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Biochemical and Physicochemical Properties of Soil Contaminated with Herbicide Triflurotox 250 EC

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Abstract

A field experiment has been undertaken to assay the effect of Triflurotox 250 EC applied in the rates of 0, 1.5, 3.0, 4.5, 6.9, 9.0 and 12.0 $mm^3\ kg^{-1}$ soil on the growth and development of spring rape and white mustard and on the biochemical characteristics of the soil. The trials were conducted on leached brown soil formed from light clay silty sand of pH equal to 5.8 in 1 M KCl. The biochemical analyses were made 7 days after the experiment was established and in the flowering phase of the plants.

The results proved that Triflurotox 250 EC applied in the rates varying from 1.5 to 12 $mm^3\ kg^{-1}$ soil had an adverse effect on the activity of dehydrogenases, acid phosphatase and alkaline phosphatase. Spring rape and white mustard were vulnerable to high concentrations of Triflurotox. The yields were negatively correlated with the herbicide rate. Potential biochemical soil activity index computed from the activities of dehydrogenases, urease, acid phosphatase and alakline phosphatase as well as the organic carbon content in the soil was negatively correlated with the Triflurotox 250 EC concentration in the soil and positively correlated with the spring rape and white mustard yields. Base saturation of soils was positively correlated with the Triflurotox concentration, in contrast to hydrolytic acidity and total exchange capacity, which were negatively correlated with the herbicide rates.

Keywords: Triflurotox 250 EC, enzymatic activity, spring rape, white mustard

Introduction

Excessive amounts of pesticides in the environment may result from a variety of breakdowns that can happen while pesticides are being transported, stored or applied. Such problems can be compounded due to some farmers not abiding by the recommended optimum doses and application procedures. This is obviously not indifferent to the state of waters, soils and plants [1]. Therefore, it is essential that the impact of particular pesticides on the natural environment, including soil metabolism, be assayed. According to Haberhauer et al. [2], persistence of pesticides in soil depends on their dose as much as on the characteristics of the soil, such as physicochemical properties, structure, temperature and moisture. The toxic effect of pesticides on humans and the environment can be direct or indirect [3].

One of the possible side-effects of using herbicides involves some disturbance of the biochemical processes occurring in soil [4]. Active substances found in many herbicides may hamper the rate of a series of biochemical processes, interfering with the soil enzymatic activity and microbial growth. Modifications in the count and activity of microorganisms may lead to upsetting the biological equilibrium of soil, which in turn depresses its fertility. All these considerations emphasise the importance of studies on the effect of pesticides on the biological activity of soil [4, 5, 6], and particularly on soil enzymes, which can serve as a good indicator of the impact of pesticides on soil metabolism. The present study aimed to determine the effect of soil contamination with herbicide Triflurotox 250 EC on soil enzymatic activity and physicochemical properties as well as on yields of spring rape and white mustard.

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Table 1. Effect of Triflurotox on the activity of soil enzymes per 1 kg d.m. of soil.

Rate of Triflurotox $mm^3 kg^{-1}$ of soil	Dehydrogenases $cm^3 H_2 kg^{-1} d^{-1}$	Urease mg $N\text{-}NH_4 kg^{-1} h^{-1}$	Phosphatase mmol PNP $kg^{-1} h^{-1}$		Potential biochemical soil activity index
			acid	alkaline	
Before sowing					
0	1.74	8.44	1.01	0.79	2.30
1.5	1.67	9.34	1.14	0.77	2.30
3.0	1.67	9.82	1.16	0.67	2.28
4.5	1.64	8.92	1.15	0.67	2.27
6.0	1.77	7.83	1.07	0.66	2.28
9.0	1.68	9.94	1.13	0.68	2.56
12.0	1.24	9.54	1.04	0.67	2.09
r	-0.70	0.32	-0.11	-0.69	-0.11
After harvest of spring rape					
0	1.04	4.94	1.09	0.61	2.01
1.5	0.78	4.87	1.13	0.53	1.98
3.0	0.79	4.95	0.93	0.50	1.83
4.5	0.74	5.15	0.90	0.52	1.75
6.0	0.69	5.45	0.95	0.55	1.83
9.0	0.53	5.34	0.74	0.57	1.52
12.0	0.67	5.13	0.64	0.55	1.45
r	-0.79	0.61	-0.95	-0.04	-0.96
After harvest of white mustard					
0	1.24	6.43	1.09	0.75	1.81
1.5	1.35	4.32	0.99	0.76	1.80
3.0	0.99	3.99	0.95	0.74	1.59
4.5	0.94	3.97	0.98	0.68	1.62
6.0	0.49	3.17	1.00	0.68	1.17
9.0	0.34	2.68	0.99	0.68	0.94
12.0	0.34	2.46	1.01	0.71	0.96
r	-0.93	-0.89	-0.25	-0.64	-0.94
LSD*	a – 0.07; b – 0.10; a x b – 0.18	a – 0.24; b – 0.36; a x b – 0.63	a – 0.02; b – 0.02; a x b – 0.04	a – 0.01; b – 0.02; a x b – 0.04	a – 0.10; b – 0.14; a x b – 0.25

*LSD for: a – plant species, b – rate of Triflurotox; r - correlation coefficients.

Methods

The trials were conducted in a greenhouse (in five replications) in plastic pots, each filled with 3.4 kg leached brown soil formed from light silty clay sand possessing the following characteristics: pH in 1 M KCl – 5.8, Hh – 13.0 mmol(H^+) · kg^{-1} soil, C_{org} – 6.0 g · kg^{-1}, exchange bases total (S) – 38.00 mmol(+) · kg^{-1}, total exchange capacity (T) – 51.5 mmol(+) · kg^{-1}, base saturation of soils (V) – 73.8%. Uniform macro- and microelements fertilization was applied with the following quantities of elements (expressed as a pure component in mg · kg^{-1} soil): P - 100 [K_2HPO_4]; K - 150 [K_2HPO_4 + KCl], Mg - 50 [$MgSO_4 \cdot 7H_2O$], Zn - 5 [$ZnCl_2$], Cu - 5 [$CuSO_4 \cdot 5H_2O$], Mn - 5 [$MnCl_2 \cdot 4H_2O$], Mo - 5 [$Na_2MoO_4 \cdot 2H_2O$], B – 0.33 [H_3BO_3]. Prior to the establishment of the experiment, both the mineral fertilizers and herbicide Triflurotox 250 EC, applied in the following doses: 0, 1.5, 3.0, 4.5, 6.0, 9.0 and 12.0 $mm^3 \cdot kg^{-1}$ soil, were mixed with a batch of soil to fill one pot. Trifluranine, which belongs

Table 2. Regression equations and determination coefficients between rates of Triflurotox and activity of enzymes.

Before sowing	
Dehydrogenases	$y = -0.0062x^2 + 0.0445x + 1.6583$; $R^2 = 0.7643$
Urease	$y = 0.0062x^2 - 0.0156x + 8.9418$; $R^2 = 0.1173$
Acid phosphatase	$y = -0.0027x^2 + 0.0308x + 1.054$; $R^2 = 0.4774$
Alkaline phosphatase	$y = 0.0021x^2 - 0.0346x + 0.7899$; $R^2 = 0.8301$
After harvest of spring rape	
Dehydrogenases	$y = 0.005x^2 - 0.0887x + 0.9976$; $R^2 = 0.8586$
Urease	$y = -0.0078x^2 + 0.1248x + 4.8012$; $R^2 = 0.6683$
Acid phosphatase	$y = -0.0002x^2 - 0.0373x + 1.1108$; $R^2 = 0.9054$
Alkaline phosphatase	$y = 0.0013x^2 - 0.0157x + 0.5743$; $R^2 = 0.2884$
After harvest of white mustard	
Dehydrogenases	$y = 0.0052x^2 - 0.1549x + 1.3934$; $R^2 = 0.8972$
Urease	$y = 0.0314x^2 - 0.657x + 5.9256$; $R^2 = 0.9105$
Acid phosphatase	$y = 0.002x^2 - 0.026x + 1.0538$; $R^2 = 0.5226$
Alkaline phosphatase	$y = 0.0014x^2 - 0.0222x + 0.7699$; $R^2 = 0.7609$

to the group of dinitro aninilines, is the active substance of Triflurotox 250 EC. The herbicide is produced by the Organika-Sarzyna Chemical Plant Ltd.

Spring rape (cv. Lisonne) and white mustard (cv. Nakielska) were sown seven days after the soil was put into the pots. Seven plants per pot were left after emergence. During the vegetative period of the crops (35 days for white mustard and 40 days for spring rape), constant soil moisture was maintained at 60% water capillary capacity. The biochemical and physicochemical analyses of soil were performed immediately before plant sowing (7 days after mixing the soil with the herbicide) and after the harvest (in the flowering phase).

The biochemical analyses comprised determination of the activities of soil dehydrogenases (Deh) with Lenhard method as modified by Casidy *et al.* [7], urease (Ure) according to the procedure by Gorin and Chine Chang [8], and acid (Pac) and alkaline phosphatases (Pal) with Tabatabai and Bremner method [9].

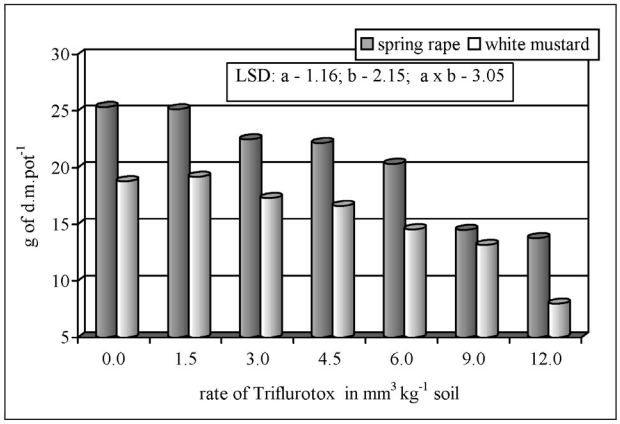

Fig. 1. Effect of Triflurotox 250 EC on d.m. yield of plants. LSD for a - plant species, b - Triflurotox rate.

The physicochemical analyses of soil involved determination of pH in KCl solution of 1 mol · dm^{-3} concentration (soil to solution ratio was 1 : 2.5), organic carbon (C_{org}) with Tiurin method [10], hydrolytic acidity (Hh) and total exchange bases (S) with Kappen method [11]. The results of the above were used to compute total exchange capacity (T) and base saturation of soils (V) with the formulas: $T = S + Hh$ and $V = S \cdot T^{-1} \cdot 100$.

Due to the fact that the analyzed herbicide caused very small changes in the physicochemical properties of soil, the paper contains only information on the mean values of pH, hydrolytic acidity, total exchange bases and organic carbon.

Furthermore, on the basis on the enzymatic activity and organic carbon content, the authors computed the potential biochemical soil activity index, using the formula $M_W = (Ure \cdot 10^{-1} + Deh + Pac + Pal) \cdot \% C_{org}$. All the laboratory analyses were conducted in three replications. The results were processed statistically using Duncan's test. In addition, the computations comprised regression equations between yields of plants and the activity of dehydrogenases, urease, acid phosphatase, alkaline phosphatase and potential biochemical soil activity index, regression equations and determination coefficients between the rate of Triflurotox and activity of the enzymes, as well as Pearson's simple correlation coefficients between the rate of the herbicide and yields of the plants, biochemical activity of the soil and its physicochemical properties. All statistical calculations were done with the help of Statistica software package [12].

Results

All pesticides, including herbicides, play an important role in the environment by modifying the enzymatic activity of soils [13, 14, 15].

The results of the present study have revealed that excessive amounts of Triflurotox 250 EC in soil for either of the investigated plant species distorted the biological equilibrium of the soil, measured by its enzymatic activity (Table 1) and by the yield of spring rape and white mustard (Fig. 1). Triflurotox 250 EC had a negative effect on the activity of dehydrogenases, acid phosphatase and alkaline phosphatase (Table 1). However, the magnitude of its toxic impact depended on the concentration of the herbicide in the soil and the species of the cultivated plants. The activity of dehydrogenases, acid phsophatase and akaline phosphatase, both in the soil samples analyzed prior to sowing and after the harvest of spring rape and white mustard crops, was negatively correlated with the degree of herbicide contamination, which was confirmed by Pearson's simple correlation coefficients between the dose of Triflurotox and the enzymatic activity of the soil (Table 1) as well as by the regression equations and determination coefficients between the herbicide rate and the activity of the enzymes (Table 2). The values of the correlation coefficients suggest that the analyzed enzymes were characterised by various degrees of vulnerability to soil contamination by the herbicide.

Nowak [14] claims that dehydrogenases are an objective reflection of the biological state of soils. In the present study these enzymes also appeared to have been the most sensitive to the analyzed herbicide (Table 1). The highest

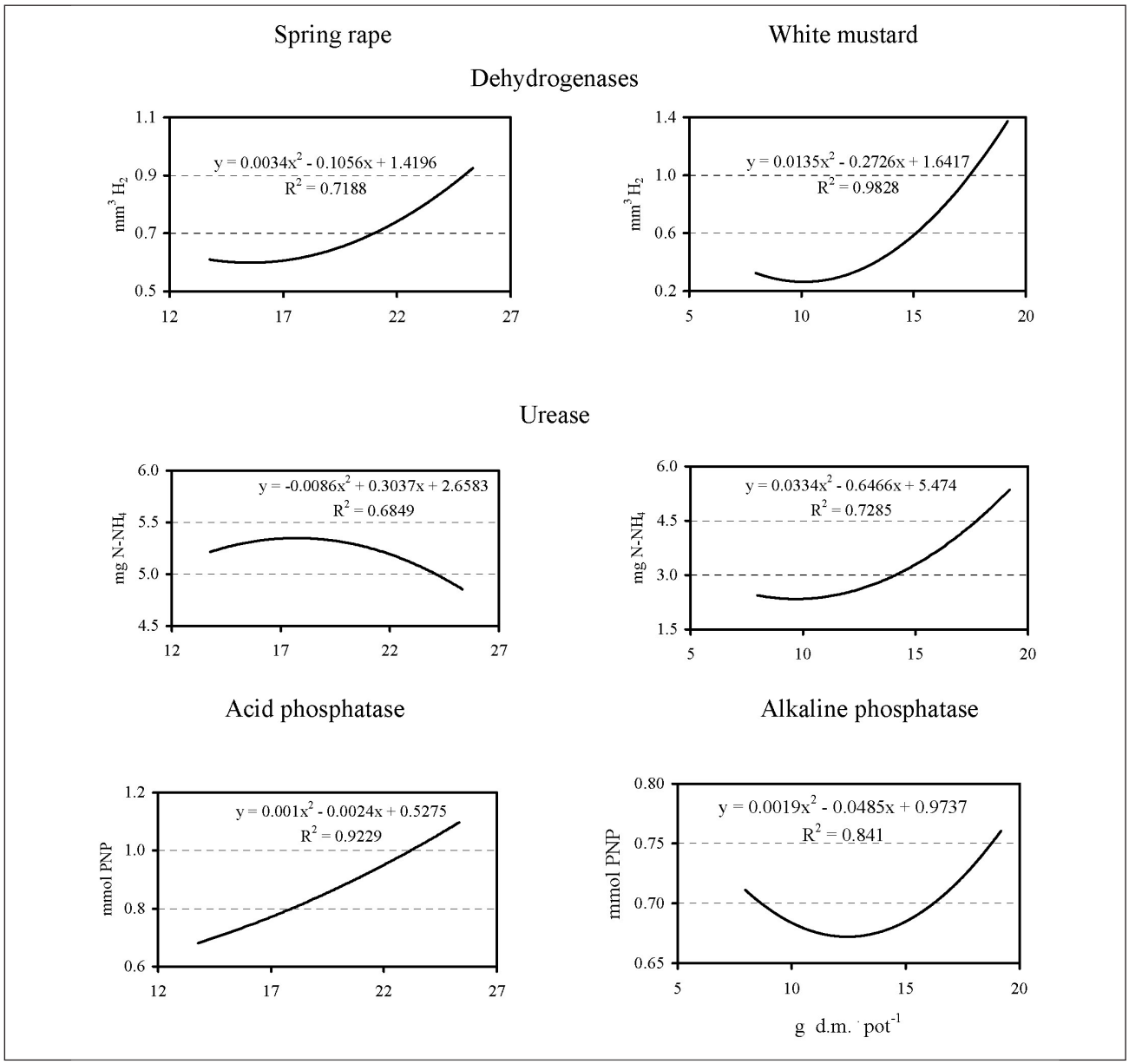

Fig. 2. Significant correlation between yields of plants and enzymatic activity per 1 kg d.m. of soil.

Table 3. Effect of the date of soil analysis on the enzymatic activity of soil.

Date of analysis / Activity		Dehydroge-nases $cm^3 H_2 kg^{-1} d^{-1}$	Urease mg $N\text{-}NH_4$ kg^{-1} h^{-1}	Phosphatase mmol PNP $kg^{-1} h^{-1}$		Potential biochemical soil activity index
				acid	alkaline	
Before sowing	spring rape and white mustard	1.63	9.12	1.10	0.70	2.30
After harvest of	spring rape	0.75	5.12	0.91	0.55	1.77
	white mustard	0.81	3.86	1.00	0.71	1.41
LSD		0.07	0.24	0.02	0.02	0.10

rate of Triflurotox 250 EC (12 $mm^3 \cdot kg^{-1}$) depressed the activity of dehydrogenases by 28.7% before sowing and by 35.6% and 72.6% after the harvest of spring rape and white mustard, respectively, in comparison to the control objects, which were not treated with the herbicides. The inhibitory effect of pesticides (Afalon, Aretit, Atrazine, Gramoxone, Igran, Tenoran, Tribunil) on the activity of dehydrogenases has also been reported by other researchers: Strzelec [16] and Pietr and Jabłońska [17] following the application of Pyramin, Furczak and Gostkowska [13] under the effect of the herbicides Gramoxone and Amniopielik, Pietr and Jabłońska [17] after treatments with Roneet and Venzar. In contrast, Nowak et al. [15], who tested the effect of Triflurotox 250 EC in conjunction of the adjuvant Ramrod 480 S.C., found that the activity of dehydrogenases was stimulated by the treatment. The activity of dehydrogenases is affected not only by the degree of contamination but also by the species of a cultivated crop, as it became evident in our investigations as well as in some earlier studies [18]. It is also influenced by the type of soil [19, 20], soil oxidation and moisture content [21]. Furczak and Kościelska [19] discovered that the negative effect of a fungicide (Eminent 125 SL) on the activity of dehydrogenases was greater in sandy soils of low buffer value than in clay soils richer in mineral coloids.

The results on the activity of the other enzymes were less consistent (Table 1). Urease turned out to be the least sensitive to the soil contamination with Triflurotex, although Nowak [14] suggested that this enzyme is vulnerable to the influence of herbicides, in contrast to the findings of Gostkowska and Furczak [22]. The activity of urease was much more closely dependant on the plant species. It was positively correlated with the herbicide concentration in the soil under spring rape (r=0.61), but showed negative correlation with this factor in the soil under white mustard (r=-0.89). These relationships grew in magnitude as the concentration of trifluranine in the soil increased. The strongest inhibition of the activity of urease in the white mustard series was observed in the objects receiving the herbicide at a rate of 12 $mm^3 \cdot kg^{-1}$ soil. In this treatment, the inhibition of the urease activity reached 61.7%. The other enzyme activity (the urease and the acid phosphatase) heven't been so strongly correlated to the herbicyde application. The negative effect of the herbicides obtained only after harvesting the plants. This might have been connected to the biomass of rhizosphere

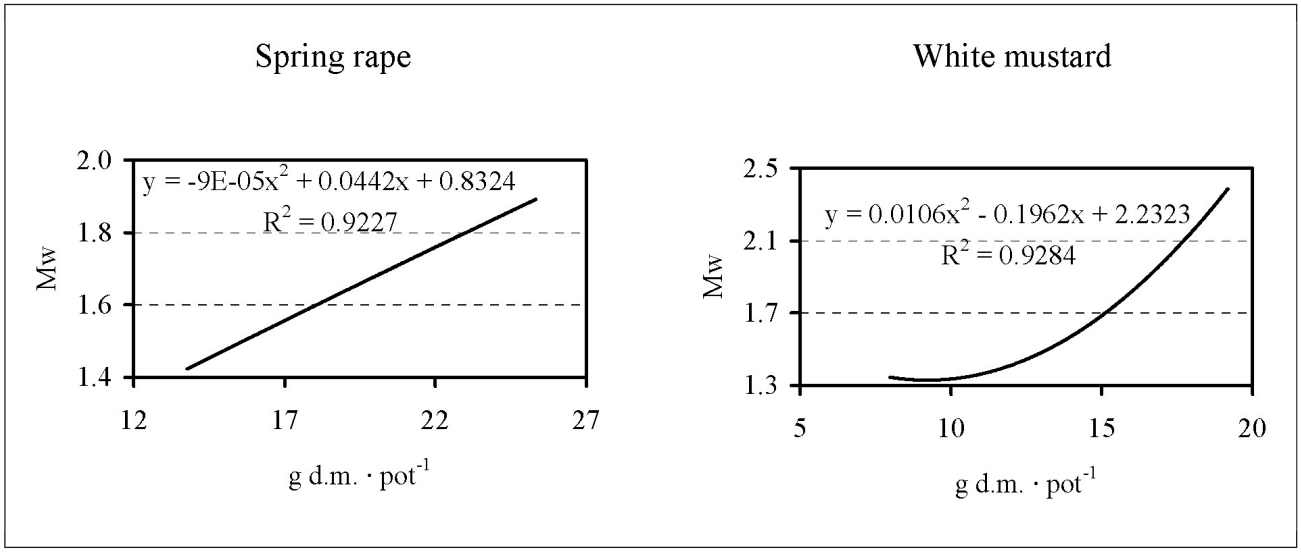

Fig. 3. Significant correlation between yields of plants (g d.m. pot^{-1}) and potential biochemical soil activity index (M_W).

Table 4. Mean physicochemical properties per 1 kg d.m. of soil.

Rate of Triflurotox mm^3 kg^{-1} of soil	Hh	S	T	V %	pH_{KCl}	C_{org} g
	mmol(+) kg^{-1} of soil					
0	16.70	38.30	55.05	69.74	5.62	5.80
1.5	16.50	38.40	55.02	70.00	5.65	6.00
3.0	16.00	37.90	54.03	70.38	5.75	6.00
4.5	16.40	37.90	54.40	69.94	5.63	6.20
6.0	15.50	37.60	53.20	70.94	5.78	6.10
9.0	15.10	37.90	53.15	71.63	5.82	6.00
12.0	14.90	38.30	53.23	72.20	5.77	5.80
r	-0.95	-0.21	-0.87	0.96	0.74	-0.22
LSD	0.80	n.s.	n.s	n.s.	0. 03	n.s.

Hh – hydrolytic acidity, S – total exchange bases, T – sorptive capacity, V – degree of base saturation, C - organic carbon content

Table 5. Effect of the date of analysis on physicochemical properties of soil.

Properties / Date of analysis		Hh	S	T	V %	pH_{KCl}	C_{org} g
		mmol(+) kg^{-1} of soil					
Before sowing	spring rape and white mustard	19.00	38.20	57.40	66.88	5.66	5.30
After harvest of	spring rape	14.10	38.50	52.70	73.13	5.73	6.20
	white mustard	14.50	37.40	52.00	72.06	5.76	6.40
LSD*		0,50	n.s	1.30	4.98	0.02	0.60

* designations under Table 4

from different kind of plants. As well as yield of plants and quantity of rhizosphere biomass dependent on the herbicyde dose application. The affected biomass rhizosphere size, is usually the number of microbes and the same enzyme activity.

Phosphatases are among those soil enzymes that usually respond negatively to herbicides [14, 23]. In our tests, Triflurotox 250 EC caused some inactivation of acid phosphatase and alkaline phosphatase, although its exact effect depended on plant species. The adverse impact of the herbicide on acid phosphatase became particularly evident in the soil under spring rape (r=-0.95), in which the activity of this enzyme in the objects treated with the highest Triflutotox rate was depressed by as much as 41%, whereas in the soil under white mustard and before sowing the plants, the activity of acid phosphatase remained on a relatively stable level. The activity of alkaline phosphatase in the series of the analyses preceding the sowing and after the harvest of white mustard was negatively correlated with the quantity of the herbicide in the soil. Inhibitory influence of pesticides (Eminent 125 SL) on the activity of soil phosphatases found some confirmation in the studies completed by Furczak and Kościelska [19]. Also Nowak et al. [15], who examined the effect of the herbicide Triflurotox 250 EC applied together with an adjuvant, found that the activity of acid phosphatase and alkaline phosphatase was distorted as a consequence of the treatment.

Due to the specific nature of enzymatic reactions which determine the conversion of certain compounds in soil, any evaluation of potential soil fertility and microbial activity based on the activity of a single enzyme may lead to erroneous conclusions. It is safer to base such assays on a larger number of enzymes, as recommended by many researchers [24, 25, 26]. Following these recommendations, we calculated the potential biochemical soil activity index from the activity of dehydrogenases, urease, acid phosphatase, alkaline phosphatase and organic carbon content in soil. The index allowed us to obtain more comprehensive information on the bioconversions occurring in the soil. The present analyses indicate that the potential biochemical soil activity index declined significantly at increasing concentrations of trifluraline in the soil after the harvest of spring rape (r=-0.96) and white mustard (r=-0.94), while remaining on a relatively constant level in the soil before sowing.

The activity of the analysed soil enzymes was modified by the rate of Triflurotox as well as by the

Tabela 6. Pearson's simple correlation coefficients between rate of Triflurotox and yields of plants, and between activity of enzymes and physicochemical properties of soil.

Variable	Triflurotox	Yield	Deh	Ure	Pac	Pal	Mw
Spring rape							
Triflurotox	1.00	-0.98*	-0.78*	0.33	-0.94*	-0.03	-0.93*
Yield	-0.98*	1.00	0.78*	-0.33	0.95*	-0.07	0.94*
Deh	-0.78*	0.78*	1.00	-0.39	0.69*	0.27	0.77*
Ure	0.33	-0.33	-0.39	1.00	-0.32	0.24	-0.18
Pac	-0.94*	0.95*	0.69*	-0.32	1.00	0.05	0.95*
Pal	-0.03	-0.07	0.27	0.24	0.05	1.00	0.10*
Mw	-0.93*	0.94*	0.77*	-0.18	0.95*	0.10	1.00
Hh	-0.82*	0.84*	0.73*	-0.41	0.73*	-0.10	0.71*
S	-0.12	0.16	0.01	0.06	0.23	-0.11	0.17
T	-0.55*	0.59*	0.42	-0.19	0.59*	-0.14	0.53*
V	0.73*	-0.73*	-0.69*	0.41	-0.59*	0.06	-0.61*
C	-0.27	0.30	-0.16	0.06	0.34	-0.55*	0.39
pH	0.67*	-0.72*	-0.63*	0.33	-0.64*	-0.01	-0.56*
White mustard							
Triflurotox	1.00	-0.94*	-0.92*	-0.86*	-0.25	-0.63*	-0.88*
Yield	-0.94*	1.00	0.87*	0.73*	0.06	0.43*	0.85*
Deh	-0.92*	0.87*	1.00	0.78*	0.22	0.77*	0.94*
Ure	-0.86*	0.73*	0.78*	1.00	0.56*	0.59*	0.72*
Pac	-0.25	0.06	0.22	0.56*	1.00	0.25	0.17
Pal	-0.63*	0.43*	0.77*	0.59*	0.25	1.00	0.66*
Mw	-0.88*	0.85*	0.94*	0.72*	0.17	0.66*	1.00
Hh	-0.46*	0.45*	0.36	0.37	0.05	0.24	0.43*
S	-0.30	0.21	0.42*	0.21	0.11	0.58*	0.43*
T	-0.49*	0.43*	0.52*	0.38	0.11	0.56*	0.57*
V	0.32	-0.35	-0.18	-0.27	0.00	0.01	-0.24
C	-0.29	0.40	0.33	-0.00	-0.33	0.01	0.60*
pH	0.60*	-0.55*	-0.68*	-0.73*	-0.24	-0.52*	-0.66*

r - correlation coefficient significant at *$p<0.05$; n = 21

plant species (spring rape and white mustard) or the date of analysis (before sowing and after harvest). Average enzymatic activity was significantly lower after the harvest of the crops than before their sowing (Table 3). Larger differences appeared in the activity of dehydrogenases and urease than in that of acid or alkaline phosphatases. Noteworthy is the fact that the activity of dehydrogenases, acid phosphatase and alkaline phosphatase was higher in the soil under white mustard than under spring rape, unlike the activity of urease or the value of the potential biochemical soil activity index.

Apart from upsetting the biochemical balance of soil, Triflurotox also affected soil physicochemical characteristics (Table 4). Whatever date of analysis or species of plant, the pH and base saturation of the soil were positively correlated with the rate of the herbicide, in contrast to its hydrolytic acidity and total exchange capacity, which were negatively correlated with this experimental factor. The hydrolytic acidity and total exchange capacity, unlike the pH and base saturation of the soils, were higher in the soil samples analyzed 7 days after establishing the experiment (prior to sowing) and after the harvest of spring rape and white mustard (Table 5).

The experiment proved that Triflurotox 250 EC determined the enzymatic activity and physicochemical properties of the soil. In addition, it was not indifferent to the growth and development of plants (Fig. 1). These observations are confirmed by the regression equations computed between the yields of rape and mustard versus the activity of the soil enzymes (Fig. 2), the potential biochemical soil activity index (Fig. 3) as well as mostly positive correlation coefficients between these variables (Table 6). Very much the same as the activity of dehydrogenases, acid phsophatase and alkaline phosphatase, spring rape and white mustard, were susceptible to high concentrations of Triflurotox. The magnitude of its toxic effect was related to the concentration of trifluraline in soil and the species of the plant cultivated (Fig. 1). The lowest rate of Triflurotox 250 EC (1.5 mg · kg^{-1} soil) neither increased nor decreased significantly the spring rape or white mustard yields. A similar effect of trifluraline, the active substance of Triflurotox 250 EC, on spring rape and white mustard has been observed in our previous studies [18]. The investigations conducted by Węgorek et al. [27] and Murawa and Adomas [28] suggested that herbicides applied at optimal doses had a positive influence on rape yields. However, higher doses of the herbicide resulted in significantly negative correlation between the herbicide rate and the yield of either plant species: spring rape (r=-0.89) or white mustard yield (r=-0.97). Symptoms of the toxic effect of Triflurotox, involving disturbed water uptake (wilting) and chlorosis of new leaves, were stronger as the herbicide concentration in the soil increased. As a result, the treatments with 12 mg · kg^{-1} soil were found to produce lower yields of white mustard (by 57%) and spring rape (by 46%).

The statistical analysis of the results showed a positive correlation between the following pairs of variables: the activity of dehydrogenases and the yields produced by both plant species, the activity of acid phosphatase and the yield of spring rape, and the activity of urease and the yield of white mustard (Table 6).

The results of our study as well as the reference literature seem to indicate that herbicides are responsible for some distortion of microbiological and biochemical processes [18, 29, 30]. When applied at optimal doses, recommended by specialists, the changes they generate in the enzymatic activity of soil or yields of crops are minimal [18, 27]. Should they enter soil in excessive amounts, herbicides are capable of disturbing the biological life of soil [18, 19]. This suggestion has been confirmed by the authors' own studies, in which Triflurotox caused extensive modifications in the activity of dehydrogenases, acid phosphatase and alkaline phosphatase in light soil (light silty clay sand). Significant negative correlation was determined between the activity of most of the enzymes analyzed or yields of the two crops and the degree of soil contamination with the herbicide. The extent and intensity of those changes increased at higher concentrations of trifluraline in soil.

Conclusions

1. Triflurotox 250 EC applied in doses ranging from 1.5 to 12 mm^3 · kg^{-1} soil had a negative influence on the activity of dehydrogenases, acid phosphatase and alkaline phosphatase.
2. Spring rape and white mustard were sensitive to high concentrations of Triflurotox. The yields of the two plant species decreased at increasing rates of the herbicide.
3. The potential biochemical soil activity index calculated on the basis of the activity of dehydrogenases, urease, acid and alkaline phosphatases, as well as the content of organic carbon, was negatively correlated with the concentration of Triflurotox 250 EC in soil, but positively correlated with the yields of spring rape and white mustard.
4. The base saturation of soils was positively correlated with the rate of Triflurotox 250 EC, unlike the hydrolytic acidity and total exchange capacity, which were negatively correlated with this variable.

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