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THE EFFECT OF METAZACHLOR USED IN MIXTURES WITH CLOMAZONE AND CHINOMERAC ON MORPHOLOGY OF PLANTS AND SEED QUALITY OF SOME CULTIVARS OF WINTER OILSEED RAPE

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Abstract. Most commonly recommended herbicide Command 480 EC applied pre-emergence causes permanent damage deteriorating quality of the yield in susceptible cultivars. In this situation, it is necessary to search for some effective herbicides that do not show phytotoxic effects on cultivars of different genetic traits. Field experiments conducted in the years 2009-2013 were set up on two different soils. The experiments studied response of four cultivars of winter oilseed rape: population Monolith, improved population ES Bourbon and Canti, and hybrid Nelson on herbicides Nimbus 283 SE and Butisan Star 416 SC applied pre-emergence. Impact of herbicides in the form of a mixture of metazachlor with clomazone, and metazachlor with chinomerac, on morphology and quality of the yield of winter oilseed rape cultivars was compared to clomazone used in the form of Command 480 EC. Symptoms of phytotoxic effects of these mixtures in each case were milder than of clomazone. Mixture of metazachlor with chinomerac proved to be the safest in relation to all cultivars, and showed no phytotoxic effect in the growing season. The studies of residues of active substances showed an increased occurrence of clomazone after using herbicide Command 480 EC, and of metazachlor when using Nimbus 283 SE in the seed cultivars ES Bourbon and Monolith, especially when cultivated in luvisols. In any case, the level of these residues did not exceed acceptable standards. The studies of quality traits of the cultivars showed no significant effects of the herbicides on the protein and fat content in seeds. Cv. Monolith showed the highest variability in the yield in years and locations, regardless of the used herbicide.

Key words: phytotoxicity, residues of active substances, seed quality, selectivity, soil herbicide

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INTRODUCTION

The use of herbicides to control weeds is an effective and quick method to keep the plantation free of these dangerous competitors. Under rapeseed protection programs against weeds, after withdrawing trifluralins and alachlor, possibility to use safe soil herbicides is significantly reduced [Franek 2000, Jarecki *et al*. 2013]. The most frequently recommended for the use, Command 480 EC, often causes occurrence of permanent damages deteriorating yield quality in sensitive cultivars [Franek and Rola 2002]. Despite biological progress in the cultivation of rapeseed cultivars connected with improving genetic traits, the threat to the proper growth and development of plants is still low soil humidification or snowless winters, leading to manifestation of the phytotoxic effect of herbicides. It affects further condition and health of plants, and consequently may lead to a decrease in the seed yield, and deterioration of its quality parameters. Improvement of quality traits in double-improved cultivars is often negatively correlated with plant vigor, which may lead to a decreased tolerance to herbicides. On the other hand, beneficial early plant vigor, high fertility and resistance of hybrid cultivars to unfavorable environmental conditions may lead to their higher tolerance to the effect of herbicides [Kotecki *et al*. 2005, Kucharski and Domaradzki 2009, Kulig *et al*. 2010, Malarz 2008, Wójtowicz and Czernik-Kołodziej 2003]. Lack of external damages and high seed yield do not always testify to a complete selectivity of herbicides, which may however affect disorders in metabolic transformations in the plant, or accumulate as residues in amounts exceeding accepted standards [Directive 2009/128EC/, Liersch *et al*. 2008, Grzegorzak *et al*. 2012, Nowacka *et al*. 2012, Zhang *et al*. 2008].

Thus, it is necessary to search for safe herbicides not showing phytotoxic effect in the growing season, and to conduct complex qualitative studies of cultivars of various genetic traits, especially of rapeseed, which is a plant of a high trading importance. They are justifiable in case of introducing new hybrid cultivars into practice which are especially sensitive to wrong cultivation practices, including application of herbicides, at the same time fulfilling EU requirements regarding quality and technological standards [Adamczewski *et al*. 2000, Franek 2000, Griffin *et al*. 2010].

The aim of the study was evaluation of the effect of two mixtures, including metazachlor, on morphology, yield quality and level of residues of active substances in the seeds of four winter rapeseed cultivars depending on location of the experiment.

MATERIAL AND METHODS

The experiments were carried out in the years 2009-2013, and were set up on black soil formed from medium-heavy loam on light loam of a very good and good wheat complex in Okrzeszyce (50°59' N; 17°01' E), as well as on lessive soil developed from slightly loamy sand on light loam, of a good rye complex belonging to the Experimental Station IUNG-PIB Jelcz-Laskowice (51°1' N; 17°20' E). The experiments were set up on a plot free from weeds with a randomized blocks design in four replications on plots of an area of 20 m^2. Before sowing and setting the experiments, full-scale cultivation treatments were conducted on the whole field with the use of ploughing system and fertilization, resulting from current requirements of the crop plant, and fulfilling the current agrotechnical recommendations for the Lower Silesian region.

The experiments studied response of four winter rapeseed cultivars to chosen herbicides: population cultivars Monolit, Canti ES and Bourbon, as well as hybrid cultivar Nelson. The selected cultivars were characterized by a high yield potential, frost resistance, resistance to lodging, semi-early maturation time, low glucosinolate content and high fat content. Differences resulting from the cultivation type of the cultivar may affect their response to herbicides. The following soil herbicides (BBCH 00) of a various mechanism of action were applied in the experiments: Command 480 EC at a dose of 0.25 $dm^3 \cdot ha^{-1}$ with clomazone content as the only active substance, Nimbus 283 SE at a dose of 3.0 $dm^3 \cdot ha^{-1}$ with metazachlor and clomazone content, as well as Butisan Star 416 SC at a dose of 3.0 $dm^3 \cdot ha^{-1}$ with metazachlor and chinomerac content in the form of mixtures. Characteristics of the used herbicides and mechanism of action and damage symptoms of active substances are given in Table 1.

Table 1. Characteristics of herbicides included in the trials
Tabela 1. Charakterystyka herbicydów uwzględnionych w doświadczeniach

Herbicide Herbicyd	Active ingredient Substancja aktywna	Dose per ha Dawka na ha	Date of application Termin stosowania (BBCH)	Mechanism of action Mechanizm działania	Symptoms in plants Objawy działania na roślinach
Command 480 EC	clomazone 480 $g \cdot dm^{-3}$	0.25 $dm^3 \cdot ha^{-1}$	BBCH 00	inhibitor of pigment synthesis inhibitor syntezy barwników	inhibits chlorophyll synthesis in the leaves, causes bleaching of leaves hamuje syntezę chlorofilu w liściach, powoduje bielenie liści
Butisan Star 416 SC	metazachlor 333 $g \cdot dm^{-3}$ + chinomerac 83 $g \cdot dm^{-3}$	3 $dm^3 \cdot ha^{-1}$	BBCH 00	inhibitor of seedling growth + growth regulator inhibitor wzrostu siewek + regulator wzrostu	absorbed by the shoots of germinating plants inhibits growth and causes deformation of the growth cone shoots and roots pobierany przez pędy kiełkujących roślin hamuje wzrost, deformacja stożków wzrostu
Nimbus 283 SE	metazachlor 250 $g \cdot dm^{-3}$ + clomazone 33.3 $g \cdot dm^{-3}$	3 $dm^3 \cdot ha^{-1}$	BBCH 00	inhibitor of pigment synthesis + inhibitor of seedling growth inhibitor wzrostu siewek + inhibitor syntezy barwników	absorbed by the shoots of germinating plants inhibits growth of cone shoots and roots + inhibits chlorophyll synthesis in the leaves, causes bleaching of leaves pobierany przez pędy kiełkujących roślin hamuje wzrost stożków wzrostu + hamuje syntezę chlorofilu w liściach, powoduje bielenie liści

Evaluation of the phytotoxic effect of the studied preparations on the plant development were conducted 1, 2-3 and 4-5 weeks after application with a bonitation method and based on the measurement of plant height, counting branches and siliques before harvest on 10 plants randomly sampled from each plot (EPPO 2006). Seed harvest was carried out in full maturity stage, and the yield value and 1000 seed weight are given after calculating for 9.0% moisture.

Protein and fat contents were determined with the use of INSTALAB 600 analyzer using near-infrared technique (NIR). Obtained results were calculated statistically with the two-way analysis of variance in a non-orthogonal design. The least significant differences were calculated for the significance level of P = 0.05. The effect of herbicides on the level of residues of active substances in the seeds of studied cultivars was conducted with the use of high-performance liquid chromatography with mass spectrometry HPLC/MS/MS.

Synthesis of the results from the long-term period was carried out with a mixed model of analysis of variances described by Czajka (1996), taking on mean potential yields of the studied cultivars from two locations and from three years as permanent effects of the studied model:

$$Y_{ijk*} = \mu_i + \alpha_i^E (j,k) + e_{ijk*}$$

where μ_i denotes the mean potential yield of the cultivar in all locations and years, while α_i^E (j,k) denotes yield response of the cultivar under environmental conditions in which the experiment was set up (location j and year k). In this model, it is assumed that μ_i j is a permanent effect, while components α_i^E (j,k) and e_{ijk*} are random variables, as they are not subject to full control of the experimenters. Other components of the analysis of variance, i.e. years, location and two- and three-way interactions were taken on as random effects. Moreover, variations were separated, connected with regression occurring between environmental effects and effects of the plot-environment interaction. The sum of squared deviations for environments (years x locations) was divided into regression and deviations from regression in order to evaluate particular cultivars regarding their suitability for particular environments. Significance of particular herbicide-cultivar variants was evaluated through determining LSD values for cultivars, herbicides and cultivar-herbicide interaction. Also, significance of variations of particular plots was analyzed from the total mean of the experiment, as well as quantity of F-statistics obtained from interaction: cultivar as herbicide × location × years variant.

RESULTS

In the cultivation of winter rapeseed, weather conditions are highly significant for obtaining high yields. The course of weather conditions in the season 2009/10 was beneficial for winter rapeseed growth, September 2009 was warm though dry, while October was quite cold and characterized by moderate rainfall. This type of weather was favorable for emergence and initial plant development. Spring and summer 2010 were moderately warm with a sufficient rainfall, which was favorable for timely harvest of seeds from the experimental plots.

In the next growing season of 2010/11, September and first half of October were moderately warm, with sufficient rainfall, owing to which the plants entered dormancy stage when they were in the rosette stage and were well-rooted. On the other hand, spring and summer were cold and humid, which at the beginning was not favorable for growth, however, further course of weather conditions enabled quick seed maturation and conducting timely harvest.

In the growing season of 2011/2012, slight deficiency of humidity in autumn resulted in poorer emergence, and in the second half of November there occurred inhibition of growth in rapeseed. The winter was long and severe with little snow cover, which caused rapeseed freezing and termination of the experiments with the necessity to set them up again.

Autumn 2012 was characterized by low rainfall, which slightly delayed rapeseed emergence. In mid-November, there occurred growth inhibition when the temperatures dropped below 0^oC. The course of weather conditions in winter was favorable for its winter survival despite several days with a temperature reaching 20^oC, owing to a thick snow cover. Spring 2013 was cold with moderate rainfall. Only in mid-June there occurred increase in temperature up to app. $28\text{-}30^oC$ during the day. Such a high temperature maintained till the beginning of July. Additionally, an optimum humidity level in that period was favorable for plant growth, for forming siliques and seed harvest.

Apart from the course of weather conditions, also selection of soil location and cultivation practices, including proper weed protection, have an influence on the yield level. In the conducted research, seed yield usually lower by 20-25% was obtained on poorer lessive soil of a slightly acidic reaction. Based on observations carried out from emergence up to flowering stage, all cultivars treated with herbicides Command 480 EC and Nimbus 283 SE responded with lack of tolerance. After application of herbicide Command 480 EC, short-lived bleaching of leaves was observed caused by rapeseed's response to an active substance, clomazone, blocking chlorophyll synthesis in plants, however, only in case of cultivars Monolit and ES Bourbon, and it maintained for 4-5 weeks since occurrence. Herbicide Command 480 EC despite the strongest phytotoxic effect did not affect plant height or 1000 seed weight regardless of the soil type and cultivar. Only in cv. ES Bourbon, decrease in the number of branches and siliques was observed, which led to a decrease in the seed yield and developing smaller seeds. In case of herbicide Nimbus 283 SE, symptoms of slight plant bleaching and emergence inhibition was observed in higher intensity on black soil, especially in cultivars Canti and ES Bourbon, in any case it affected morphology and seed yield structure. All studied cultivars indicated highest tolerance to the effect of herbicide Butisan Star 416 SC, regardless of the location and soil type, which positively affected the seed yield, number of branches, siliques and 1000 seed weight (Table 2, 3).

The studies on the residues of active substances of herbicides indicated presence of clomazone after applying herbicide Command 480 EC, and of metazachlor after applying herbicide Nimbus 283 SE on lessive soil in the cultivation of population cultivars Monolit and ES Bourbon. Lower level of residues of metazachlor was detected after using herbicide Butisan Star 416 SC, in the cultivation of cv. Monolit on lessive soil, while in the cultivation of cv. ES Bourbon on black soil (Table 4). In each case, however, the amounts did not exceed accepted standards (Directive 2009/128/EC).

The research on quality traits of four winter rapeseed cultivars did not indicate any significant effect of herbicides on the fat and protein content in the seeds. Some differences in the amounts of these components were visible depending on the soil, as cultivars grown on lessive soils were characterized by a slightly lower fat content and higher protein content, while cultivars grown on black soils contained higher amount of fat and lower amount of protein (Table 4).

Table 2. The sensitivity of the Monolit i Canti cultivars of winter rape on the applied herbicides and their effect on plant height, morphology and seed yield
Tabela 2. Wrażliwość odmian rzepaku ozimego Monolit i Canti na zastosowane herbicydy i ich wpływ na wysokość roślin, morfologię i plon nasion

Herbicyd Herbicide	Laskowice						Okrzeszyce					
	F BBCH 14	plant height wysokość roślin cm	no of branches per plant liczba rozgałęzień	no of siliques per plant liczba łuszczyn	seed yield plon nasion $Mg \cdot ha^{-1}$	MTN WTS g	F BBCH 14	plant height wysokość roślin cm	no of branches per plant liczba rozgałęzień	no of siliques per plant liczba łuszczyn	seed yield plon nasion $Mg \cdot ha^{-1}$	MTN WTS g
Monolit												
Control	1	123.5	3.5	70	27.2	5.2	1	147.3	6.2	102	36.2	4.5
Command 480 EC	3-4	125.5	3.9	65	28.1	5.3	3	151.1	6.1	101	38.1	4.5
Nimbus 283 SE	3	123.0	4.0	68	26.9	4.9	2	149.1	6.2	104	36.3	4.4
Butisan Star 416 SC	1	124.0	4.1	72	28.7	5.4	1	147.9	6.2	105	37.9	4.5
$LSD_{0.05}$ – $NIR_{0,05}$ herbicides – herbicydy		2.42	0.57	10.6 ns – ni	4.12 ns – ni	0.46		4.79 ns – ni	0.70 ns – ni	16.5 ns – ni	5.71 ns – ni	0.62 ns – ni
Canti												
Control	1	151.2	3.8	73	25.0	5.1	1	153.5	5.7	100	25.4	5.1
Command 480 EC	3	151.0	3.9	75	26.0	5.2	3	155.6	5.9	102	26.0	5.2
Nimbus 283 SE	2-3	150.6	3.8	78	25.2	4.8	3	153.0	6.0	107	25.0	4.8
Butisan Star 416 SC	1	152.3	3.8	72	29.1	5.3	1	157.1	6.2	111	28.8	5.3
$LSD_{0.05}$ – $NIR_{0,05}$ herbicides – herbicydy		3.89 ns – ni	0.42 ns – ni	10.9 ns – ni	3.71 ns – ni	0.64 ns – ni		6.4 ns – ni	0.66 ns – ni	15.3 ns – ni	4.56 ns – ni	0.51 ns – ni

ns – ni not significant differences – różnice nieistotne
F – phytotoxicity – susceptibility of plants to herbicides in scale 1:9 where – fitotoksyczność – wrażliwość roślin na herbicyd w skali 1:9, gdzie: 1 – complete weeds control – no reaction of crop – brak działania na roślinę uprawną, 9 – no reaction of weeds – crop damaged – zniszczenie rośliny uprawnej

Table 3. The sensitivity of the ES Bourbon i Nelson cultivars of winter rape on the applied herbicides and their effect on plant height, morphology and seed yield

Tabela 3. Wrażliwość odmian rzepaku ozimego ES Bourbon i Nelson na zastosowane herbicydy i ich wpływ na wysokość roślin, morfologię i plon nasion

Herbicyd Herbicide	Laskowice						Okrzeszyce					
	F BBCH 14	plant height wysokość roślin cm	no of branches per plant liczba rozgałęzień	no of siliques per plant liczba łuszczyn	seed yield plon nasion Mg·ha^{-1}	MTN WTS g	F BBCH 14	plant height wysokość roślin cm	no of branches per plant liczba rozgałęzień	no of siliques per plant liczba łuszczyn	seed yield plon nasion Mg·ha^{-1}	MTN WTS g
ES Bourbon												
Control	1	126.0	3.6	70	26.3	5.6	1	149.9	6.0	102	32.2	4.7
Command 480 EC	3	123.9	3.0	62	24.1	5.5	3	148.8	5.9	92	33.1	4.7
Nimbus 283 SE	2-3	126.5	4.2	70	26.2	5.7	3	149.2	6.2	104	29.2	4.5
Butisan Star 416 SC	1	127.7	4.2	82	29.0	5.8	1	150.7	6.2	104	33.6	4.9
$LSD_{0.05}$ – $NIR_{0,05}$ herbicides – herbicydy		2.52	0.537	10.6 ns – ni	5.11 ns – ni	0.39 ns – ni		4.91 ns – ni	0.72 ns – ni	15.6 ns – ni	5.46 ns – ni	0.39 ns – ni
Nelson												
Control	1	149.2	4.2	70	27.5	5.4	1	150.5	5.9	105	34.2	4.7
Command 480 EC	3	151.0	3.9	68	28.2	5.4	3	152.3	5.9	101	35.0	4.6
Nimbus 283 SE	2-3	150.6	4.4	74	26.1	5.3	2-3	149.4	6.1	102	34.8	4.8
Butisan Star 416 SC	1	152.3	4.4	76	28.1	5.5	1	153.4	6.2	104	36.0	4.8
$LSD_{0.05}$ – $NIR_{0,05}$ herbicides – herbicydy		4.61 ns – ni	0.48 ns – ni	11.2 ns – ni	4.91 ns – ni	0.33 ns – ni		7.1 ns – ni	0.63 ns – ni	11.6 ns – ni	4.25 ns – ni	0.37 ns – ni

for explanations, see Table 2 – objaśnienia pod tabelą 2

Table 4. Effect of herbicides on the residue levels of herbicides and quality of winter rape seeds
Tabela 4. Wpływ herbicydów na poziom pozostałości herbicydów i jakość nasion odmian rzepaku ozimego

Herbicide Herbicyd	Laskowice			Okrzeszyce		
	levels of herbicide residues poziom pozostałości herbicydów mg·kg^{-1}	crude fat tłuszcz surowy %	crude protein białko surowe %	levels of herbicide residues poziom pozostałości herbicydów mg·kg^{-1}	crude fat tłuszcz surowy %	crude protein białko surowe %
Monolit						
Control	not detected – nie wykryto	35.4	23.2	not detected – nie wykryto	38.4	21.0
Command 480 EC	0,008 clomazone	36.0	23.7	not detected – nie wykryto	38.8	20.7
Nimbus 283 SE	0,008 metazachlor	35.3	23.7	not detected – nie wykryto	38.5	20.3
Butisan Star 416 SC	0,002 metazachlor	35.0	23.5	not detected – nie wykryto	38.4	20.9
Canti						
Control	not detected – nie wykryto	37.2	22.3	not detected – nie wykryto	40.3	20.2
Command 480 EC	not detected – nie wykryto	37.6	22.0	not detected – nie wykryto	39.7	20.2
Nimbus 283 SE	not detected – nie wykryto	36.7	23.1	not detected – nie wykryto	40.0	19.7
Butisan Star 416 SC	not detected – nie wykryto	37.6	22.1	not detected – nie wykryto	40.1	19.8
ES Bourbon						
Control	not detected – nie wykryto	36.6	22.8	not detected – nie wykryto	40.0	19.9
Command 480 EC	0.006 clomazone	36.7	22.7	not detected – nie wykryto	40.0	20.0
Nimbus 283 SE	0.004 metazachlor	36.8	22.4	0.002 metazachlor	39.8	19.6
Butisan Star 416 SC	not detected – nie wykryto	37.0	21.9	0.002 metazachlor	39.9	20.3
Nelson						
Control	not detected – nie wykryto	37.3	23.3	not detected – nie wykryto	40.2	18.7
Command 480 EC	not detected – nie wykryto	37.9	22.8	not detected – nie wykryto	39.8	18.8
Nimbus 283 SE	not detected – nie wykryto	37.1	23.4	not detected – nie wykryto	40.1	18.9
Butisan Star 416 SC	not detected – nie wykryto	37.3	23.5	not detected – nie wykryto	40.0	18.8
$LSD_{0.05}$ – $NIR_{0,05}$ herbicides × cultivars – herbicydy × odmiany		2.41	1.44	1.72	1.72	1.12

* statistically significant differences compared to the control – różnice istotne statystycznie w stosunku do kontroli

Analysis of variance indicated significant variation in rapeseed yields in particular years of research. The lowest rapeseed yield was obtained in 2010 (2.77 $Mg\cdot ha^{-1}$). However, 2011 was characterized by a significantly higher yields (3.42 $Mg\cdot ha^{-1}$). On better soil in Okrzeszyce rapeseed yields were significantly higher (3.47 $Mg\cdot ha^{-1}$) compared with the results obtained in Jelcz Laskowice (2.73 $Mg\cdot ha^{-1}$). Significant interactions between years or locations and cultivars in particular herbicide variants indicate a great influence of soil and climatic conditions on the yields of cultivars and effectiveness of the studied herbicides. Among the studied cultivars, Monolit was characterized by significantly higher yields, whereas cv. Canti gave significantly lower yields in the analyzed years. Herbicide Nimbus 283 SE caused slight decrease in the yield of the analyzed cultivars compared with the control. Based on Tables 6 and 7 it may be concluded that Nimbus 283 SE caused slight decrease in the yields, particularly in cv. Monolit. Also, cv. ES Bourbon under the effect of this chemical preparation indicated lower yields compared with the control plot. After analyzing F-statistics representing quantity of environmental interaction of the analyzed cultivars in particular variants of plant protection, it may be stated that cv. Monolit indicated significant variability in the yield in years and locations, regardless of the applied herbicide. Low value of F-statistics for this cultivar on plots with herbicide Nimbus 283 SE was caused by lower yields of this cultivar under the effect of the discussed chemical substance. Herbicide Nimbus 283 SE, however, decreased stability of the yield in cv. Nelson compared with other plant protection treatments. On the other hand, herbicide Butisan Star 416 SC caused higher yield stability in cultivars Canti, ES Bourbon and Nelson (Tables 5, 6, 7).

Table 5. Analysis of variance of the yields of winter rape cultivars in different herbicide variants
Tabela 5. Analiza wariancji plonów odmian rzepaku ozimego w różnych wariantach herbicydowych

Source of variation – Źródło zmienności	Number of degrees of freedom Liczba stopni swobody	Mean square Średni kwadrat
Years – lata (1)	2	858.27**
Location – miejscowość (2)	1	1088.55**
Years x location – lata x miejscowość	2	1546.16**
Cultivars x herbicides – odmiany x herbicydy (3)	19	13.95*
Years x cultivars – lata x odmiany	38	11.10*
Location x cultivars – miejscowość x odmiany	19	5.36*
Years x location x cultivars – lata x miejscowość x odmiany	38	8.31**
Regression towards the environment – regresja względem środowiska	228	1.29

* significant at p = 0.05 – istotny przy p = 0,05; ** significant at p = 0.01 – istotny przy p = 0,01

Table 6. Yields of winter rape depending on the applied herbicide from two locations
Tabela 6. Plonowanie odmian rzepaku w zależności od stosowanego herbicydu z dwóch lokalizacji, $dt \cdot ha^{-1}$

	Cultivar – Odmiana				
Herbicydy – Herbicides	Monolit	Canti	ES Bourbon	Nelson	mean – średnia
Control – Kontrola	34.0	28.1	29.3	31.6	30.75
Command 480 EC	34.1	29.7	30.4	31.2	31.35
Nimbus 283 SE	29.8	28.3	27.8	30.1	29.00
Butisan Star 416 SC	34.2	30.6	31.8	32.5	32.28
Mean – Średnia	33.03	29.18	29.83	31.35	30.85

$LSD_{0.05}$ – $NIR_{0,05}$	
cultivars – odmiany	2.12
herbicides – herbicydy	2.46
cultivars × herbicides – odmiany × herbicydy	3.51

Table 7. Variable yielding of varieties in different herbicide variants and locations
Tabela 7. Zmienność plonowania odmian w różnych wariantach herbicydowych i lokalizacjach

Objects – Obiekty	Evaluation of the main impact Ocena efektu głównego	F-statistics Statystyka F	F-statistics of interactions between objects and locations Statystyka F interakcji obiektów z lokalizacjami
Monolit – control	3.055	3.27*	10.83*
Monolit – Command 480 EC	3.139	3.34*	25.06*
Monolit – Nimbus 283 SE	-1.120	1.82*	0.60
Monolit – Butisan Star 416 SC	3.272	5.50*	23.31
Canti – Control	-2.878	3.62*	16.74*
Canti – Command 480 EC	-1.228	1.63	3.03
Canti – Nimbus 283 SE	-2.661	3.72*	8.50
Canti – Butisan Star 416 SC	-0.320	0.58	0.58
ES Bourbon – Control	-1.620	3.68*	0.63
ES Bourbon – Command 480 EC	-0.528	1.50	0.09
ES Bourbon – Nimbus 283 SE	-3.086	4.61*	6.76
ES Bourbon – Butisan Star 416 SC	0.814	1.64	0.22
Nelson – Control	0.820	1.27	0.15
Nelson – Command 480 EC	0.264	0.42	0.54
Nelson – Nimbus 283 SE	-0.845	0.19	12.59*

DISCUSSION

Rapeseed yields are determined by many mutually dependent production factors. One of the most essential factors are cultivar traits [Wójtowicz 2005, Wójtowicz and Czernik-Kołodziej 2003, Wielebski 2009]. Cultivation „00” of rapeseed cultivars, although significantly improved the quality of oil and protein feed, genetically removing erucic acid and glucosinolates resulted in great changes in metabolism and deteriorated plant vigor and adaptation to agroecological conditions, especially in population cultivars. The use of the heterosis effect significantly affected increase in the yield quantity from 10 to 20% in hybrid cultivars compared with population cultivars. These cultivars are also characterized by high early vigor and by higher tolerance of unfavorable environmental conditions [Bartkowiak-Broda 2002]. Conducted research indicated significant variability in the yield in years and locations in population cultivar

Monolit, compared with hybrid cultivar Nelson, especially with herbicide Nimbus 283 SE, which is proved by a low value of F-statistics in the applied statistical model. Obtained results confirm Weber's research on the effect of environment on variability of the yield in rapeseed cultivars under conditions of Lower Silesia [Weber *et al*. 2003].

Apart from selection of cultivars, also effective elimination of the competitive effect of weed infestation is the condition to obtain high yields. However, sometimes despite good weed control on the field, harvested yield is low. It occurs when a cultivar responds with emergence inhibition, leaf chlorosis, permanent leaf and silique deformations to the applied herbicides [Franek and Rola 2002, Krawczyk and Adamczewski 2002].

It often occurs that lack of a visible unfavorable herbicide effect during growth may negatively affect deterioration of quality indices in rape seeds.

Conducted research indicated that of the herbicides applied in winter rapeseed cultivation, only Command 480 EC and Nimbus 283 SE used directly after sowing had a phytotoxic effect on all cultivars, which manifested itself with leaf bleaching as a result of inhibiting chlorophyll synthesis in plants by an active substance, clomazone, though only in case of cultivars Monolit and ES Bourbon, which maintained up to flowering and significantly decreased number of branches in cv. Monolit compared with the control plot.

The basic criterion in quality evaluation of rape seeds in oil technology is fat content. Although fat content in rape seeds is genetically conditioned, expression of this trait is to a large degree determined by habitat and agrotechnical factors, including stand protection against weed infestation [Muśnicki *et al*. 1997, Liersch *et al*. 2008, Łozowicka *et al*. 2012]. The conducted research on quality traits did not indicate any significant effect of the studied herbicides on the content of fat and protein in rape seeds regardless of the cultivar. However, common use of herbicides, especially soil application, inspires further research on the dynamics of distribution in soil environment and on their effect on the level of residues of active substances in the seeds [Kucharski and Sadowski 2014]. Concentration of residues of active substances of herbicides detected in the soil is mostly higher compared with the one determined in winter rape seeds, which affects successive growth of crop cultivation. Rouchaud *et al*. [1992] also indicated residues of metazachlor in the soil environment, its slower degradation and relocation, as well as negative effect on cereal cultivation.

In the analyzed rapeseed samples from plots with herbicides, no exceeding of accepted values of residues of the studied active substances was observed, and the determined concentration was on the level of detection limit of the applied methods of analysis, although when compared with the plot with no herbicide application, their higher occurrence was observed in the seeds [Kucharski and Sadowski 2014].

The research on the residues of active substances of herbicides indicated presence of small amounts of clomazone in the seeds in case of using herbicide Command 480 EC, and of metazachlor in case of using herbicide Nimbus 283 SE, which were detected in all studied cultivars, though only on lessive soils.

SUMMARY

Among the applied herbicides, only Command 480 EC and Nimbus 283 SE, applied directly after sowing rapeseed, had a phytotoxic effect on all cultivars. It manifested

itself with leaf bleaching caused by the active substance, clomazone. In case of herbicide Nimbus 283 SE, stronger symptoms of phytotoxic effect, leading to a significant yield decrease, were observed in cultivars Canti and Burbon, grown on black soils.

The residues of active substances of herbicides were detected in all studied cultivars, but only cultivated on lessive soils. Presence of small amounts of clomazone was indicated in plants after using herbicide Command 480 EC, and of metazachlor after using herbicide Nimbus 283 SE and Butisan Star 416 SC.

No influence of herbicides was observed on the content of protein and fat in the seeds of the studied rapeseed cultivars. The highest variability in the yield in years and locations was indicated by cv. Monolit, especially under the effect of herbicide Nimbus 283 SE.

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ODDZIAŁYWANIE METAZACHLORU STOSOWANEGO W MIESZANINACH Z CHLOMAZONEM I CHINOMERAKIEM NA MORFOLOGIĘ ROŚLIN I JAKOŚĆ NASION KILKU ODMIAN RZEPAKU OZIMEGO

Streszczenie. Możliwości ochrony rzepaku przed chwastami z zastosowaniem herbicydów doglebowych są znacznie ograniczone. Najczęściej zalecany do użycia w tym terminie Command 480 EC powoduje występowanie trwałych uszkodzeń pogarszających jakość plonu u wrażliwych odmian. W tej sytuacji poszukuje się skutecznych środków chwastobójczych nie wykazujących fitotoksycznego oddziaływania na odmiany o różnych cechach genetycznych. Przeprowadzone w latach 2009-2013 badania, realizowano w warunkach doświadczeń polowych, zakładanych na dwóch zróżnicowanych glebach.

W doświadczeniach badano reakcję czterech odmian rzepaku ozimego: populacyjnych – Monolit, ES Bourbon i Canti oraz mieszańcowej – Nelson na zastosowane doglebowo herbicydy Nimbus 283 SE oraz Butisan Star 416 SC. Oddziaływanie badanych herbicydów występujących jako mieszaniny metazachloru z chlomazonem oraz metazachloru z chinomerakiem na morfologię i jakość plonu odmian rzepaku ozimego porównywano do działania chlomazonu użytego w formie herbicydu Command 480 EC. Objawy fitotoksycznego oddziaływania badanych mieszanin w każdym przypadku były niższe od chlomazonu. Najbardziej bezpieczna w stosunku do wszystkich odmian okazała się mieszanina metazachloru z chinomerakiem, dla której w trakcie wegetacji nie wykazano fitotoksycznego oddziaływania. Badania pozostałości substancji aktywnych wykazały zwiększoną obecność chlomazonu po zastosowaniu herbicydu Command 480 EC oraz metazachloru w przypadku użycia herbicydu Nimbus 283 SE w nasionach odmiany Monolit i ES Bourbon uprawianych zwłaszcza na glebie płowej. W każdym przypadku były to jednak ilości nie przekraczające dopuszczonych norm. Badania cech jakościowych odmian nie wykazały istotnego wpływu herbicydów na zawartość białka i tłuszczu w nasionach. Odmiana Monolit wykazywała najwyższą zmienność plonowania w latach i lokalizacjach niezależnie od stosowanego herbicydu.

Słowa kluczowe: fitotoksyczność, herbicyd doglebowy, selektywność, pozostałości substancji aktywnych, jakość nasion

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