

EFFECT OF FERTILIZATION OF WINTER SPELT WHEAT WITH MICRONUTRIENTS AND AMINO ACID PREPARATIONS ON PHYTOPHAGOUS INSECTS

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ABSTRACT

Background. In Poland there is a growing interest in winter spelt wheat cultivation. There are not many detailed studies on phytophagous entomofauna. Cereal leaf beetles and grain aphids are major pests of cereal crops.

Material and methods. The numbers of the aphid *Sitobion avenae* and larvae of *Oulema* spp. were analyzed on the winter spelt wheat cv. 'Rokosz' treated with micronutrient fertilizers and amino acid preparations. The percentage of wheat leaf blade damage caused by foraging of *Oulema* spp. larvae was also calculated, as well as correlation coefficients between the number of insects and the magnitude of damage and the yield of wheat grain.

Results. The use of microelement fertilization resulted in a smaller number of *Oulema* spp. larvae. Wheat on which Zn or a combination of all microelements (Cu + Zn + Mn) were applied was characterized by the lowest abundance of grain aphid as compared with the control and other combinations of micronutrient fertilization application. *Oulema* spp. larvae caused damage to the surface of wheat blades at the level of 10%.

Conclusion. Fertilization of winter spelt wheat with micronutrients results in a smaller number of both phytophages feeding on it and damage caused by them.

Key words: grain aphid, cereal leaf beetles, spelt wheat, fertilization of plants, heavy metals

INTRODUCTION

In Poland there is a growing interest in winter spelt wheat cultivation (Knapowski *et al.*, 2016). So far, no detailed research has been carried out in our country on harmful entomofauna inhabiting this wheat species (Kaniuczak and Bereś, 2011).

Besides cereal leaf beetles, aphids belong to the most important cereal pests (Mrówczyński *et al.*, 2005; Walczak, 2010). In addition to causing direct losses (suction of juices from plants), aphids can also

be viral vectors. This feature is particularly dangerous for winter crops, as cereals infected in autumn, at the early development stages, may have stunted growth in spring and, as a result, give less yield (Gałęzewski, 2007).

In order to minimize the use of the chemical method, the widest possible use of non-chemical methods has been recommended for many years - in other words, various environmentally friendly ways to reduce the number of pests are sought (Nawrot *et al.*, 2010; Lamparski, 2016).

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Micronutrients have an impact not only on insects but also on crops. Their use leads to a better growth and development of a crop, and thus to enhance its resistance to biotic stress factors (Mogren and Trumble, 2010; Grzeškowiak, 2016).

Heavy metals have a clear effect on physiology, growth and development of insects (Fountain and Hopkins, 2001; Ilijin *et al.*, 2009; Mogren and Trumble, 2010). Some herbivorous insects efficiently utilize various parts of metal-hyperaccumulator plants, as they can accumulate and store large amounts of metals in their bodies (Boyd, 2007; Migula *et al.*, 2011). Herbivore polyphagous species can overcome the toxic effects of metals merely by avoiding certain foods (Behmer *et al.*, 2005).

Zinc and copper bind to the cytosol metallothionein in the midgut of many organisms and are essential elements, but at high concentrations they can be toxic. Copper and zinc are metals of great importance as enzymatic agents in biological processes and metabolism (Jensen and Trumble, 2003; Kosiorek, 2016).

Copper accumulates at the highest concentrations in flowers compared with the other metals. Copper and cadmium have the highest translocation indices, as well as higher bioconcentration factors, as compared with lead which was mostly immobile in the plant. Copper poses the highest risk due to its high mobility within the plant. In particular, the accumulation of metals in leaves and flowers suggests that herbivores and pollinators visiting and foraging on these tissues may be exposed to potentially toxic compounds (Hladun *et al.*, 2015).

Zinc is an essential metal associated with about 300 enzymes which are responsible for multiple actions in the organism, including regulation of cellular processes, antioxidant response and protection against apoptosis. In excess, however, it may severely disturb the cellular environment, increasing oxidative stress (Koh, 2001; Kosiorek, 2016).

Manganese is an essential element for plants, intervening in several metabolic processes, mainly in photosynthesis and as an antioxidant enzyme cofactor. Nevertheless, an excess of this micronutrient is toxic for plants. Mn phytotoxicity is manifested in a reduction of biomass and photosynthesis, and biochemical disorders such as oxidative stress. Some studies on Mn toxicity and Mn translocation from

soil to plant cells in Mn^{2+} form have demonstrated its importance under low pH and redox potential conditions in the soil (Millaleo *et al.*, 2010).

The aim of this study was to estimate the effect of winter spelt wheat fertilization with micronutrients and amino acid preparations on phytophagous insects.

MATERIAL AND METHODS

The experiment was carried out at the University of Technology and Life Sciences Agricultural Experimental Station in Minikowo (Nakło nad Notecią commune, Nakło district, Kuyavian-Pomeranian Voivodeship) ($53^{\circ} 10' N$; $17^{\circ} 44' E$) in 2016–2017.

The values of mean monthly air temperatures and monthly rainfall totals in the years of conducting field experiments were usually similar to those from many years (Table 1, Fig. 1). Higher rainfall, compared with the many-year period, was found in both years of the field study. The year 2017 was exceptionally abundant in rainfall. Annual rainfall was by 131 mm higher than in the many-year period. The mean air temperature during the years of entomological research was higher than in the case of a many-year period. The warmest year was 2016. On average, a temperature higher by 1 degree was obtained compared with the many-year period. May and June of both analyzed years were warmer compared with the many-year period.

The research treatment was winter spelt wheat cv. 'Rokosz', which was grown in soil classified as the very good rye complex, quality class III a. This soil was characterized by a neutral reaction, and the contents of available forms of P, K and Mg indicate very high or high abundance of these elements. However, the amount of Cu allows classification of the soil to the average fertility class, and based on the contents of Mn and Zn, it was found that it was below the limit values (Table 2).

Wheat was sown in autumn, between the 20th and 30th September 2016 and 2017. In autumn, 103 kg $K \cdot ha^{-1}$ and 30 kg $P \cdot ha^{-1}$ was sown preplant in the form of: potassium salt (57%) and triple superphosphate (46%), respectively. Nitrogen was sown in the spring in the form of ammonium nitrate (34%). All sprays, after dissolving the appropriate doses of micronutrients and amino acid preparations in the volume of water corresponding to 200 $dm^3 \cdot ha^{-1}$, were made one day.

Table 1. Total monthly rainfall and mean monthly air temperature for the many-year period 1949–2017 according to the data reported by the RZD in Minikowo

Weather factor	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Total rainfall, mm	30	24	28	29	48	55	79	59	42	36	36	36
Mean air temperature, °C	-2.1	-1.2	2.2	7.5	12.8	16.2	17.9	17.4	13.4	8.1	3.4	-0.1

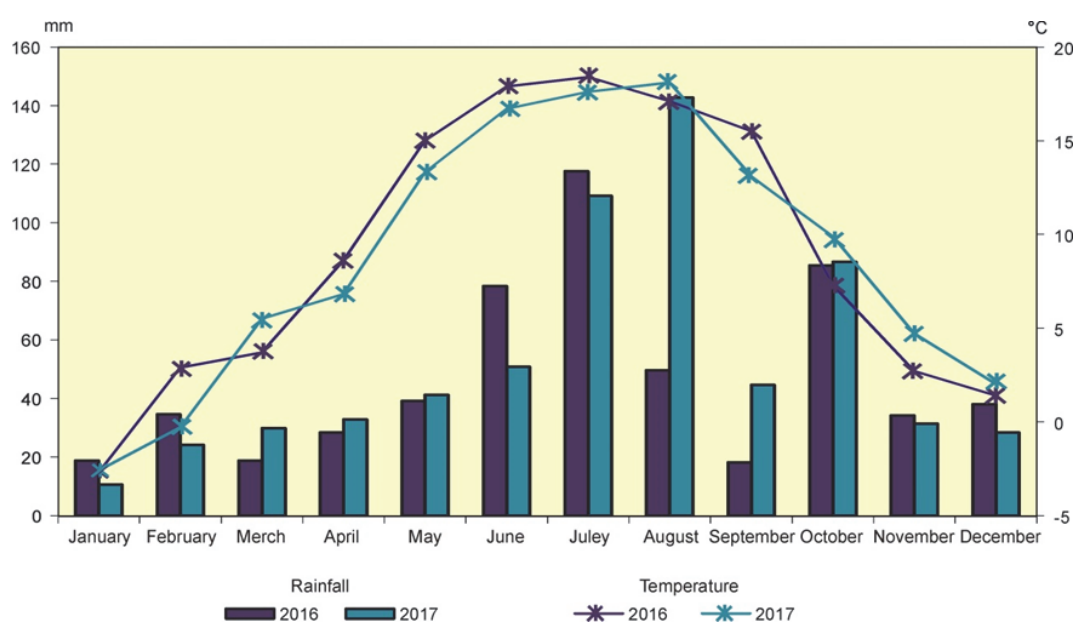


Fig. 1. Total monthly rainfall and mean monthly air temperature in the field experimental years, according to the data reported by the RZD in Minikowo

Table 2. Soil physicochemical properties

Parametr		Range	Mean	
total N	organic C	g·kg ⁻¹	0.75–0.91	0.84
			6.96–8.69	8.25
Available	P		69.9–83.8	78.3
	K		179–219	206.0
	Mg	mg·kg ⁻¹	51.7–94.7	76.0
	Zn		6.94–13.8	8.76
	Cu		5.50–7.10	6.40
	Mn		205–417	380.0
pH in KCl			6.3–7.0	6.8
Hydrolytic acidity		mmol(+)·kg ⁻¹	11.9–17.5	14.9

The previous crop for the cereal was the winter form of oilseed rape. All autumn and spring cultivation practices, sowing grain, treatments during cereal growth and its harvest (92-99 BBCH) were made according to the cultivation requirements optimal for the tested plants. Depending on the condition of the cultivated plantation and the needs during the growth of cereals, crop protection preparations were used for wind bent-grass, dicotyledonous weeds and for basic fungal diseases. These were herbicides: Isoguard 500 SC – $2 \text{ dm}^3 \cdot \text{ha}^{-1}$, Aminopielik Tercet 500 SC – $1.8 \text{ dm}^3 \cdot \text{ha}^{-1}$, Aurora 40 WG in a dose of $20 \text{ g} \cdot \text{ha}^{-1}$ and fungicides: Sylwet Gold – $0.1 \text{ dm}^3 \cdot \text{ha}^{-1}$ and Yamato 303 SE – $1.5 \text{ dm}^3 \cdot \text{ha}^{-1}$.

Two factors were analyzed, each of them at several levels:

- the primary factor was fertilization with microelements:
 - control – no fertilization with microelements,
 - Cu $0.1 \text{ kg} \cdot \text{ha}^{-1}$ ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$),
 - Zn $0.2 \text{ kg} \cdot \text{ha}^{-1}$ ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$),
 - Mn $0.3 \text{ kg} \cdot \text{ha}^{-1}$ ($\text{MnSO}_4 \cdot \text{H}_2\text{O}$),
 - Cu + Zn + Mn;
- the secondary factor was fertilization with amino acid preparations:
 - control,
 - Amino zboże,
 - Amino rzepak,
 - Protifert LMW.

In the spring during the shooting stage (BBCH 39) micronutrients were used (in the form of technical salts) along with amino acid preparations (Amino zboże and Amino rzepak are foliar fertilizers, whereas Protifert LMW is a biostimulating fertilizer rich in biologically active amino acids and peptides).

On each of the combinations of experimental plots (2 by 6 m in size) the number of insects or the level of plant damage was organoleptically compared. The number of *Oulema* spp. larvae at the beginning of flowering of winter spelt wheat (BBCH 61-62) on 25 stems was analyzed, as well as the number of *S. avenae* at the beginning of flowering stage (BBCH 61-62) on 25 ears and the percentage of wheat leaf blade damage at the beginning of milk stage (BBCH 73-75) caused by feeding of the larvae of *Oulema* spp. on 25 plants and expressed in%.

Insects were determined according to the insect identification keys (Müller, 1976, Warchałowski,

2003). The results were presented as insect inhabitation, i.e. the sum of pests determined with the organoleptic method – in individuals per 25 plants or ears and as a percentage of damage caused by feeding of the cereal leaf beetles larvae (EPPO, 2005).

Statistical data processing

The obtained results were subjected to statistical analysis. The experiment was carried out in a randomized split-plot design. The obtained results (from 4 replications) were subjected to analysis of variance (ANOVA) using the STATISTICA PL 2013 software (StatSoft Polska). Comparisons of the treatment means were made based on Tukey's multiple range test at the significance level $P < 0.05$. Linear correlation coefficients between the number of insects and the size of damage and the grain yield of winter spelt wheat were also calculated.

RESULTS AND DISCUSSION

There is not much research on the subject of insect pests attacking winter spelt wheat, and Kaniuczak and Bereś (2011) consider their study results regarding the comprehensive recognition of species composition of the pests feeding on this plant the first in the country.

In the present study, the larvae of *Oulema* spp. occurred in the intensity of 7 individuals per 25 analyzed stems (Table 3). It was noted that the use of fertilization with microelements resulted in a smaller number of this pest compared with the control. Application on plots of two out of three tested amino acid preparations (Amino rzepak and Protifert LMW) resulted in a significant increase in the number of the pest larvae compared with the control. Plots on which only Zn and Mn were used (without the addition of an amino acid preparation) proved to be the least inhabited by the analyzed phytophage (3.13 individuals per 25 stems).

Kaniuczak and Bereś (2011) report that in 2008 the maximum intensity of occurrence of *Oulema* spp. larvae on winter spelt wheat was around 5th June (6 ind. per 100 plants), and in 2009 between the 21st-30th May/1st-10th June (9-10 ind. per 100 plants).

Table 3. Effect of fertilization with microelements (I) and amino acid preparations (II) on the number of *Oulema* spp. larvae on spelt wheat at the beginning of flowering stage [ind./25 stems]

I	II				Mean
	Control	Amino zboże	Amino rzepak	Protifert LMW	
Control	5.63	6.25	12.50	8.13	8.13
Cu 0.1 kg·ha ⁻¹ (CuSO ₄ ·5H ₂ O)	7.50	4.38	7.50	11.88	7.83
Zn 0.2 kg·ha ⁻¹ (ZnSO ₄ ·7H ₂ O)	3.13	5.00	8.75	10.63	6.88
Mn 0.3 kg·ha ⁻¹ (MnSO ₄ ·H ₂ O)	3.13	5.63	6.25	11.88	6.72
Cu + Zn + Mn	6.88	6.88	4.38	6.88	6.26
Mean	5.25	5.63	7.88	9.88	7.16
HSD _{0.05} for:	I 1.85	II 1.48	II/I 3.30	I/II 3.45	

In other studies, the authors state that larval densities ranged from 22 to 26 ind. per 100 stalks for winter wheat and from these data their estimate yield losses of 0.5 to 4% for winter wheat. *Oulema melanopus* was in all the three study years more abundant than *Oulema gallaeciana* (Urlich *et al.*, 2004).

In the present study, the obtained results for grain aphid on wheat were no longer as unambiguous as in the case of larvae of *Oulema* spp. It was observed that the plots with wheat on which Zn and the combination of all micronutrients (Cu + Zn + Mn) were applied were characterized by the smallest number of this pest compared with the control and the other combinations of microelement fertilization application. Similarly to the *Oulema* spp. larvae, Protifert LMW applied on wheat plants, to the least degree limited the occurrence and feeding of grain aphid. It was found, on average, nearly 29 aphids on the 25 ears of winter spelt wheat analyzed (Table 4).

According to Ruszkowska (2002), the mass occurrence of aphids depends to a great extent on the course of meteorological conditions. The development of numerous colonies of these bugs is favored by warm and moderately moist years. Then, in just over a dozen days, their number may increase up to several dozen times. Both adults and aphid larvae are harmful. Kaniuczak (2014), in turn, claims that the harmfulness of this group of insects is associated with sucking of juices from leaf blades, stems and ears. At high numbers, and especially during periods of moisture deficiency, their feeding leads to

significant weakening of plants. Indirect harmfulness is also dangerous. It involves transmission of viruses through aphids, including the barley yellow dwarf virus (BYDV), which is dangerous for cereals. Kaniuczak and Bereś (2011) report that in 2008–2009 intensification of cereal aphids (without distinction of species) was very variable as to their number and date of appearance on winter spelt wheat. Walczak *et al.* (2014) claim that the % of winter wheat stems affected by *Sitobion avenae* F. in 2013 was within a range of 3.1-4.0% in the Kuyavian-Pomeranian Voivodship. In another study, *S. avenae* occurred in the number of 1.5 individuals per stem on winter triticale at GS 65 stage; 2 individuals per stem at GS 70 and 2.7 individuals per stem at GS 74 stage (Sempruch *et al.*, 2004).

At the milk stage, winter spelt wheat was inhabited by a very small number of pests. The only damage caused by feeding the cereal leaf beetle larvae was a visible symptom of the effects of the presence of phytophagous entomofauna on wheat plants during this period (Table 5). In the present study, damage by *Oulema* spp. larvae on winter wheat leaves was found within the range from 5 to 20%. On average, 10% level of damage to the leaves of the host plant was obtained. Of the analyzed levels of fertilization with micronutrients, the lowest level of damage by the larvae of this pest was obtained for Cu and the combination of all micronutrients (Cu + Zn + Mn). In contrast, the application of Amino rzepak and Protifert LMW resulted in the highest values of these damage to wheat leaves.

Table 4. Effect of fertilization with microelements (I) and amino acid preparations (II) on the number of *S. avenae* on spelt wheat at the beginning of flowering stage [ind./25 ears]

I	II				
	Control	Amino zboże	Amino rzepak	Protifert LMW	Mean
Control	26.25	30.00	30.63	38.13	31.25
Cu 0.1 kg·ha ⁻¹ (CuSO ₄ ·5H ₂ O)	28.13	33.13	36.25	30.00	31.88
Zn 0.2 kg·ha ⁻¹ (ZnSO ₄ ·7H ₂ O)	13.75	29.38	17.50	43.75	26.10
Mn 0.3 kg·ha ⁻¹ (MnSO ₄ ·H ₂ O)	38.13	21.88	28.13	29.38	29.38
Cu + Zn + Mn	17.50	27.50	18.75	36.88	25.16
Mean	24.75	28.38	26.25	35.63	28.75
HSD _{0,05} for:	I 2.53	II 2.48	II/I 5.55	I/II 5.58	

Table 5. Effect of fertilization with microelements (I) and amino acid preparations (II) on leave damage by *Oulema* spp. larvae on spelt wheat at milk stage [%]

I	II				
	Control	Amino zboże	Amino rzepak	Protifert LMW	Mean
Control	13.00	16.50	20.00	12.25	15.44
Cu 0.1 kg·ha ⁻¹ (CuSO ₄ ·5H ₂ O)	8.25	5.50	7.25	7.75	7.19
Zn 0.2 kg·ha ⁻¹ (ZnSO ₄ ·7H ₂ O)	7.50	4.75	13.75	12.25	9.56
Mn 0.3 kg·ha ⁻¹ (MnSO ₄ ·H ₂ O)	5.00	5.75	18.50	15.50	11.19
Cu + Zn + Mn	4.50	8.00	7.00	7.00	6.63
Mean	7.65	8.10	13.30	10.95	10.00
HSD _{0,05} for:	I 1.02	II 1.15	II/I 2.56	I/II 2.56	

In comparison with these results, Kaniuczak and Bereś (2011) state that the area of the damaged flag leaf blade by *Oulema* spp. larvae on winter spelt wheat was between 17% and 31% in 2008–2009. Walczak *et al.* (2014), in turn, report that % of damaged winter wheat stems in 2013 was 6.6–8.0% in the Kuyavian-Pomeranian Voivodeship. In 2013, the occurrence of cereal leaf beetles on winter wheat was observed throughout the country. Beetles and larvae damaged on average 7.1% of stems (in 2012 – 7.8%), which was below the national mean for the last 22 year (9.0%). Since 2006, the country-wide mean level of harmfulness has ranged from 7.0–7.8% of damaged winter wheat stems. Despite the decline in the national level of harmfulness, in some

voivodeships a higher mean number of damaged winter wheat stems has been found compared with that recorded in 2012.

In the present study, the obtained wheat yield was correlated with the occurrence of the studied pests (Fig. 2). It was found that the obtained correlation coefficients between the number of cereal leaf beetles larvae at the beginning of flowering stage and the level of damage of these phytophages analyzed at the milk stage of winter spelt wheat and the grain yield were negative and non-significant (-0.0644 and -0.3449, respectively), while in the case of correlation between the number of grain aphid at the flowering stage of the plant and the grain yield the coefficient obtained was non-significant but positive (0.2374).

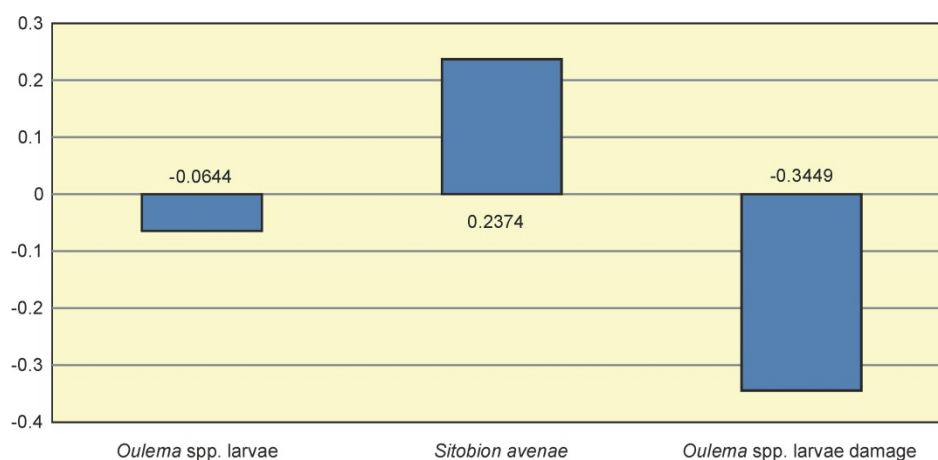


Fig. 2. Correlation coefficients between the number of cereal leaf beetle larvae, the number of grain aphid and level of damage caused by foraging of *Oulema* spp. larvae and the grain yield of spelt wheat

Also, Urlich *et al.* (2004) found that the significant negative correlation between beetle abundances and the hydrothermal index indicates that higher precipitation and/or lower temperature had a negative effect on the activity of *O. melanopus* and *O. gallaeciana*. In a study by Lamparski (2016) the presence of larvae of cereal leaf beetles at the shooting stage of spring barley did not affect the crop yield. The numbers of grain aphid was significantly correlated with the grain yield at shooting stage and earing of spring barley, but only on the plots where the soil was mixed with the chopped straw of the previous crop.

Analysis of the results obtained from the present author's study shows that the application fertilization with microelements (salts of copper, zinc, manganese and their mixture) at the shooting stage of winter spelt wheat resulted in a smaller number of larvae of cereal leaf beetles and grain aphid at the flowering stage compared with the control. A similar situation was noted in the case of the examined level of damage caused by *Oulema* spp. larvae.

Moawad *et al.* (2015) treated tomatoes with different combinations of Zn, also including $ZnSO_4 \cdot 7H_2O$. They report that the mean mortality for white fly, *Bemisia argentifolii*, for $ZnSO_4 \cdot 7H_2O$ was 52% and for the control = 0, the mean mortality for *Liriomyza trifolii*, also for this Zn combination, = 62% and for the control = 0, and the mean mortality for tomato

leaf miner, *Tuta absoluta*, = 62% and for the control = 0. Kazemi-Dinan *et al.*, (2014) report that feeding by the butterfly *Pieris napi*, sawfly larvae of *Athalia rosae* and beetles of *Phaedon cochleariae* was significantly reduced by metal concentrations from above $1000 \mu g Zn \cdot g^{-1} DW$ and $18 \mu g Cd \cdot g^{-1} DW$. By contrast, metals did not affect oviposition. Generalist survival decreased with increasing concentrations of individual metals, whereby the combination of Zn and Cd had an additive toxic effect even at the lowest applied concentrations of $100 \mu g Zn \cdot g^{-1}$ and $2 \mu g Cd \cdot g^{-1}$. Sarwar (2011) reports that Zn had a significant influence on the rice stem borers population (*Scirpophaga* species) (Lepidoptera: Pyralidae) and paddy yield over the unfertilized control. Average yield per hectare was increased at all rates of Zn and by applying it at the rates of 20, 25 and $30 kg \cdot ha^{-1}$, the differences in grain yield were not significant, but production increased significantly over the untreated crop due to varying pest prevalence. With respect of borers incidence, a higher dose of $30 kg Zn \cdot ha^{-1}$ markedly decreased infestation, while applications at 20 and 25 kg permitted slightly more deadhearts and whiteheads incidence, but differed significantly from the unfertilized control. The study implies that the grain yield increased due to suppressive effects of Zn fertilizer on the incidence of rice stem borers at crop maturity stage, and the use of soil amendments strategy can create an unfavorable environment for

pest inducing resistance through antibiosis or feeding inhibition.

Here are some examples of reviews that evaluate the effects of metal and metalloid pollution on insect behaviors in terrestrial systems. In terrestrial habitats (ingestion behavior), the application of $\text{CuCl}_2 \cdot 3\text{Cu}(\text{OH})_2$ had a positive behavioral outcome for *Folsomia manolachei* and *Folsomia quadrioculata*, no effect for *Isotomurus palustris* and a negative behavioral outcome for *Onychiurus armatus* (Filser *et al.*, 2000). The application of $\text{Zn}(\text{NO}_3)_2$ had a negative behavioral outcome for *Folsomia candida* (Fountain and Hopkin, 2001). The application of ZnSO_4 had a negative behavioral outcome for *Schistocerca gregaria* (Behmer *et al.*, 2005). In terrestrial habitats (taxis behavior), the application of CuSO_4 had a negative behavioral outcome for *Drosophila melanogaster* and after the application of ZnCl_2 no effect was found in *Drosophila melanogaster* (Bahadorani and Hilliker, 2009). In terrestrial habitats (oviposition) the application of CuSO_4 had a negative behavioral outcome for *Drosophila melanogaster* and ZnCl_2 had a negative behavioral outcome also for *D. melanogaster* (it indicates that there was an initial positive response to low concentrations vs. controls that then became negative as concentrations increased. In choice assays, aversion results in a negative behavioral outcome) (Bahadorani and Hilliker, 2009).

CONCLUSIONS

1. The application of microelement fertilization (salts of copper, zinc, manganese and their mixture) on winter spelt wheat results in a smaller number of feeding larvae of cereal leaf beetles.
2. Wheat treated with zinc salts and a mixture of microelements is less attractive food for the cereal aphid.
3. The fertilization of winter spelt wheat with copper salts and a combination of microelements (Cu + Zn + Mn) results in the lowest level of damage by *Oulema* spp. larvae.
4. Winter spelt wheat is inhabited and damaged by phytophagous entomofauna at a level not affecting a reduction in the grain yield.

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WPLYW NAWOŻENIA MIKROELEMENTAMI I PREPARATAMI AMINOKWASOWYMI PSZENICY OZIMEJ ORKISZ NA FITOFAGI OWADZIE

Streszczenie

Badano wpływ traktowania nawozami mikroelementowymi i preparatami aminokwasowymi pszenicy ozimej orkisz 'Rokosz' na ważniejsze fitofagi owadzie (skrzypionki zbożowe, mszycę zbożową). Eksperyment wykonano w RZD Minikowo w latach 2016–2017. Stosowano mikroskładniki (Cu, Zn oraz Mn) w formie soli technicznych oraz trzy preparaty handlowe (dolistne nawozy biostymulujące).

Nawożenie pszenicy mikroelementami spowodowało zmniejszenie liczebności larw *Oulema* spp. w porównaniu z obiektem kontrolnym. Działanie odwrotne wykazano w stosunku do preparatów aminokwasowych. Pszenica, na której aplikowano Zn lub kombinację mikroelementów (Cu + Zn + Mn), zasiedlana była przez istotnie mniejszą liczbę osobników mszycy zbożowej w porównaniu z obiektem kontrolnym oraz pozostałymi kombinacjami stosowania nawożenia mikroelementami. W fazie początek kwitnienia pszenicy ozimej orkisz (BBCH 61–62) na 25 źdźbłach występowało średnio 7 larw skrzypionek zbożowych oraz 29 mszyc zbożowych. W fazie dojrzałości młecznej (BBCH 73–75) pszenica ozima orkisz była atakowana przez bardzo nieliczne owady. W tym okresie liście pszenicy były uszkodzone przez larwy *Oulema* spp. od 5 do 20%. Otrzymane współczynniki korelacji pomiędzy liczebnością larw skrzypionek zbożowych, poziomem uszkodzeń powodowanych przez te fitofagi oraz liczbą mszyc zbożowych na pszenicy a plonem ziarna były nieistotne.

Słowa kluczowe: metale ciężkie, mszyca zbożowa, nawożenie roślin, pszenica ozima orkisz, skrzypionki zbożowe