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Comparative Evaluation of Thiamethoxam Based Insecticide Efficiency for Winter Wheat Seed Dressing

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ABSTRACT.

The present article contains the results of the comparative evaluation of neonicotinoid Thiamethoxam effectiveness against ground beetle on different varieties of winter wheat that are grown in two climate zones of the Russian Federation. It was shown that seed dressing with Thiamethoxam containing chemicals reduced the invasion of ground beetles during autumn tillering by 70-98% and preserved the crop efficiency during spring vegetation at the same level. The authors established correlation between biological effect and application rate of the active ingredient per 1 ton of seeds. There was no significant difference identified in insecticide activity depending on Thiamethoxam concentration in the seed dresser and content of additional and/or other fungicides. Pests plant damage to crops that were seed dressed with Thiamethoxam before seed drilling was close to effectiveness against ground beetle in the respective variants of the trials. Soil and climate conditions and varietal features of winter wheat did not influence significantly on Thiamethoxam activity against the target pest species.

Key words: Thiamethoxam, neonicotinoids, insecticide and fungicide seed dresser, winter wheat, biological activity

INTRODUCTION

Current issues and threats to the stable development of agriculture provide the necessity for improvement of grain production agrotechnologies. Production of competitive grain crops is impossible without effective crop protection against a variety of pests and, primarily, phytophages [1,2,3]. Application of crop protection chemicals and optimization of protective measures are based on target oriented approach, economic and ecologic feasibility [4,5]. On the one hand, their effectiveness should be quite high and have a stable and long-term effect, on the other hand, the effect should be within the biosphere capacity. Thus, the choice of active ingredient for seed dresser, its biotic and abiotic properties is determinant.

The share of pest damage to crop yield is 1/3 (around 8%) of the total yield loss (around 25%). As a rule, the yield loss is estimated by gross grain production, whilst grain quality loss sometimes prevails in this aspect [1]. One of the most harmful winter wheat pests is considered to be ground beetle. This pest is widespread within the zone of winter wheat cultivation, especially, in the regions with failed crop rotation and planting after preceding grain crops. Non-optimized technologies and high ecological plasticity of ground beetle contribute to the spread of its habitat and harm to crops. Winter wheat crops can be totally damaged by the pest at the stage of germination or significantly harm crop wintering and its further vegetation. High larvae count contributes to thinning of crops and increases the risk of crop re-drilling. Air and soil temperature, moisture and other factors influence on larvae daily consumption of crops leaves and duration (prolongation) of their ontogenesis period. However, the pest harm remains consistently high [6].

Crop protection consists of a complex of protective measures. Chemical method of crop protection is effective in autumn (seed dressing) and spring (crop spraying) [2,5]. Seed dressing is an ecologically oriented method of crop protection, it is less safe for entomofauna as compared to the technology of pesticide spraying during vegetation. Besides, it is characterized by high effectiveness, financial and economical availability. It can be further corrected based on current phytosanitary situation with a wide range of chemicals that belong to different chemical classes [4,7], which provides selective or complex activity against pests and prevention of resistance development [8]. Neonicotinoid insecticides are used in anti-resistance programs and provide new possibilities of effective crop protection with the most harmful crop pest [9,10,11,12]. They can be used alone or as a part of complex chemical formulations for crop protection against pests and diseases.

The purpose of the study was to perform comparative evaluation of neonicotinoid Thiamethoxam included in different chemical formulations of seed dressers for protection against ground beetle in different climatic zones of the RF.

MATERIALS AND METHODS.

Harmful objects. The pest species (ground beetle or *Zabrus tenebrioides Goeze = Zabrus gibbus Fabr.)* belong to *Coleoptera* order, *Carabidae* family. During a year, one generation of insects develops. Larvae appear with winter wheat sprouting and develop for 250-260 days, they feed at night on soil surface and hide in ground holes during the day. Pupas develop for 12-14 days. The development is epicene, fertility at feed availability is up to 100 eggs, at feed unavailability – up to 30 eggs. It is one of the most harmful pests for grain crops in their area of growing, the risk of winter wheat crop damage can be up to 40% [13]. Economic threshold of pests harmfulness (ETPH) varies at different stages of crop development: during germination – 0.2-0.5 larvae per 1 m^2 or 3-4 larvae of I stage of development/1 m^2; during tillering (autumn) – 3-6 larvae of II-III stage of development/1 m^2, during aftergrowth (spring) – 3-4 feeding larvae per 1 m m^2 [3].

Trial plots location. The trials were conducted in two climate zone of agricultural crops cultivation in the RF: II – zone of black earth forest steep, Povolzhskiy and North Caucasus Regions (Krasnodarskiy Kray, Krasnodarskiy Scientific Research Agricultural Institute: heavy black soil, leached, low-humic – 3.2%, NO_3 – 20.0 mg/kg, P_2O_5 – 40,0 mg/kg, K_2O – 300 mg/kg, pH – 5.9); III – zone of dry steep brown earth, North Caucasus Region of agricultural crops cultivation (Rostov Oblast, Salskiy Region, “Uspekh Agro” Llc: dark brown soil, heavy clay-loamy, content of humus 3.1%, pH – 6.9).

Winter wheat varieties. *Grom* (soft winter wheat) variety complies with the requirements to "valuable" wheat varieties. It is characterized by field resistance and tolerance to brown rust. It is resistant to dust smut and mildew, low susceptible to yellow rust, septoriosis and stinking smut, medium susceptible to ear fusariosis. Frost resistance is higher than average. Drought resistance is high. *Rostovchanka* (soft winter wheat) variety complies with the requirements to "valuable" wheat varieties. It is characterized by above average frost resistance, standard drought resistance. It is not prone to logging. It is resistant to brown rust, medium resistant to mildew, medium susceptible to septoriosis, susceptible to stinking smut and ear fusariosis, resistant to dust smut. *Krasnodarskaya-99* (soft winter wheat) is a medium early variety, it complies with the requirements to "valuable", rarer to "strong" varieties. Resistance to logging is 8.8 – 9.0 points, to grain falling – 8.8 – 9.0 points, to drought – 8.5 – 8.8 points, frost resistance is above average. The variety is low susceptible to different types of rust, mildew, septoriosis, medium resistant to fusariosis, susceptible to brown rust. *Irishka* (soft winter wheat) is a semi-dwarf variety that complies with the requirements to "valuable" varieties. It is highly resistant to logging, does not drop kernels. It is highly resistant to brown rust and stem rust, mildew; moderately resistant to septoriosis and yellow rust, low susceptible to stinking smut, moderately resistant to fusariosis. Frost and drought resistance was above average.

Active ingredient with insecticide activity – Thiamethoxam. According to the IUPAC classification, Thiamethoxam (5-methyl-3-(2-chlorthiazole-5-ylmethyl)-1,3,5-oxydiazinan-4-ylidene-N-nitroatnine) is a neonicotinoid that is characterized by systemic effect. It affects nicotinic receptors in insects nervous system and exerts quick stomach effect. It is a contact insecticide that is active against the main grain crop pests [14,15]. The chemical favorably influences on plants [16], increases their resistance to unfavorable environmental factors (drought, soil salination, etc.) as well as pest damage and viral infection. It activates protective plants functions [17].

Chemicals. Thiamethoxam in contained in the following studied chemicals: insecticides fungicides of "Syngenta" Llc 1) Vibrance Integral (Thiamethoxam 175 g/L + Sedoxan 25 g/L + Fludioxonil 25 g/L + Tebuconazole 10 g/L), 2) Dividend Supreme (Thiamethoxam 92.3 g/L + Difenoconazole 39.92 g/L + Mefenoxam 3.08 g/L) and 3) Selest Top (Thiamethoxam 262.5 g/L + Difenoconazole 25 g/L + Fludioxonil 25 g/L), insecticide Cruiser (Thiamethoxam 350 g/L) of "Syngenta" Llc and insecticide Tiara (Thiamethoxam 350 g/L) of "RosAgroChim" Llc. All the chemicals are in the form of suspension concentrate (SC).

Method of seed dressing. Winter wheat seeds were treated with the chemicals 1-2 days prior to the seed drilling. Application rate per 1 tom of seeds is presented in Table 1.

Table 1. Thiamethoxam content (g per 1 ton of winter wheat seeds) based on application rate of insecticide fungicide or insecticide seed dresser

№	Tradename	Application rate, L/t	Content of Thiamethoxam, g/L	Application rate Thiamethoxam, g/t
1.	Vibrance Integral, SC	1.5	175.0	262.5
2.	Vibrance Integral, SC	1.75	175.0	306.25
3.	Vibrance Integral, SC	2.0	175.0	350.0
4.	Dividend Supreme, SC	1.5	92.3	138.75
5.	Dividend Supreme, SC	2.0	92.3	184.6
6.	Dividend Supreme, SC	2.5	92.3	230.75
7.	Selest Top, SC	0.5	262.5	131.25
8.	Selest Top, SC	0.7	262.5	183.75
9.	Selest Top, SC	0.9	262.5	236.25
10.	Cruiser, SC	0.5	350.0	175.0
11.	Cruiser, SC	1.0	350.0	350.0
12.	Tiara, SC	1.0	350.0	350.0

Pests threshold control was based on biological peculiarities of their development and complied with the respective methodological and methodical requirements [18]. Pests threshold control was performed in autumn and during spring tillering of winter wheat.

Parameters. Biological effectiveness (%) of Thiamethoxam against ground beetle in different trials was estimated taking into account the amount of pests in the control [18] – BE; biological effectiveness per 1 g of active ingredient (Thiamethoxam) – BE/g of a.i.; increase (decrease) of biological effectiveness (ΔБЭ, %) based on concentration change (ΔC) of a.i. (Thiamethoxam) in the chemical: $\Delta BE = (BE_i - BE_{i-1})/(C_i - C_{i-1}) * 100$.

Statistical processing of the obtained data was performed by the software package Microsoft Excel. Arithmetical mean (M), standard deviation (SD) and variation coefficient (CV) were calculated by the formula CV=S/M*100%.

Significance of difference between the variants was estimated based on paired two-tailed t-test for mean values.

RESULTS AND DISCUSSION.

One of the main aspects in evaluation of biological effectiveness of insecticide is the effect dependence on a) pests invasion and b) weather conditions. The studies, conducted in 2014-2015 in Krasnodarskiy Kray (II zone) and Rostov Region (III zone), were aimed at evaluation of effectiveness of Thiamethoxam against ground beetle on Grom winter wheat variety drilled after preceding grain crop (winter wheat).

In Krasnodarskiy Kray the pests count (larvae of 1 and 2 stage of development) on winter wheat crops, that were not seed dressed, in autumn (beginning of tillering) was equal to 10.5 ± 3.1 larvae/m^2 (M ± SD) and in spring – to 11.5 ± 3.4 larvae/m^2, which was significantly (more than by 2 times) higher than ETPH. The acceptable values of ETPH in the south of Russia were 3-4 larvae of 1 stage of development or 0.5 larvae of 3 stage of development per 1 m^2 (during autumn germination) and 3-4 larvae per 1 m^2 (during spring tillering).

In Rostov Region the pests count was equal to 9.5 ± 2.7 larvae of 1 and 2 stage of development/m^2 during autumn pest threshold control and 8.0 ± 2.6 larvae/m^2 in spring. Pests count values varied up to 30% depending on the replications of pest threshold control. Average pest count values in the two studied zones were equal to 10.0 ± 2.7 and 9.8 ± 3.4 larvae/m^2, respectively, for autumn and spring pests threshold control. Value difference for each region as compared to the total average was not more than 5% in autumn and 15-17% in spring, i.e. those deviations were significantly lower than fluctuations within each sampling.

Variation coefficient ranged within 27-29% in autumn and 30-34% in spring. The obtained results indicated on similar tendency of pests development in 2014-2015 regardless of soil characteristics (leached heavy black soil, low-humic and dark brown, clay loamy soil) and weather conditions (acute decrease of precipitation level as compared to long-time average annual in Krasnodarskiy Kray and significant decrease or insignificant lack of moisture in soil in Rostov Region during sprouting). It can be suggested that lack of significant differences in weather conditions during sprouting, one variety drilled after the same preceding crop and similar rate of pest population development should determine similar insecticide activity of Thiamethoxam against ground beetle.

Still, the tendency towards better biological effectiveness (BE) of Thiamethoxam in Vibrance Integral was observed in III climate zone (Rostov Region) as compared to II zone (Krasnodarskiy Kray)

(Table 2): difference in effectiveness ranged from 13 to 6% depending on the application rate, the difference was significant ($p<0.05$) only in trials with the lowest application rate (in this series of trials) of the insecticide (262.5 g of a.i/1 ton of seeds).

Table 2. Parameters of Thiamethoxam biological activity (insecticide fungicide Vibrance Integral) during autumn pest threshold control depending on the rates of application and concentration of a.i.

Application rate, L/t	C	ΔC	Krasnodar Region			Rostov Region		
			BE	BE/g	ΔBE	BE	BE/g	ΔBE, %
1.5	262.50	0	71.4*	27.2		84.2*	32.1	
2.0	306.25	43.75	81.0	26.4	21.8	89.5	29.2	12.1
2.5	350.00	43.75	88.1	25.2	16.3	94.8	27.1	12.1

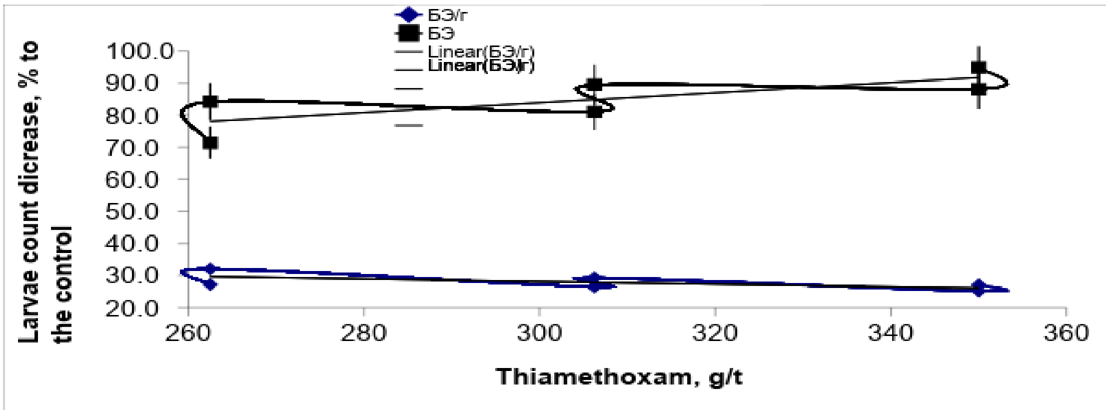
Note: C – concentration of active ingredient - Thiamethoxam, g/t; ΔC – increase of active ingredient (a.i.) concentration, g/t; BE – biological effectiveness, %; ΔBE – increase of effectiveness per 1 g of active ingredient; * - difference between the samples is significant at $p<0.05$.

Variation coefficient of BE in Krasnodarskiy Kray was higher than in Rostov Region (8.7 vs 7.7%). It should be noted that biological effectiveness increase (ΔBE) in Krasnodarskiy Kray was more significant, when the application rate was changed from 262.5 to 306.5 g of Thiamethoxam per 1 ton of seeds, than in Rostov Oblast (22 vs 12%, Table 2). This cannot be explained only by the influence of weather conditions (low level of precipitations during drilling and germination).

It is known that the life cycle of ground beetle can change depending on their habitat [13]. The pest is more active in conditions of sufficient moisture and lower temperature. Ground beetle fertility and pest invasion also depend on these conditions (high level of precipitations contributes to its increase) [19]. In Krasnodarskiy Kray the deficit of precipitations in September-December 2014 was 24.3% (long-time average annual was 250 mm) and in Rostov Region – 18.4% (long-time average annual was 171 mm), in October-November – 39.2 and 20.1%, respectively. Despite lower deficit of precipitations as compared to long-time average annual levels in Rostov Region, their absolute quantity was lower than in Krasnodarskiy Kray (139.5 and 191.5 mm in September-December 2014, respectively). Ground beetle count in Krasnodarskiy Kray was similar to ground beetle count in Rostov Region. Thiamethoxam lower effectiveness at the application rate 262.5 g/t in Krasnodarskiy Kray can be possibly explained by impossibility to create pest toxic concentration around the seed and in rhizosphere due to lack of moisture in soil.

The dependence of biological effectiveness (BE and BE/g of a.i.) on Thiamethoxam application rate was described by the equation of linear regression with high coefficient of approximation (0.98-1): *Krasnodarskiy Kray:* $y=0.1909x + 21.717$; $R^2 = 0.99$ for BE and $y = -0.0232x + 33.385$; $R^2 = 0.98$ for BE/g a.i.; *Rostov Region:* $y = 0.1211x + 52.4$; $R^2 = 1$ for BE and $y = -0.0572x + 46.971$; $R^2 = 0.99$ for BE/g a.i.

Summarized data on two regions allowed the authors to draw the correlation between biological effectiveness and Thiamethoxam concentration in the seed dressing (Figure 1).



БЭ – BE БЭ/г д.в. – BE/g of a.i.

Figure 1. Influence of Thiamethoxam application rate (as a part of insecticide and fungicide seed dressing Vibrance Integral formulation for Grom winter wheat variety seed treatment) on biological effectiveness (BE) and

on biological effectiveness per 1 g of active ingredient (BE/g). Summarized data obtained in Krasnodar and Rostov Regions.

Approximation coefficient (R^2) for linear dependence did not exceed 0.57 (BE: y = 0.156x + 37.058; R^2 = 0.57 and BE/g a.i.: y = -0.0402x + 40.178; R^2 = 0.41).
Thus, within the limited sampling it was difficult to describe biological effect as regards to Thiamethoxam application rate in the linear model with high significance.
Since Thiamethoxam effectiveness trials were performed in different years (2015-2015), using different varieties of soft winter wheat (Grom, Irishka, Rostovcjanka-3 and Krasnodarskaya-99) in two (II and III) climate zones, the studied neonicotinoid was included into different chemicals (insecticide fungicide Vibrance Integral, Dividend Supreme, Selest Top and insecticides Cruiser, Tiara) in different concentrations (175 g/L, 92.3 g/L and 262.5 g/L of Thiamethoxam) and the chemicals were used in various application rates, it was important to identify the significance of BE dependence on a.i. concentration. Biological effectiveness per 1 g of a.i. (Thiamethoxam) (BE/g of a.i.) closely correlated with application rate. Still, in our view, it can be used alone, especially during the screening of different compounds and comparative evaluation of their effectiveness. The influence of varietal features on pest resistance of grain crops, which is around 10% [7], can be ignored, as well as the influence of weather conditions (except extreme), which was shown in trials with Grom variety in two cultivation zones drilled after the same preceding crop and with similar pest invasion in autumn.
Thiamethoxam biological effectiveness (including per 1 g of a.i.) in different trials (42 variants) under different cultivation technologies is shown in Table 3. Concentration of insecticide a.i. (according to the application guidelines) was equal to 131.25; 138.8; 175.0; 183.75; 184.6; 230.8; 236.25; 262.5; 306.3; 350.0 (Table 1, 3).
Biological effectiveness of insecticide fungicides Dividend Supreme and Selest Top, as well as for Vibrance Integral, has linear character with high coefficient of approximation. Based on the results obtained for Selest Top in II climate zone of cultivation (for 2 years of studies), R^2 = 0.82, in III zone - R^2 = 0.80; for Dividend Supreme in II zone - R^2 = 0.98, in III zone - R^2 = 0.87. Coefficients of approximation for Thiamethoxam biological effectiveness per 1 g (BE/g a.i.) of Selest Top were equal to R^2 = 0.88 and R^2 = 0.81 in zones II and III, respectively; of Dividend Supreme - R^2 = 0.99 regardless of the trial area. As a rule, approximation coefficient of linear BE per 1 g of a.i. dependence was higher (in some cases significantly) than during evaluation of biological effectiveness by Thiamethoxam content considering its concentration in the chemical and application rate per 1 ton of seeds.

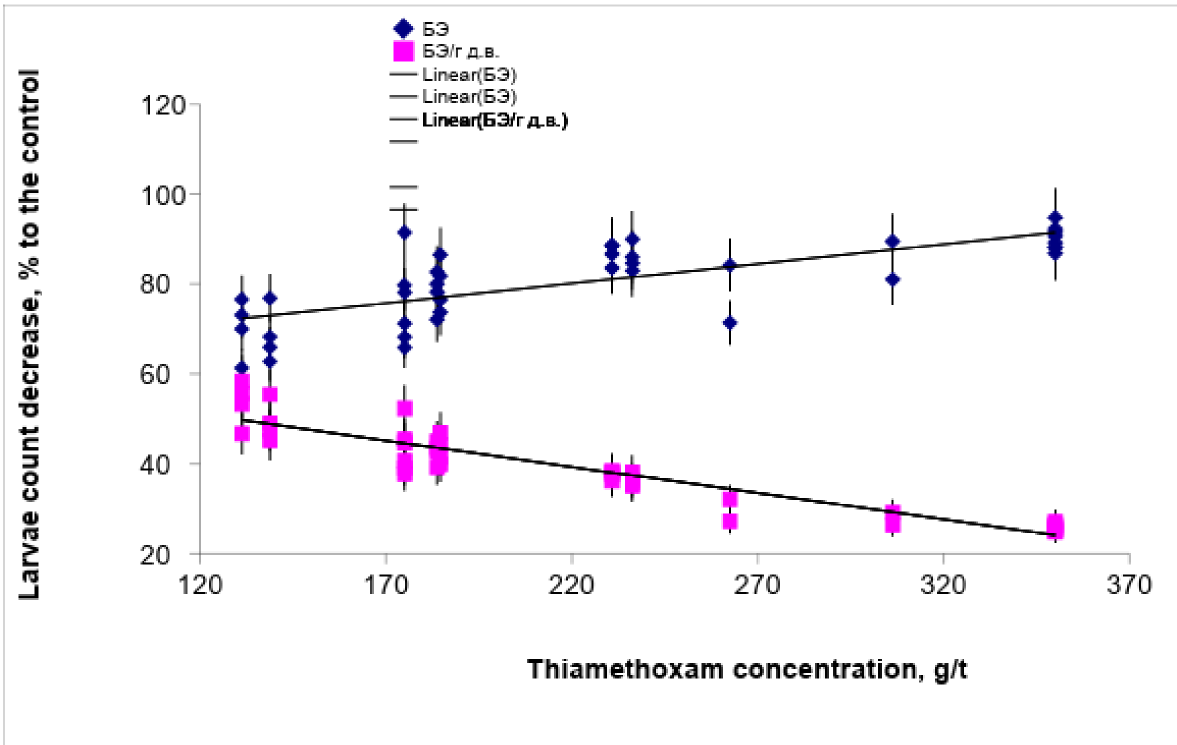
Table 3. Biological effectiveness of Thiamethoxam against ground beetle on winter wheat varieties

№	Region	Year	Variety	Seed dressing	C, g/t	BE	BE/g of a.i.
1.	III	2011/2012	Rostovchanka 3		131.25	61.3	46.7
2.	III	2010/2011			131.25	70.0	53.3
3.	II	2011/2012	Krasnodarskaya-99	Selest	131.25	73.1	55.7
4.	II	2010/2011		Top	131.25	76.6	58.4
5.	III	2012/2013	Irishka		138.80	65.9	47.5
6.	II	2012/2013	Grom		138.80	68.2	49.1
7.	III	2011/2012	Irishka	Dividend	138.80	62.8	45.2
8.	II	2011/2012	Grom	Supreme	138.80	76.9	55.4
9.	II	2012/2013	Grom	Cruiser	175.00	65.9	37.7

10.	II	2011/2012			175.00	71.2	40.7
11.	II	2010/2011			175.00	79.7	45.5
12.	III	2012/2013	Irishka		175.00	78.1	44.6
13.	III	2011/2012			175.00	91.5	52.3
14.	III	2011/2012			175.00	68.2	39.0
15.	III	2011/2012	Rostovchanka 3		183.75	72.1	39.2
				Selest			
16.	III	2010/2011		Top	183.75	80.0	43.5
17.	II	2010/2011	Krasnodarskaya-99		183.75	78.2	42.6
18.	II	2011/2012			183.75	82.7	45.0
			Irishka	Dividend			
19.	III	2012/2013	Irishka	Supreme	184.60	76.5	41.4
20.	III	2011/2012			184.60	73.7	39.9
21.	II	2012/2013	Grom		184.60	81.8	44.3
			Grom				
22.	II	2011/2012			184.60	86.5	46.9
23.	III	2012/2013	Irishka		230.80	83.6	36.2
24.	III	2011/2012			230.80	86.6	37.5
25.	II	2012/2013	Grom		230.80	88.6	38.4
26.	II	2011/2012			230.80	88.5	38.3
27.	III	2011/2012	Rostovchanka 3		236.25	83.0	35.1
28.	III	2010/2011			236.25	90.0	38.1
29.	II	2011/2012	Krasnodarskaya-99	Selest	236.25	84.6	35.8
30.	II	2010/2011		Top	236.25	86.0	36.4
31.	II	2014/2015	Grom		262.50	71.4	27.2
32.	III	2014/2015			262.50	84.2	32.1
33.	II	2014/2015			306.30	81.0	26.4
34.	III	2014/2015			306.30	89.5	29.2
35.	III	2014/2015		Vibrance	350.00	94.8	27.1
36.	II	2014/2015		Integral	350.00	88.1	25.2
37.	III	2010/2011	Rostovchanka 3		350.00	89.2	25.5
38.	III	2011/2012			350.00	91.5	26.1
39.	II	2010/2011	Krasnodarskaya-99	Cruiser	350.00	90.6	25.9
40.	II	2011/2012			350.00	92.3	26.4
41.	III	2014/2015	Grom	Tiara	350.00	86.8	24.8
42.	II	2014/2015		Tiara	350.00	88.1	25.2

Note: C – concentration of a.i. – Thiamethoxam, g/t; BE – biological effectiveness, %; BE/g of a.i. – biological effectiveness per 1 g of a.i., %; zone II – Krasnodar Region, zone III – Rostov Region.

Results of 42 trials of Thiamethoxam effectiveness against ground beetle during autumn tillering of winter wheat indicate on a wide range of biological activity level depending on the content of a.i. in the working solution for seed dressing: significance of BE varied from 61.3% at 131.25 g/t to 94.8% at 350 g/t of Thiamethoxam (Table 3). BE develops linearly (including when calculated per 1 g of a.i.) (Figure 2): y = 0.087x + 60.842 is the equation of linear regression for BE, coefficient of approximation is R^2 = 0.55; for BE/g a.i.: y = - 0.1169x + 65.016, R^2 = 0.86, i.e. biological effectiveness against pests per 1 g of Thiamethoxam has more significant linear character.



БЭ – BE

БЭ/г д.в. – BE/g of a.i.

Figure 2. Influence of Thiamethoxam application rate (as a part of insecticide and fungicide seed dressing Vibrance Integral formulation for winter wheat seed treatment) on biological effectiveness (BE) and on biological effectiveness per 1 g of active ingredient (BE/g). Summarized data obtained in Krasnodar and Rostov Regions in 2010-2015. Winter wheat varieties – Grom, Rostovchanka, Krasnodarskaya-99, Irishka.

It should be noted that BE close to 80% (average value for each variant) was observed at Thiamethoxam concentration 184.6 g/t (Table 4). If we take into account ETPH (3-4 larvae of 1 stage of development / 1m^2 during germination and 3-6 larvae of II-III stages of development / 1 m^2 during tillering), larvae invasion of up to 10 / 1 m^2 can be reduced to acceptable threshold even in Thiamethoxam concentration of 131.25 g/t (BE=70.3%). At the same time, higher ground beetle invasion rate requires BE not less than 80% for reduction of pest count (to the threshold level) from 20 larvae / 1 m^2 and 90% - from 30 larvae / 1 m^2 (pest count 10-fold higher than ETPH was registered in Rostov Region in 2010-2011 during the trials on evaluation of insecticide fungicide Selest Top). As it can be seen in Table 4, such effectiveness is observed in Thiamethoxam concentration for winter wheat seed dressing not lower than 184.6 g/t (80%) and 350 g/t (90%), respectively. At the same time, to prevent possible spontaneous pest count boost (regardless of baseline), it is necessary to monitor constantly the growth of ground beetle population considering weather forecast and other provoking factors [20].

Increase of BE per 1 g of a.i. is of interest to the researchers due to wide range of BE and need in optimization of application rate, that provide the required BE. This data indicates on the insecticide activity stability. Thus, when switching Thiamethoxam concentration from 131.25 g/t to 138.8 – 175.0 and 183.75 g/t, effectiveness increase varied from 20 to 28%; from 306.3 g/t to 350.0 g/t – it was significantly lower – 11%. Concentration change from 183.75 to 184.6 g/t and from 230.8 to 236.25 g/t led to sudden change of Δ BE/g of a.i., while BE parameter barely changed. Stable high biological effectiveness against ground beetle was achieved at Thiamethoxam content ≈ 190 g/t. Probably, Thiamethoxam content 350.0 g/t was excessive and it as enough to apply 306.3 g of a.i. per 1 ton of seeds, because Δ BE was 10% (pest count fluctuation was up to 30% depending on the trial replication).

Table 4. Average biological effectiveness of Thiamethoxam against ground beetle on winter wheat varieties

Parameter	C, g/t	BE, %	BE/g a.i., %	Δ C, g/t	Δ BE/g a.i., %
M	131.25	70.3	53.5		
SD		6.5	5.0		
K		9.3	9.3		
M	138.8	68.5	49.3	7.6	23.8
SD		6.1	4.4		
K		8.8	8.8		
M	175	75.8	43.3	36.2	20.2
SD		9.4	5.4		
K		12.4	12.4		
M	183.75	78.3	42.6	8.8	28.4
SD		4.5	2.4		
K		5.7	5.7		
M	184.6	79.6	43.1	0.8	161.8
SD		5.7	3.1		
K		7.1			
M	230.8	86.8	37.6	46.2	15.6
SD		2.3	1.0		
K		2.7			
M	236.25	85.9	36.4	5.4	-17.0
SD		3.0	1.3		
K		9.3			
M	262.5	77.8	29.6	26.3	-30.9
STD	262.5	9.1	3.4		
K		9.3			
M	306.3	85.3	27.8	43.8	17.0
SD	306.3	6.0	2.0		
K		9.3			
M	350	90.2	25.8	43.7	11.3
SD		2.6	0.8		
K		9.3			

M – arithmetical mean, SD - standard deviation, K - variation coefficient, ΔC – concentration change, ΔBE/g a.i. – increase (decrease) of biological effectiveness per 1 ΔC

Biological effectiveness of Thiamethoxam against ground beetle was stable: in spring period it was different from autumn period on average by ± 4 - 6%. Plant damage in autumn either corresponded to biological activity level or differed by ± 2 - 5%; in spring it differed by 10%. At the same time, biological effectiveness was lower than plants pest damage reduction. It should be noted that considerable differences in parameters values were observed in different variants of trials with minimum norms of Thiamethoxam application rate.

CONCLUSION.

Crop protection against pests should provide acceptable level of biological effectiveness against the target pest and minimization of unfavorable influence on environment. Ecologically oriented approach is based not on extermination of pests, but on limitation of pest population growth to the economically acceptable threshold [21]. This approach development involves constant renewal of chemicals on the market [9] for prevention of resistance, improvement of technological properties of drugs, optimization of application norms, spectrum broadening, study of quantitative correlations between biological effectiveness and active ingredient content in the chemical, creation and analysis of databases on effectiveness of the most widespread active ingredients.

It is important to reduce impact on agroecosystem and provide ecologically oriented crop protection measures against pests [22], which involve careful choice of active ingredients based on their chemical characteristics and insecticide activity. Neonicotinoids meet such criteria alone and as a part of compositions with combined activity. Due to systemic activity, stability, effect duration, technological properties and low persistence of neonicotinoids [23], neonicotinoid based insecticides become more widespread in crop and animal production [24,25].

Thiamethoxam application against different pests showed not only its high effectiveness but also its bioactivating activity that influenced on the rate of primary and secondary metabolism [17].

Besides, due to synergism in complex drugs, the concentration of Thiamethoxam can be decreased preserving its biological effect.

The obtained data proves high effectiveness of Thiamethoxam in the composition of complex chemicals for winter wheat seed dressing against ground beetle in the conditions of two climate zones of the RF.

The trials results showed high stable effectiveness against the studied pest that was achieved at Thiamethoxam concentration in the working solution of seed dresser ≈ 190 …. 306 g/t. Soil and weather conditions, varietal peculiarities of winter wheat and chemicals properties that included Thiamethoxam do not influence significantly on the insecticide activity against the target pest. This activity is characterized by linear dependence on the application rate per 1 ton of seeds. Thiamethoxam seed dressed crop damage by the studied pest correlates with the dynamics of biological effectiveness development.

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