haplic chernozem taken from soil layer 0.0 - 0.6 m are given in table 1. They were determined by the following methods: N_{an} = N-NH_4^+ + N-NO_3^-, N-NH_4^+ – colorimertically by Nessler`s agent, N-NO_3^- – colorimertically by the phenol 2.4 disulphonic acid, P – colorimertically (Mehlich III - MEHLICH, 1984), K and Ca – flame photometry (Mehlich III - MEHLICH, 1984), Mg – AAS (Mehlich III - MEHLICH, 1984), S – spectrometrically ICP OES (Zbíral, 2002), Cox – oxidometrically (Ťjurin, 1966), N_t – by distilling (Kjeldahl - BREMNER, 1960), pH/KCl –potentiometrically (1.0 mol.dm^{-3} KCl). Experiment consisted of 5 treatments (0; 2xTi0.2; 3xTi0.2; 2xTi0.4; 3xTi0.4). 0 – control treatment without MgTi fertilizer; 2xTi0.2 – two applications of MgTi in the dose of 0.2 l.ha^{-1}; 3xTi0.2 – three applications of MgTi in the dose of 0.2 l.ha^{-1}; 2xTi0.4 – two applications of MgTi in the dose of 0.4 l.ha^{-1}; 3xTi0.4 – three applications of MgTi in the dose of 0.4 l. ha^{-1}. The fertilizer was applied in the spring during two, or three different growth stages: BBCH 29, BBCH 32, BBCH 55 (table 2). The plant sampling was carried out two or three weeks after spraying by the fertilizer. Growth phase (BBCH 32, BBCH 55, BBCH 65 - 69) in which plant samples were taken for study of aboveground phytomass creation are given in table 3. To determine the content of the assimilative pigments (chlorophyll a, chlorophyll b and carotenoids) in leaves was used the spectrophotometric method (LICHTENTHALER, 1987). Acquired results were processed by mathematical and statistical method, by analysis of variance (ANOVA) using Statgraphics PC program, version 5.0.

Mg-Titanit fertilizer (stimulator) is liquid, dark brown fertilizer EC (European Community) with bulk density 1.36 kg.l^{-1}. It contains 8.5 g of titanium in 1 liter of fertilizer, 3% of magnesium, 4% of sulfur. Titanium is in form of titanium ascorbate and sulfur with magnesium are in form of magnesium sulphate ($MgSO_4$).

Table 1

Soil agrochemical parameters before the foundation of experiments in a soil layer 0.0 - 0.6 m

Year	Nmin	P	K	Ca	Mg	S	Nt	C_{ox}	pH_{KCl}
	mg.kg^{-1}							%	
2010/2011	23.10	29.0	203	6 100	400	55.3	1 146	1.11	6.56
2011/2012	22.25	62.6	250	6 925	354	8.5	1 575	1.44	7.12

Table 2

Treatments of experiment

Treatments		Growth phase of Mg-Titanit application		
		BBCH 29	BBCH 32	BBCH 55
number	designation	dosage ($l.ha^{-1}$)		
1	0	0	0	0
2	2 x $Ti_{0,2}$	0.2	0.2	0
3	3 x $Ti_{0,2}$	0.2	0.2	0.2
4	2 x $Ti_{0,4}$	0.4	0.4	0
5	3 x $Ti_{0,4}$	0.4	0.4	0.4

Table 3

Growth stages of sampling of winter wheat plant and spraying stimulator Mg-Titanit

Type of treatment			
1st Ti spray	1st sampling and subsequent 2nd Ti spray	2nd sampling and subsequent 3nd Ti spray	3rd sampling
growth phase			
end of tillering BBCH 29	coming to stalk BBCH 32	earing BBCH 55	flowering - end of flowering BBCH 65 – 69

RESULTS AND DISCUSSIONS

The data presented in the Table 4 show that the applications of Mg-Titanit in the growth phases BBCH 29 and BBCH 32 stimulated the formation of the wheat aboveground phytomass. After the repeated, second application of Mg-Titanit the differences were increased significantly in the weight of the aboveground phytomass in the the growth stage BBCH 55 between the unfertilized variant 1 and the other variants in comparison with the first application and they achieved the level of 26.37 % or 27,26 %. The third spraying with Mg-Titanit was applied only in the variants 3and 5 and it tended to inhibit the formation of the wheat aboveground phytomass (var. 3 versus var. 2) or to inhibit it evidentially (var. 5 versus var 4). The detected facts correspond with both DOBROMILSKA´S findings (2007) about the positive impact of the fertilizer Mg-Titanit on plants and WALACE´S et al. (1977) data pointing out the possible inhibitive impact of the fertilizer containing titanium on plants. The detected data also confirmed the findings of KOVÁČIK and VICIAN (2012) about the positive or negative impact of Mg-Titanit depending on its application dose, date of application and the cultivated crop.

Table 4

The effects of the dose and the date of application of Mg-Titanit on the dynamic creation of aboveground phytomass (100 % dry matter) of winter wheat (mean of two years)

Treatments		Sample/growth stage						
		0./ BBCH 29	I./ BBCH 32		II./ BBCH 55		III./ BBCH 65 – 69	
number	designation	weight of one plant at g (1pl/g)		%	1pl/g	%	1pl/g	%
1	0	0.2305	1.0035	100.00	1.8015	100.00	5.0135 a	100.00
2	2 x $Ti_{0,2}$	0.2305	1.0255	102.19	2.2765	126.37	5.9565 b	118.81
3	3 x $Ti_{0,2}$	0.2305	1.0255	102.19	2.2765	126.37	5.8445 ab	116.58
4	2 x $Ti_{0,4}$	0.2305	1.0470	104.33	2.2925	127.26	7.0155 c	139.93
5	3 x $Ti_{0,4}$	0.2305	1.0470	104.33	2.2925	127.26	6.1600 b	122.87
$LSD_{0,05}$							0.8427	
$LSD_{0,01}$							1.1453	

1pl/g – weight of one plant at gram, $LSD_{0,05}$ – limit of significant difference at the level α = 0.05 (LSD test), different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

The second, third and fourth samplings of the aboveground phytomass prove that the effect of the application dose 0.4 $l.ha^{-1}$ was higher than the effect of the dose 0.2 $l.ha^{-1}$ (var. 2 and 3 versus var. 4 and 5). The maximal aboveground phytomass was evidential statistically in the variant where Mg-Titanit was applied in the total dose 0.8 $l.ha^{-1}$ N, in two one-off 0.4 $l.ha^{-1}$ doses. The different results were achieved by VICIAN et al., (2012). They had higher yields of winter rape cultivation when they applied the lower doses, i.e. 0.2 $l.ha^{-1}$ dose of Mg-Titanit rather than 0.4 $l.ha^{-1}$ dose.

One of the first impacts of the excessive application of nutrients including titanium is a lower content of the total chlorophyll (KOVÁČIK and VICIAN, 2012). The Table 5 shows that after the application of Mg-Titanit the content of the total chlorophyll was not decreased. On the contrary, the content of the total chlorophyll was increased, however, in majority examples it was not evidential. The given facts prove that the amount of titanium added to the crops by Mg-Titanit was not excessive.

Mg-Titanit had impact on both components of the total chlorophyll. i. e. chlorophyll *a* and chlorophyll *b*. In the wheat leaves the maximal contents of the total chlorophyll were detected in the growth stages BBCH 65 – 69 (last sampling) in the crops which were added maximum Mg-Titanit, i. e. totally 0.8 $l.ha^{-1}$ and 1.2 $l.ha^{-1}$ (var. 4 and 5).

Table 5

Impact of trial treatments on dynamics of changes of pigment contents in leaves of winter wheat (mean of two years)

Treatment number	Treatment designation	Growth stage	Chlorophyll *a* ($mg.m^{-2}$)	Chlorophyll *b* ($mg.m^{-2}$)	Chlorophyll *a+b* ($mg.m^{-2}$)	Carotenoid ($mg.m^{-2}$)
1	0Ti	BBCH 32	369.462 a	162.151 a	531.616 a	90.692 a
2 – 3	$Ti_{0,2}$		369.347 a	163.269 a	532.616 a	92.808 a
4 – 5	$Ti_{0,4}$		378.424 a	150.385 a	528.809 a	93.808 a
$LSD_{0,05}$			16.0924	26.6154	38.9923	7.4077
$LSD_{0,01}$			22.1038	36.5577	53.5616	10.1730
1	0Ti	BBCH 55	398.116 a	202.923 a	601.039 a	94.654 a
2 – 3	$Ti_{0,2}$		407.808 a	202.308 a	610.116 a	100.192 b
4 – 5	$Ti_{0,4}$		404.231 a	202.731 a	606.924 a	92.116 a
$LSD_{0,05}$			12.5692	13.4269	18.0307	5.2769
$LSD_{0,01}$			17.2692	18.4461	24.7654	7.2500
1	0Ti	BBCH 65 - 69	374.270 a	152.423 a	526.693 a	94.519 a
2	$2xTi_{0,2}$		389.385 ab	170.770 ab	560.155 ab	97.327 a
3	$3xTi_{0,2}$		384.847 ab	172.923 ab	557.770 ab	95.192 a
4	$2xTi_{0,4}$		393.193 ab	180.154 b	573.348 b	94.5194 a
5	$3xTi_{0,4}$		398.693 b	193.693 b	592.424 b	90.5194 a
$LSD_{0,05}$			20.1269	26.6308	42.2769	6.8923
$LSD_{0,01}$			27.0769	35.8308	56.8770	9.2730

$LSD_{0,05}$ – limit of significant difference at the level $\alpha = 0.05$ (LSD test), different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

As the biggest aboveground phytomass and the maximal amount of chlorophyll was formed in the growth stage BBCH 65 – 69 in the variants 4 and 5, it was expected to achieve the highest grain yield and straw yield in the variant 4 and 5. The assumption was fulfilled, however, in 85% there the positive correlation was not proved between the formed phytomass and the yield of generative organs, or between the chlorophyll content and the yield of the cultivated crops (KOVÁČIK, 2014). The Table 6 shows that the wheat grain yield was higher in all the variants fertilized by Mg-Titanit in comparison with the control variant but only in the variant 4 the difference was significant.

The impact on the straw yield was more considerable than on the grain yield. In all variants treated by Mg-Titanit there the straw yield was evidentially higher than in the control variant. Similarly, in all variants where Mg-Titanit was applied the ratio between the straw phytomass and grain was increased (Table 6). The straw yield alike the grain yield was higher in the variant 4, i.e. in the variant where 0.8 $l.ha^{-1}$ Mg-Titanit was applied totally in two doses of 0.4 $l.ha^{-1}$.

Table 6

The influence of application Mg-Titanit fertilizer on the grain and straw yield of winter wheat (mean of two years)

Treatment		Grain		Straw		Straw/ Grain
number	designation	$t.ha^{-1}$	%	$t.ha^{-1}$	%	
1	0	6.61 a	100.00	7.48 a	100.00	1.13
2	2 x $Ti_{0,2}$	6.70 a	101.36	8.08 bc	108.02	1.21
3	3 x $Ti_{0,2}$	6.72 a	101.59	7.83 ab	104.68	1.17
4	2 x $Ti_{0,4}$	7.11 b	107.49	8.32 c	111.16	1.17
5	3 x $Ti_{0,4}$	6.81 a	103.03	8.23 bc	109.96	1.21
$LSD_{0,05}$		0.2488		0.4633		
$LSD_{0,01}$		0.3348		0.6233		

$LSD_{0,05}$ – limit of significant difference at the level α = 0.05 (LSD test), different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

When we compare the variants of one-off application dose 0.2 $l.ha^{-1}$ (var. 2 and 3) with the variants of one-off application dose 0.4 $l.ha^{-1}$ (var. 4 – 5) regardless the number of applications it is evident that higher yields of grain and straw were achieved with higher one-off application doses than with lower ones (Table 7).

Table 7

Impact of Mg-Titanit fertilizer dose on winter wheat grain and straw yield regardless number of applications (average two years)

Treatment		Grain		Straw		Straw/ Grain
number	designation	$t.ha^{-1}$	%	$t.ha^{-1}$	%	
1	0	6.61	100.00	7.48	100.00	1.13
2 – 3	$Ti_{0,2}$	6.71	101.51	7.96	106.42	1.19
4 – 5	$Ti_{0,4}$	6.96	105.30	8.28	110.70	1.19

The evaluation of the impact of Mg-Titanit number of sprayings, regardless the application dose Mg-Titanit (var. 2 and 4 versus var. 3 and 5), proves that higher grain and straw yields were achieved with a lower number of applications – two applications (Table 8).

The presented data confirm that it is more suitable to carry out two sprayings not three and it is also more suitable when the one-off application dose is 0.4 $l.ha^{-1}$ not 0.2 $l.ha^{-1}$ from the aspect of the amount of winter wheat grain and straw yield.

Table 8

Impact of Mg-Titanit fertilizer application number on winter wheat grain and straw yield regardless application dose

Treatment		Grain		Straw		Straw/ Grain
number	designation	$t.ha^{-1}$	%	$t.ha^{-1}$	%	
1	0	6.61	100.00	7.48	100.00	1.13
2	2 x Ti	6.91	104.54	8.20	109.63	1.19
3	3 x Ti	6.77	102.42	8.03	107.35	1.19

CONCLUSIONS

The applications of Mg-Titanit in the growth stages BBCH 29 and BBCH 32 stimulated the formation of the aboveground phytomass of winter wheat and tended to increase the content of the total chlorophyll in leaves. The repeated second application of Mg-Titanit increased more significantly the formation of the aboveground phytomass than the first application. The third application of Mg-Titanit with the dose of 0.2 $l.ha^{-1}$ inhibited non-essentially the formation of the wheat aboveground phytomass and the dose 0.4 $l.ha^{-1}$ inhibited it essentially. The increased total dose of Mg-Titanit up to 0.8 $l.ha^{-1}$ resulted in the increased wheat grain yield. Mg-Titanit increased more significantly the straw yield than the grain yield. The highest grain and straw yield was achieved with the total dose of 0.8 $l.ha^{-1}$, i.e. after two applications of Mg-Titanit in the dose of 0.4 $l.ha^{-1}$.

From the viewpoint of the amount of grain and straw yield better parametres were achieved if one-off application dose of Mg-Titanit was 0.4 $l.ha^{-1}$ in comparison with the dose 0.2 $l.ha^{-1}$, regardless whether there were two or three applications of Mg-Titanit.

ACKNOWLEDGEMENT

This paper was supported by VEGA project 1/0591/13.

BIBLIOGRAPHY

1. CARVAJAL, M. F., MARTINEZ-SANCHEZ, F., ALCARAZ, C. F. 1994. Effect of Ti(IV) on some physiological activity indicators of *Capsicum annuum* L. plants. J. Hort. Sci. 69, 1994 427 - 432.
2. CARVAJAL, M., ALCARAZ, C. F. 1998. Why titanium is a beneficial element for plants. J. Plant Nutr. 21: 655–664
3. DUFFY, B., SCHWIETERT, C., FRANCE, A., MANN, N., CULBERTSON, K., HARMON, B., MCCUE, J. P. 1998. Transition metals as protease inhibitors, Biol. Trace Elem. Res. 64, 1998, 1–3, p. 197–213.
4. DOBROMILSKA, R. 2007. Wplyw stosowania Tytanitu na wzrost pomidora drobnoowocowego. Rocz. AR Pozn., 383, Ogrodnictwo 41, 451–454.
5. KOVÁČIK, P., VICIAN, M. 2012. Vplyv foliárnej aplikácie hnojiva Mg-titánit na úrodové parametre pšenice letnej f. ozimnej a kapusty repkovej pravej f. ozimnej. Záverečná správa vypracovaná na základe zmluvy (Reg. č. 172/2011/SPU) medzi Intermag Sp. z o. o. Osiek, Poľsko a SPU v Nitre, Slovensko. Nitra, 2012, 69 p.
6. KOVÁČIK, P. 2014. Princípy a spôsoby výživy rastlín. Nitra : SPU v Nitre, 2014. 189 s.
7. KUŽEL, S., CÍGLER, P., HRUBÝ, M., VYDRA, J., PAVLÍKOVÁ, D., TLUSTOŠ, P. 2007. The effect of simultaneous magnesium application on the biological effects of titanium. In: Plant Soil Environ., *53*, 2007 (1): 16–23.
8. LICHTENTHALER, H. K. 1987. Chllorophyll and Carotenoides: Pigments of Photosynthetic Biomembranes. In: Methods in Enzymology. 148, pp.350-382.
9. PAIS, I. 1983. The biological importance of titanium. Journal of Plant Nutrition, *6*, 3–131.
10. TRAETTA-MOSCA, F. 1913. Titanium and the rare metals in the ash of the leaves of Kentucky tobacco cultivated in Italy. Gazzetta Chimica Italiana, *43*: 437–440.
11. TICHÝ I., TÓTH, J. 1990. Výsledky overovania Titavinu v cukrovej repe. Agrochémia, 30, 1990, 8, p. 225 – 229.
12. VICIAN, M., KOVÁČIK, P., LOŽEK, O., POLLÁKOVÁ, N., SKAWIŃSKI, M. 2012. The impact of application of foliar fertilizer with titanium content on the yield parameters of oilseed rape. In: Vedecké práce Katedry agrochémie a výživy rastlín a Katedry pedológie a geológie. Nitra : Slovenská poľnohospodárska univerzita v Nitre, 2012. p. 165-170. ISBN: 978-80-552-0890-9.
13. WALLACE, J., W EBSTER, J., WOODALL, W. 1977. The role of filter feeders in stream ecosystems, Arch. Hydrobiol., 79, 506–532.

14. YAGHOUBI, S., SCHWIETERT, CH. W., MCCUE, J. P. 2000. Biological Roles of Titanium. *Biological Trace Element Research. vol. 78, 2000,* 205 – 217.
15. ZBÍRAL, J. 2002. Analýza půd I – Jednotné pracovní postupy. ÚKZÚZ Brno, 2002, 197 p. ISBN 8086548155.