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EFFECT OF FOLIAR FERTILIZERS AND THEIR MIXTURES ON PHYTOPATHOGENIC *FUSARIUM* FUNGI

WPŁYW NAWOZÓW DOLISTNYCH I ICH MIESZANIN NA GRZYBY FITOPATOGENNE Z RODZAJU *FUSARIUM*

Abstract: The paper focuses on the response of phytopathogenic *Fusarium* fungi to various concentrations of foliar fertilizers: Mikrovit Fe, Mikrovit Zn, urea, magnesium sulphate, and the mixtures of Mikrovit Fe + urea + magnesium sulphate, and Mikrovit Zn + urea + magnesium sulphate added to the medium. Under in vitro conditions, the analysis determined the influence of the foliar fertilizers on linear growth, biomass increment and sporulation of the following fungi: *Fusarium poea*, *Fusarium sulphureum* and *Fusarium culmorum*.

Mikrovit Zn revealed the strongest fungistatic properties among the tested foliar fertilizers. Applied to the medium in 1.0 mm^3/cm^3 concentration, it very strongly inhibited the linear growth (91.93–94.17 %) and sporulation of all tested fungi and most strongly limited biomass increments in *F. poea* and *F. sulphureum*, whereas mixtures of Mikrovit Zn and Mikrovit Fe with urea and magnesium sulphate revealed slightly weaker fungistatic effect. Urea applied in 1.0 mm^3/cm^3 concentration reduced increments of the test fungi biomass in the range from 56.73 to 64.03 %, while magnesium sulphate, as the only one among the fertilizers used for the experiment, stimulated surface growth, biomass increment and sporulation process in all tested fungi. It should be remembered that in the agrocenoses the effect of foliar fertilizers on fungi infecting plants is more complex and conditioned by many factors. Therefore, it is necessary to conduct further research on the influence of foliar application of fertilizers on plant healthiness.

Keywords: *Fusarium*, foliar fertilizers, linear growth, biomass, sporulation

Among phytopathogenic organisms fungi of *Fusarium* genus deserve special attention, since they are the most common in the environment where they infect many plant species causing various diseases which are difficult to control, such as fusarium wilts, take-all diseases or dry rot [1–2]. In the opinion of many authors [3–5] fusarioses are particularly dangerous in cereal crops since they not only contribute to yield losses, but infect grains with mycotoxins. Chemical plant protection is the most efficient method to combat these diseases, but it may negatively affect the quality of raw plant materials and pollute the environment. Several authors reported that increasingly

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common foliar fertilization not only positively affects the crop yield and its quality but may also efficiently prevent and protect plants against infectious diseases [6–12].

The investigations were conducted to test whether commonly applied foliar fertilizers Mikrovit Fe, Mikrovit Zn, magnesium sulphate, urea and their mixtures (Mikrovit Fe + magnesium sulphate + urea, and Mikrovit Zn + magnesium sulphate + urea) may limit the development of the following phytopathogenic fungi: *Fusarium poea* (Peck) Wollenw., *Fusarium culmorum* (W.G. Smith) Sacc. and *Fusarium sulphureum* Schlecht. under in vitro conditions.

Materials and methods

The fertilizers were tested on the phytopathogenic fungi selected from the collection owned by the Agricultural Environment Protection Department: *Fusarium poea*, *Fusarium culmorum* and *Fusarium sulphureum*, isolated from infected wheat kernels. Each of the studied fertilizers, ie Mikrovit Fe (Fe – 3 %, N – 4.50 %, pH – 3.2), Mikrovit Zn (N – 4.50 %, Zn – 3.5 %, pH – 2.0), magnesium sulphate (Mg – 15.65 %, S – 17.20 %, pH – 6.8) and urea (N – 46 %) and Mikrovit Fe + magnesium sulphate + urea, and Mikrovit Zn + magnesium sulphate + urea) were added to PDA medium with pH = 6.32 to obtain their medium concentrations of 0.1 mm^3/cm^3 (field dose) and 1.0 mm^3/cm^3. Subsequently, the tested fungus inoculum was supplied to Petri dishes containing the consolidated medium with added tested fertilizers. The experiment was conducted in five replications for each fertilizer combination and for each individual tested fungus. Petri dishes with the medium without fertilizers provided the control. The fungi were cultured in a thermostat at 23 ^{o}C. Daily increments of the fungi colonies served to compute the coefficient of the tested fungi linear growth rate in each fertilizer combination and on the control.

$$T = \frac{A}{D} + \frac{b_1}{d_1} + \ldots + \frac{b_x}{d_x}$$

where: T – linear growth rate coefficient,
A – mean of colony diameter measurements [mm],
D – number of days since the experiment outset,
b_1, ..., b_x – increment of colony diameter since the last measurement [mm],
d_1, ..., d_x – number of days since the last measurement.

After three weeks of fungi culturing on PDA media with added foliar fertilizers and on the control, the number of spores was assessed in the Thome hemocytometer. The fungi biomass growth was maintained in 300 cm^3 Erlenmayer flasks on 100 cm^3 of the modified PDA medium (without agar-agar) with the foliar fertilizers added in the same concentrations as in the experiment on Petri dishes. The effect of individual foliar fertilizers on the linear growth of the studied phytopathogenic fungi was presented as a difference between fungus colony diameter on the control Petri dishes and fungus colony diameter on the Petri dishes with individual fertilizer concentrations, and converted into the inhibition-stimulation coefficient acc. to Abbot [3]. Biomass increments were assessed in the same way. The results were elaborated statistically using ANOVA and the significance of differences was assessed by means of the t-Student test.

Results and discussion

For their development, fungal organisms need macroelements and microelements which they use for hyphae formation and production of numerous biologically active compounds and enzymes [14–15]. Conducted experiments allowed to determine that surface growth, biomass increment and sporulation of the tested fungus species were modified by the kind of foliar fertilizer and its concentration. Moreover within the same *Fusarium* genus, the tested fungi species differ with their sensitivity to the applied fertilizer preparations. The fact was confirmed by the Authors' and other previous investigations [16–21]. Among the tested foliar fertilizers, Mikrovit Zn applied in 1.0 mm^3/cm^3 concentration revealed the strongest fungistatic effect, almost completely (91.94–94.12 %) inhibiting the linear growth and blocking sporulation process in all tested fungal organisms (Tables 1, 3).

Table 1

Coefficients of rate (T) and inhibition of tested fungi linear growth

Foliar fertilizers	Concentration [mm^3/cm^3]	*F. poea*		*F. sulphureum*		*F. culmorum*	
		[T]	[%]	[T]	[%]	[T]	[%]
Urea	1.0	23.77	56.74	18.45	64.03	21.33	61.20
	0.1	55.45	6.35	44.80	20.79	52.28	16.80
Magnesium sulphate	1.0	73.06	+5.07*	81.01	+26.02	49.44	21.17
	0.1	60.40	1.98	49.77	16.07	89.50	+38.30
Mikrovit Fe	1.0	79.48	0.95	39.80	26.70	61.46	15.02
	0.1	80.60	+0.43	70.98	20.50	77.30	+11.02+
Mikrovit Zn	1.0	1.00	94.17	1.00	91.93	1.55	94.18
	0.1	61.29	35.94	62.90	+6.05	37.70	43.22
Mikrovit Fe + urea + magnesium sulphate	1.0	9.95	84.17	24.16	54.43	6.10	86.75
	0.1	59.58	31.18	63.09	+9.69	32.64	49.65
Mikrovit Zn + urea + magnesium sulphate	1.0	29.68	58.90	29.8	41.90	10.58	80.46
	0.1	80.10	0.20	52.1	8.62	34.03	48.34
Control		80.25		59.63		70.75	
$LSD_{0.05}$ for fertilizer kind		1.67		2.11		2.31	
$LSD_{0.05}$ for fertilizer concentration		1.13		1.14		1.24	

* + denotes linear growth stimulation.

On the other hand inhibition of *F. culmorum* and *F. sulphureum* biomass growth reached 67.88 % and 68.83 %, respectively (Table 2).

Table 2

Coefficient of biomass increment coefficient depending on foliar fertilizer [%]

Foliar fertilizers	*F. poea*		*F. sulphureum*		*F. culmorum*	
	Concentration [mm^3/cm^3]					
	1.0	0.1	1.0	0.1	1.0	0.1
Urea	44.60	5.35	53.25	41.48	22.92	10.91
Magnesium sulphate	17.85	+7.14	+17.46	4.36	+21.83	+11.64
Mikrovit Fe	73.21	73.21	46.58	58.22	52.40	55.31
Mikrovit Zn	91.07	55.35	68.33	39.30	67.88	50.22
Mikrovit Fe + urea + magnesium sulphate	69.64	75.00	60.00	56.77	66.96	64.05
Mikrovit Zn + urea + magnesium sulphate	73.21	70.53	56.77	53.31	71.32	65.50

\+ denotes biomass increment stimulation.

A strongly inhibiting effect on *Fusarium* fungi was also observed after the application of English foliar fertilizer Yeald to the medium, which similar as Mikrovit Zn contained zinc [21]. Combined application of Mikrovit Zn with urea and magnesium sulphate in the Authors' own experiments more weakly affected the studied phytopathogenic fungi species. In the conducted experiment magnesium sulphate was the only fertilizer whose supplement in the medium, particularly in the higher concentration (1.0 mm^3/cm^3), stimulated hyphae surface growth and biomass increment in all test fungi species. Moreover it favoured sporulation, primarily in *F. poea* and *F. culmorum* (Table 3).

Table 3

The impact of foliar fertilizers on test fungi sporulation (quantity in 1 $cm^3 \times 10^6$)

Foliar fertilizers	*F. poea*		*F. sulphureum*		*F. culmorum*	
	Concentration [mm^3/cm^3]					
	1.0	0.1	1.0	0.1	1.0	0.1
Urea	0.16	0.30	8.96	2.78	1.10	0.59
Magnesium sulphate	12.04	17.23	1.55	3.24	2.10	2.80
Mikrovit Fe	0.30	0.35	13.87	1.52	14.60	3.27
Mikrovit Zn	—	0.22	—	1.55	—	2.12
Mikrovit Fe + urea + magnesium sulphate	0.05	0.20	0.15	0.4	0.87	2.30
Mikrovit Zn + urea + magnesium sulphate	3.00	0.10	0.17	2.45	0.30	1.00
Control	9.90		2.17		1.72	

Therefore, it may be assumed that the availability in the medium of other elements, such as magnesium or sulphur alleviates the fungistatic effect of zinc. On the other hand, on media with added 1.0 mm^3/cm^3 (field dose) of urea, limited surface growth of the tested fungi in the range from 56.73 % to 64.03 % and their biomass increment (22.93–53.255) were observed (Tables 1, 2). Irrespective of which concentration of this fertilizer was applied, a considerable reduction of the produced spore number was observed in *F. poea* and *F. culmorum* (Table 3), as well as modified colour of aerial mycelium (naturally pink became white). Mikrovit Fe revealed weak fungistatic properties, particularly in a short experiment on Petri dishes. No matter which concentration was applied, this fertilizer limited the linear growth of *F. sulphureum* by 23.6 % and *F. culmorum* only by 2.0 %.

A variable effect of iron on *Fusarium* fungi was demonstrated also by other authors [16, 22], since iron may inhibit growth of fungal pathogens at limited element availability and stimulate at the element excess in the environment. On the other hand, Mikrovit Fe mixture with urea and magnesium sulphate had stronger effect, which may have resulted from accumulation of the fungistatic properties of its components (Tables 1–3). The number of *F. sulphureum* macroconidia on the medium containing 1.0 mm^3/cm^3 of this fertilizer mixture was thirteen times lower than in the control (Table 3), while the components of this mixture, ie urea and Mikrovit Fe applied separately in 1.0 mm^3/cm^3 concentration, strongly stimulated spore formation in *F. sulphureum*. The total number of spores produced by the phytopathogens evidences their infection potential, therefore, at reduced spore number the risk of plant infection diminishes [14].

Conclusions

Strong fungistatic properties, particularly of Mikrovit Zn and its mixtures with commonly used fertilizers, ie urea and magnesium sulphate and urea used separately, as presented in the paper, may find applications in the agricultural practice. It should be expected that application of these foliar fertilizers in cultivation of plants requiring zinc feeding, ie vegetables and fruit trees may result in less frequent occurrence of fungal diseases, especially when they are caused by fungi of *Fusarium* genus. Moreover, fungistatic properties of foliar fertilizers may undoubtedly contribute to reduce the amount of herbicides used for plant protection. Therefore, it is necessary to undertake research on the effect of foliar fertilizers on plant healthiness.

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WPŁYW NAWOZÓW DOLISTNYCH I ICH MIESZANIN NA GRZYBY FITOPATOGENNE Z RODZAJU *FUSARIUM*

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Abstrakt: Badano reakcję grzybów chorobotwórczych z rodzaju *Fusarium* na dodatek do podłoża hodowlanego różnych stężeń nawozów dolistnych: Mikrovit Fe, Mikrovit Zn, mocznik, siarczan magnezu oraz mieszanin: Mikrovitu Fe + mocznik + siarczan magnezu i Mikrovitu Zn + mocznik + siarczan magnezu. W warunkach *in vitro* oceniano wpływ nawozów dolistnych na wzrost liniowy, przyrost biomasy i zarodnikowanie grzybów: *Fusarium poea*, *Fusarium sulphureum* i *Fusarium culmorum*.

Spośród badanych nawozów dolistnych Mikrovit Zn odznaczał się najsilniejszymi właściwościami fungistatycznymi. Zaaplikowany do podłoża hodowlanego w stężeniu 1.0 mm^3/cm^3 bardzo silnie hamował rozrost powierzchniowy (91.93–94.17 %) i zarodnikowanie wszystkich testowanych grzybów oraz najsilniej ograniczał przyrost biomasy *F. poea* i *F. sulphureum*. Natomiast nieco słabszą efektywność fungistatyczną wykazywały mieszaniny: Mikrovitu Zn oraz Mikrovitu Fe z mocznikiem i siarczanem magnezu. Mocznik zastosowany w stężeniu 1.0 mm^3/cm^3 ograniczał przyrosty biomasy grzybów testowych w zakresie od 56.73 do 64.03 %. Z kolei siarczan magnezu, jako jedyny spośród zastosowanych w doświadczeniu nawozów, stymulował wzrost powierzchniowy, przyrost biomasy oraz proces sporulacji wszystkich grzybów testowych. Należy pamiętać, że w agrocenozach oddziaływanie nawozów dolistnych na grzyby porażające rośliny jest bardziej złożone i uwarunkowane wieloma czynnikami. Dlatego istnieje potrzeba przeprowadzania badań nad wpływem aplikacji nalistnej nawozów na zdrowotność roślin.

Słowa kluczowe: *Fusarium*, nawozy dolistne, wzrost liniowy, biomasa, zarodnikowanie