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Micro-rates of herbicides used in sugar beet crop – influence on herbicide residues level in roots and soil

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Abstract: The aim of present investigation was to evaluate the influence of low-rates application on herbicide residues in soil and roots of sugar beet. Chemical weed control in sugar beet was applied at recommended and reduced (about 50 and 66%) doses of herbicides including substances such as: phenmedipham, desmedipham, ethofumesate, metamitron, triflusulfuron and oil adjuvant applied 4 times at 7- to 10-day intervals starting at the onset of weed emergence. Samples of soil and roots of sugar beet were taken at the day of lifting. Phenmedipham, desmedipham and ethofumesate residues were analysed using HPLC with UV-detection. Metamitron residues were analysed using GLC with ECD detection. At lifting time, in soil samples, where recommended herbicide doses were applied, the residues of separate active substance of herbicides amounted from 0.0056 to 0.0124 $mg \cdot kg^{-1}$. Sum of all detected residues of applied substances amounted 0.0323-0.0373 $mg \cdot kg^{-1}$. In sugar beet root samples, the residues amounted respectively 0.0011 to 0.0085 $mg \cdot kg^{-1}$and 0.0085-0.0224 $mg \cdot kg^{-1}$. Application of the reduced doses by about 50% influenced on a significant decrease of residues about 38-50% average. For samples, where reduction of herbicide dose amounted 66%, the decrease of residues level, in comparison with results obtained at recommended doses, was statistically significant and amounted 69-77% average. Residues of active substances determined in roots of sugar beet did not exceed EU acceptable limits.

Keywords: herbicide, micro-rates, residue, sugar beet

INTRODUCTION

Monitoring of herbicide residues allows controlling the quality of agricultural products and contamination of soils. The results from monitoring studies need to be compared to the acceptable amounts of the EU standards. The standards define maximum residue limits for different active ingredients and plant products.

Information on the residue and degradation rate of herbicides allows evaluating the behavior of herbicides in the environment. Low soil and plant residues of herbicide constitute problems for their determination and make it difficult to estimate the effect of these herbicides on following crops and health of consumers [1].

Herbicides are often applied at rates higher than required for weed control under ideal conditions. This is done primarily to compensate losses that occur at the target site in the plant [2].

A micro-rate program of herbicides used in sugar beets was developed and introduced to farmers by Dr Alan G. Dexter – professor at North Dakota State University, USA [3]. This program is attractive from economical point of view and has been accepted by most of sugar beet growers in the USA. The micro-rate program uses low rates of herbicides in combination (phenmedipham + desmedipham + ethofumesate + triflusulfuron + clopyralid) applied 3 or more times at 5- to 7-day intervals starting at the onset of weed emergence. Herbicides are used at rates reduced approximately by 2-3 times comparing with rates recommended in a conventional herbicide split application programs [4, 5]. Since 2003 the initial experiments with evaluation of micro-rates of herbicides in sugar beet crop were conducted in Poland [3, 6].

The aim of present investigation was to evaluate the influence of micro-rate applications on herbicide residues in soil and roots of sugar beet.

MATERIALS AND METHODS

Field experiments were conducted during a two-year period 2006-2007 in arable fields in South-West Poland. The field trial was set up as a randomized complete block design with four replicates. All farming activities were carried out in accordance with conventional agricultural practice and in line with recommendations from officials. Chemical weed control in sugar beet was carried out at recommended and reduced (about 50 and 66%) doses of herbicides including substances such as phenmedipham, desmedipham, ethofumesate, metamitron, triflusulfuron and oil adjuvant (Table 1) applied 4 times at 7- to

10-day intervals starting at the onset of weed emergence. The rates of active ingredients of the herbicidal preparation applied in different combinations are given in Table 2.

Table 1. Characteristics of herbicidal preparations used in experiments

Common name of preparation	Active substance [a.s.]	IUPAC name	Content of a.s.
Betanal Progress 274 OF	phenmedipham	methyl 3-(3-methylcarbaniloyloxy) carbanilate	91 $g \cdot l^{-1}$
	desmedipham	3-phenylcarbamoyloxyphenyl-carbamate	71 $g \cdot l^{-1}$
	ethofumesate	(±)-2ethoxy-2,3-dihydro-3,3-dimethyl-benzofuran-5-yl methanesulfonate	112 $g \cdot l^{-1}$
Goltix 700 SC	metamitron	4-amino-4,5-dihydro-3-methyl-6-phenyl-1,2,4-triazin-5-one	70%
Safari 50 WG	triflusulfuron	2-[4-dimethylamino-6-(2,2,2-trifluoroethoxy)-1,3,5-triazin-2-ylcarbamoylsulfamoyl]-m-toluic acid	50%
Actirob 842 EC	methylated fatty acids from rape seed oil	-	733 $g \cdot l^{-1}$

Table 2. Herbicide combinations

Treatments	Dose per ha	Combinations
Betanal Progress 274 OF + Goltix 700 SC + Safari 50 WG + Actirob 842 EC	1.0 l 1.0 l 30 g 1.0 l	full dose combination“A”
Betanal Progress 274 OF + Goltix 700 SC + Safari 50 WG + Actirob 842 EC	0.5 l 0.5 l 15 g 1.0 l	dose reduced about 50% combination “B”
Betanal Progress 274 OF + Goltix 700 SC + Safari 50 WG + Actirob 842 EC	0.33 l 0.33 l 10 g 1.0 l	dose reduced about 66% combination “C”

Samples of soil and roots of sugar beet were taken at the day of lifting. Samples were taken from the middle of each plot to avoid interference and side effects from the neighboring plots. Sampling of soil was carried at depth 0-20 cm.

Samples from each plot were well mixed and stored in polyethylene bags at minus 18 °C until sample extraction. Soil moisture content was determined for each soil sample. The samples were dried at 105 °C for 24 h.

Phenmedipham, desmedipham and ethofumesate residues were analysed using high performance liquid chromatography (SHIMADZU HPLC measuring set: pump LC-10AT, degasser DGU-4A) with UV-detection (SPD-10A). Metamitron residues were analysed using gas chromatography (SHIMADZU GC - A17) with ECD detection. By reason of low dose use and lack of analitical method the triflusulfuron residues were not determined.

The recoveries of the active substances were determined by fortification of soil and root samples at concentrations of 0.0001, 0.001, 0.01 and 0.1 mg kg^{-1} in three replicates. The average recoveries and quantification limits of the methods for all concentrations are given in Table 3. Analytical procedures were performed at the Institute in Laboratory of Residue Research [7, 8]. All experimental data were calculated using the statistical program Statgraphics Centurion, version XV.

Table. 3. The recoveries and quantification limits of the analytical method

Tested substance	Average recoveries [%]		Limit of detection* [mg kg^{-1}]	
	soil	roots	soil	roots
phenmedipham	90	84	0.0001	0.0001
desmedipham	92	87	0.0001	0.0001
ethofumesate	86	76	0.0001	0.0001
metamitron	89	82	0.0001	0.0001

* for 30 g of sample

RESULTS

At lifting time, in soil samples, where recommended herbicide doses were applied, the residues of separate active substance of herbicides amounted from 0.0056 to 0.0124 mg kg^{-1}. Sum of all detected residues of applied substances amounted 0.0323-0.0373 mg kg^{-1}. Microrate applications (reduced doses by 50%) influenced on a decrease of residues about 38% average. The decrease of residues level was statistically significant for 69% of soil samples. For samples, where reduction of herbicide dose amounted 66%, residues of active ingredient in soil were the lowest. The decrease of residues level, in comparison with results obtained for recommended doses, was statistically significant and amounted 70% for average. Sum of all detected residues of applied substances amounted 0.0100-0.0113 mg kg^{-1}.

In sugar beet roots samples, the residues of active substances, were lower than in soil. For samples where recommended herbicide doses were applied, the residues of separate active substance amouted from 0.0011 to 0.0085 mg kg^{-1}. Sum of all detected residues of applied substances amounted 0.0085-0.0224 mg kg^{-1}. Application of the reduced doses by about 50% influenced on a significance decrease of residues about 50% for average (0.0008-0.0052 mg kg^{-1}). For samples, where reduction of herbicide dose amounted 66%, the decrease of residues level, in comparison with results obtained for recommended doses, was statistically significant and amounted 77% for average. Sum of all detected residues of applied substances amounted 0.0021- 0.0046 mg·kg^{-1}.

Results obtained from all experiments are shown in Tables 4 and 5.

Table 4. Residues of active substances in soil

Combina-tion	Residues* [mg kg^{-1}]				
	phen-medipham	des-medipham	ethofu-mesate	metamitron	sum of residues
year 2006					
“A”	0.0124	0.0096	0.0085	0.0068	0.0373
“B”	0.0082	0.0049	0.0061	0.0047	0.0239
“C”	0.0036	0.0025	0.0029	0.0023	0.0113
$LSD_{0.05}$	0.00326	0.00271	0.00286	0.00213	0.00837
year 2007					
“A”	0.0102	0.0083	0.0056	0.0082	0.0323
“B”	0.0072	0.0050	0.0029	0.0041	0.0192
“C”	0.0041	0.0015	0.0019	0.0025	0.0100
$LSD_{0.05}$	0.00241	0.00311	0.00209	0.00273	0.00611

* average residues for 4 replications, A, B, C – herbicide combinations (see Tab. 2)
LSD – least significant difference

Table 5. Residues of active substances in sugar beet roots

Combina-tion	Residues* [mg kg^{-1}]				
	phen-medipham	des-medipham	ethofu-mesate	metamitron	sum of residues
year 2006					
"A"	0.0085	0.0078	0.0042	0.0019	0.0224
"B"	0.0052	0.0043	0.0011	0.0011	0.0117
"C"	0.0021	0.0012	0.0006	0.0007	0.0046
$LSD_{0.05}$	0.00196	0.00223	0.00042	0.00054	0.00524
year 2007					
"A"	0.0026	0.0032	0.0016	0.0011	0.0085
"B"	0.0010	0.0014	0.0009	0.0008	0.0041
"C"	0.0005	0.0008	0.0005	0.0003	0.0021
$LSD_{0.05}$	0.00061	0.00093	0.00046	0.00039	0.00261

* Explanation as for Tab. 4.

DISCUSSION

In Poland, since 2003, field experiments to evaluate efficacy of reduced herbicide rates (micro-rates) for weed control in sugar beets were conducted. Micro-rates system gives a good results when all farming activities are carried out in accordance with conventional agricultural practice and in line with recommendations for split-reduced rates application [3, 6, 9]. After micro-rate system application, the weed control and yield of sugar beet roots are comparable to results obtained for conventional systems used in sugar beet production.

Meaningful role to increase weed control by low herbicide rates is prevention of nozzle plugging from herbicide precipitation in a tank by application a specific adjuvant, usually based on methylated esters of fatty acids or derivatives of plant oil [3, 6, 10].

The highest concentration of herbicide active substances was determined from treatments, where herbicide was applied at full (recommended) dose. Reduction of herbicide dose (application of micro-rates) caused a decrease of residues. In older systems used for weed control in sugar beets, herbicides were applied at high, single dose. Usually, metamitron was applied at the rate of 3.5-4.9 kg ha^{-1}, and residue determined from similar experiments was even 5-10 times higher than in micro-rate system [8].

In our experiment residues of active substances determined in roots of sugar beet did not exceed maximum residue limit (0.1 mg kg^{-1}). Application of herbicides in micro-rates system allowed to reduce the herbicide dose (without lost of weed control efficacy) and therefore limited the risk for agricultural environment contamination.

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