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EFFECTIVENESS OF DICAMBA + PROSULFURON AND REACTION OF SUGAR MAIZE (*ZEA MAYS* SSP. *SACCHARATA* KOERN.) VARIETIES

SKUTECZNOŚĆ CHWASTOBÓJCZA ORAZ SELEKTYWNOŚĆ MIESZANINY SUBSTANCJI AKTYWNYCH DIKAMBA + PROSULFURON W RÓŻNYCH ODMIANACH KUKURYDZY CUKROWEJ (*ZEA MAYS* SSP. *SACCHARATA* KOERN.)

Summary. The aim of this research was to evaluate the reaction of 10 varieties of sugar maize on the active substances dicamba + prosulfuron and assess the effectiveness of this mixture. An experiment was carried out at the Experimental-Didactic Station at Swadzim in 2008-2010. Ten sugar maize hybrids were studied. Spraying herbicide with crop oil concentrate was performed at the five- to six-leaf stage. A week after the herbicide application, weeds were collected and weighed. On this basis, the effectiveness of active substances was measured (%). The crop was evaluated visually in five periods on a 1-9 scale. After the plants came to milk ripeness, cob yield (t·ha^{-1}), share of first class cobs (%), cob length (cm), number of grains per cob and cobs per hectare were defined. It was found that the average effectiveness of the herbicide was 53-60% against the three examined weed species, namely ‘Garrison’, ‘GSS 8529’ and ‘Rustler’. Transient, phytotoxic action of active substances on the three sugar maize varieties was observed. Dicamba + prosulfuron affected the growth of cob yield, share of first class cobs and cob length. The mixture had no effect on the number of grains per cob and number of cobs per hectare.

Key words: dicamba, herbicide effectiveness, maize, prosulfuron, sensitivity

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Introduction

One of the problems in maize production is weed control. Maize is particularly sensitive to weed infestation. In the early stages of development, from emergence to covering, the subspecies is characterized by slow growth, which creates favourable conditions for the emergence and development of competing weeds. Additionally, this problem arises when the plant is grown in monoculture (Weber et AL. 1995, SNOPCZYŃSKI and GOŁĘBIOWSKA 2008). In all previously published data on losses caused by weeds, the greatest single loss is attributed to reduced crop yields (NADEEM et AL. 2008). Estimates of crop losses due to weed competition have usually ranged from 10 to 25% of total crop production (FRIESEN and SHEBESKI 1960). MCROSTIE (1949) used the lowest of these estimates and placed the losses due to weed competition in Canada at $131 500 000. This included cereal, row, hay and crops.

The best way to reduce weeds is to use herbicides and their mixtures (DOGAN et AL. 2005). The main problem in the chemical care of sugar maize plantation is its sensitivity to herbicides. This applies in particular to extra sweet varieties of this subspecies. Some active ingredients are not always secure, and phototoxic action can interfere with several life processes of plants, which results in changes in their morphology (e.g. necrosis, discoloration, growth retardation). They are usually transient, but in extreme cases they may even decrease the yield by 10-15% and lead to deterioration of its quality (ABOU-ZIENA et AL. 2008, SNOPCZYŃSKI and GOŁĘBIOWSKA 2008). This situation necessitates a concerted effort to explore new possibilities of an effective weed control in sugar maize, and to help protect crops from secondary weeds (KIERZEK and MIKLASZEWSKA 2009).

The objective of this study was to assess the response of 10 sugar maize varieties to the active substances dicamba + prosulfuron and to evaluate the efficacy of the mixture.

Materials and methods

Experimental materials and procedures

The experiment was carried out in 2008-2010 at the Experimental – Didactic Station in Swadzim (52°26′N, 16°45′E) which is part of the Poznań University of Life Sciences. The study was a randomized complete block design established with a split-plot arrangement of treatments. The experiment was set up in four replications (in four blocks). On each experimental plot, which covered 12 m^2, a 100 plants were sown in two rows. In the experiment 10 sugar maize hybrids were studied, namely ‘Claudia’, ‘EX 0871663’, ‘Garrison’, ‘Golda’, ‘GSS 8529’, ‘Rana’, ‘Royalty’, ‘Rustler’, ‘Sweet Talk’ and ‘Tessa’.

The experiment was set up on lessives, quality class IVb. The macroelement and pH content was assessed according to research procedures/standards (Regional Chemical and Agricultural Station in Poznań): P_2O_5 – PB.64 ed. 6 of 17.10.2008, K_2O – PB.64 ed. 6 of 17.10.2008, Mg – PB.65 ed. 6 of 17.10.2008, pH – PB.63 ed. 6 of 17.10.2008.

Table 1 presents soil conditions in Swadzim.

Table 1. Content of nutrients in the soil at Swadzim ($mg \cdot kg^{-1}$)
Tabela 1. Zawartość składników pokarmowych w glebie w Swadzimiu ($mg \cdot kg^{-1}$)

Nutrient Składnik	2008	2009	2010
P	85.0	96.0	88.0
K	101.0	141.0	124.0
Mg	75.0	66.0	73.0
pH_{KCl}	5.40	5.55	5.37

During the sugar maize plant vegetation, from May to September, daily meteorological data were collected: temperature, using a mercury thermometer, and rainfall, using pluviometer. The weather conditions at Swadzim are presented in Tables 2 and 3.

Table 2. Average monthly air temperature at Swadzim (°C)
Tabela 2. Średnia miesięczna temperatura powietrza w Swadzimiu (°C)

Year Rok	May Maj	June Czerwiec	July Lipiec	August Sierpień	September Wrzesień
2008	15.1	19.6	20.7	18.8	13.5
2009	14.0	16.0	20.3	20.1	15.8
2010	12.2	18.4	22.6	19.2	13.0

Table 3. Sum of monthly precipitation at Swadzim (mm)
Tabela 3. Suma miesięcznych opadów atmosferycznych w Swadzimiu (mm)

Year Rok	May Maj	June Czerwiec	July Lipiec	August Sierpień	September Wrzesień
2008	14.3	8.6	65.6	95.1	19.4
2009	109.9	113.8	75.4	26.2	48.6
2010	110.5	43.4	97.5	143.5	69.9

In addition, to extend the characteristics of weather conditions on the basis of air temperature and precipitation, Selyaninov coefficient was calculated from the equation:

$$K = \frac{10 \cdot P}{t \cdot l}$$

where:

P – total monthly rainfall,
t – average temperature of the period,
l – number of days in the period.

Coefficient values are summarized in Table 4.

Table 4. Selyaninov's hydrothermal coefficient *K*
Tabela 4. Współczynnik hydrotermiczny Sielianinowa *K*

Year Rok	May Maj	June Czerwiec	July Lipiec	August Sierpień	September Wrzesień
2008	0.30	0.15	1.02	1.63	0.48
2009	2.29	2.37	1.20	0.44	0.78
2010	2.92	0.78	1.39	0.73	1.78

K: < 0.50 – drought, 0.51-1.00 – semi-drought, 1.01-2.00 – good humidity, > 2.01 – large humidity.
K: < 0,50 – susza, 0,51-1,00 – półsusza, 1,01-2,00 – dobre uwilgotnienie, > 2,01 – za duże uwilgotnienie.

Dicamba + prosulfuron were applied one time at a dose of 300 $g \cdot h^{-1}$ when sugar maize plants were at the five- to six-leaf stage. Herbicide spraying treatment was performed, using a sprayer with a single nozzle and pressure of 175 kPa. Herbicide treatment included crop oil concentrate of isodecyl alcohol ethoxylate (90%) in a water dilution of 70 ml per 100 l as recommended on the herbicide label. Control plants, which received no herbicide treatment, were treated with water and isodecyl alcohol ethoxylate and the weeds were removed by hand.

Evaluation of the herbicide effectiveness

Weed status was measured one week after herbicide application, when the sugar maize plants were at the six- to five-leaf stage. Seven species of weeds were evaluated: barnyard grass (*Echinochloa crus-galli* L.), quack grass (*Agropyron repens* L.), lamb's quarters (*Chenopodium album* L.), European field pansy (*Viola arvensis* L.), black bindweed (*Polygonum convolvulus* L.), small-flowered Crane's-bill (*Geranium pusillum* L.), shepherd's purse (*Capsella bursa pastoris* L.). Individual weeds with roots were collected from each plot after removal of impurities, and their weight was determined ($g \cdot m^{-2}$). The effectiveness of herbicides is shown by the percentages (%) relative to control plots, made one week after application of the herbicide.

Rating susceptibility of varieties

Sugar maize plant injury symptoms were visually rated in five periods: one day, one week, three weeks and five weeks after herbicide treatment and before harvest. One person carried out the assessment in each measurement. Discolouration, necrosis, reduced plant height and total destruction were taken into account as the injury. Injury ratings were based on a scale from 0 (no injury) to 9 (complete destruction of plants).

Assessment of yield parameters

Cobs were collected manually, after the plants came to milk ripeness (BBCH 70). The factors that were determined include:

– leafless cob yield ($t \cdot ha^{-1}$) – cobs were collected from each plot, ground leaves were removed and then weighted,

– share of first class cobs (%) – full grained cobs (100%) were separated from all harvested cobs, then the percentage of completely full grained cobs was calculated for all cobs of the varieties,
– cob length (cm) – 10 consecutive cobs on each plot were measured with a ruler,
– number of grains per cob – in the next 10 cobs on each plot, the number of grains per row and the number of rows of cobs were counted, the number of grains in the cob results from these two values,
– number of cobs per 1 ha – all cobs were collected from each plot, then the result was converted into pieces per 1 ha.

Statistical analysis

The collected data were respectively averaged from plots and the years of the research. The results underwent the analysis of variance with the use of statistical programme STATPAK. The significance of differences and the lowest significant difference were set at the level of 0.05.

Results and discussion

On the control plots in 2008-2010, the average occurrence of weed differed slightly, and there were no significant differences between the years (Table 5). There was no interaction with the year. Over the three years of the research, the control field was unweeded mostly by barnyard grass – the average weight was 173.3 $g \cdot m^{-2}$, whereas shepherd's purse occurred in the smallest quantities on control plots – the average weight reached 4.3 $g \cdot m^{-2}$. When applied, the herbicide reduced weeds (Table 5). Weed size was different depending on the species. Barnyard grass was among the most often observed weeds – 108 $g \cdot m^{-2}$. Shepherd's purse was in the lowest quantities – the average weight reached 1.3 $g \cdot m^{-2}$. Herbicide efficacy compared to control objects was similar in the years of the research and it was between 53 and 60%. The efficacy of the herbicide on weeds tested was different (Table 5). The largest percentage occurred in quack grass, while 67.2%, the lowest efficiency was observed in the case of the European field pansy, shepherd's purse and lamb's quarters – 30-34.1%. KNEZEVIĆ et AL. (2003) reach a similar conclusion. They note that the post-emergence application of prosulfuron does limit common barnyard grass, common ragweed (*Ambrosia artemisiifolia* L.) and lamb's quarters. On the basis of their research on maize, ODHIAMBO and RANSOM (1993) found that dicamba is one of the most effective active ingredients to combat Striga density. However, RAHMAN et AL. (2008) note that dicamba-resistant biotype of *Chenopodium album* exists in nature. After increasing the recommended dose of the active substance, it was effective against resistant biotype, but also caused damage to corn.

The study showed that the mixture of dicamba + prosulfuron exerts a transient, phytotoxic effect on three varieties of sugar maize, namely 'Garrison', 'GSS 8529' and 'Rustler' (Table 6). The sensitivity of the plants was manifested by white discoloration and a slightly lower growth. The damage was not large, as indicated by 2 on the 1-9 scale. The plant damage appeared within three and five weeks after herbicide treatment. By the harvest time (fifth sign), these symptoms disappeared. There were no phytotoxic

Table 5. Weight of weeds before and after herbicide treatment and herbicide efficacy
Tabela 5. Masa chwastów przed zastosowaniem i po zastosowaniu herbicydu oraz jego skuteczność chwastobójcza

Weed Chwast	Weight of weeds – Masa chwastów ($g \cdot m^{-2}$)								Herbicide efficacy Skuteczność herbicydu (%)
	control kontrola				after herbicide treatment po zastosowaniu herbicydu				
	2008	2009	2010	mean średnio	2008	2009	2010	mean średnio	
Barnyard grass Chwastnica jednostronna	88	296	136	173.3	57	175	92	108.0	62.3 ab
Quack grass Perz właściwy	36	22	52	36.7	25	17	32	24.7	67.2 a
Lamb's quarters Komosa biała	30	0	0	10.0	9	0	0	3.0	30.0 f
European field pansy Fiołek polny	26	4	8	12.7	8	2	3	4.3	34.1 f
Black bindweed Rdest powojowaty	37	0	82	39.7	29	0	42	23.7	59.6 bc
Small-flowered Crane's-bill Bodziszek drobny	61	44	39	48.0	39	23	19	27.0	56.3 c
Shepherd's purse Tasznik pospolity	3	2	8	4.3	1	1	2	1.3	31.0 f
Mean Średnio	40	52	46	46.0	24	31	27	27.3	59.3 bc
$LSD_{0.05}$ $NIR_{0,05}$	n.s. – n.i.				n.s. – n.i.				5.87
Herbicide efficacy (%) Skuteczność herbicydu (%)	–				60	53	59	59.3	–

Values designated with the same letters create homogeneous groups.
n.s. – non significant differences.
Wartości oznaczone tymi samymi literami tworzą grupy jednorodne.
n.i. – różnice nieistotne.

effects of test substances active in the remaining seven varieties of sugar maize, mainly 'Claudia', 'EX 0871663', 'Golda', 'Rana', 'Royalty', 'Sweet Talk' and 'Tessa'. In their research, WALIGÓRA et AL. (2008) demonstrate that the use of dicamba on sugar maize

Table 6. 10 varieties of sugar maize plant injury caused by mixture of active substances dicamba + prosulfuron (9-steps scale: 0 – no injury, 9 – complete destruction of plant)
Tabela 6. Uszkodzenia 10 odmian kukurydzy cukrowej powodowane przez mieszaninę substancji aktywnych dikamba + prosulfuron (skala 9-stopniowa: 0 – brak uszkodzeń, 9 – totalne zniszczenie rośliny)

Variety Odmiana	Control Kontrola	1 day after treatment 1 dzień po zabiegu	1 week after treatment 1 tydzień po zabiegu	3 weeks after treatment 3 tygodnie po zabiegu	5 weeks after treatment 5 tygodni po zabiegu	Before the harvest Przed zbiorem
‘Claudia’	1	1	1	1	1	1
‘EX 0871663’	1	1	1	1	1	1
‘Garrison’	1	1	1	2	2	1
‘Golda’	1	1	1	1	1	1
‘GSS 8529’	1	1	1	2	2	1
‘Rana’	1	1	1	1	1	1
‘Royalty’	1	1	1	1	1	1
‘Rustler’	1	1	1	2	2	1
‘Sweet Talk’	1	1	1	1	1	1
‘Tessa’	1	1	1	1	1	1

plants may cause temporary damage to some varieties. Three weeks after spraying, white discoloration was observed on the leaves, but by the harvest time, visible injury disappeared. According to MARKOVIĆ et AL. (2008) prosulfuron may have phytotoxic effects on maize plants. In their experience, eight weeks after application of the active substance, damage to 5% of the tested plant was observed. At the end of vegetation, injury of maize plants did not disappear.

There was no interaction between data about leafless cob yield and the years of the research (Fig. 1). The average yield of the varieties on control plots was 20.4 $t \cdot ha^{-1}$, but after applying the herbicide, it reached 19.34 $t \cdot ha^{-1}$. Cob yield after herbicide application for control decreased or increased, the differences were significant. The largest yield increase was observed in ‘GSS 8529’ hybrid and amounted to 1.05 $t \cdot ha^{-1}$. The biggest drop in yield was observed in ‘EX 0871663’ hybrid and amounted to 0.57 $t \cdot ha^{-1}$. Herbicide application in ‘Garrison’ hybrid did not cause any significant difference in the yield.

There was no interaction between data about the number of first class cob share and the years of the research (Fig. 2). The average of the first class cobs on control plots was 71.1%, but after applying the herbicide it reached 72.6%. The use of herbicide in most cases increased the number of the first class cobs. The highest significant increase in this parameter in the yield was found in ‘Rana’ – 3.0% and ‘GSS 8529’ – 2.9%. Application of the herbicide did not affect significantly the change in the number of the first class cobs in ‘Tessa’ and ‘Garrison’ hybrids.

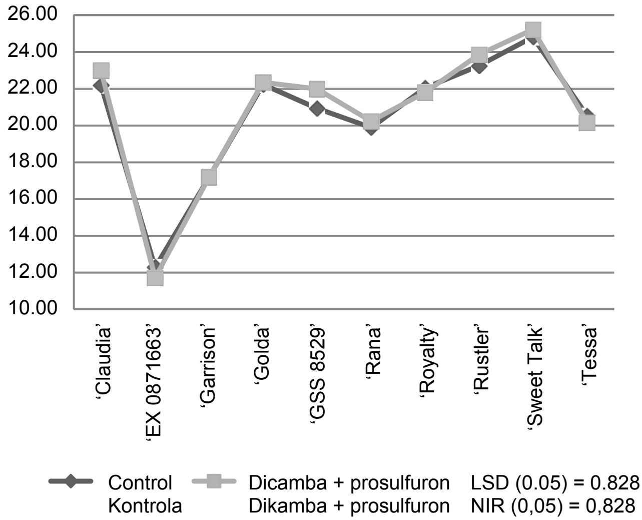

Fig. 1. Leafless cob yield by 10 varieties of sugar maize after dicamba + prosulfuron treatment (t·ha^{-1})
Rys. 1. Plon odkoszulkowanych kolb 10 odmian kukurydzy cukrowej pielęgnowanych mieszaniną dikamby i prosulfuronu (t·ha^{-1})

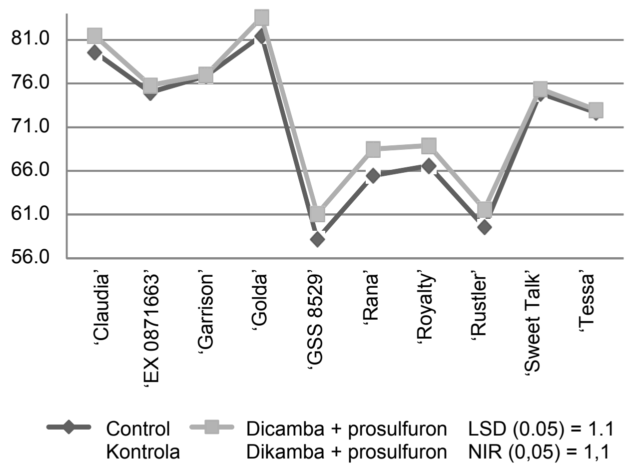

Fig. 2. Share of I class cobs by 10 varieties of sugar maize after dicamba + prosulfuron treatment (%)
Rys. 2. Udział kolb I klasy 10 odmian kukurydzy cukrowej pielęgnowanych mieszaniną dikamby i prosulfuronu (%)

There was no interaction between data about cob length and the years of the research (Fig. 3). The average hybrid cob length on control plots was 20.8 cm, but after applying the herbicide it reached 21.0 cm. The active substance used in most hybrids contributed significantly to an increase in cob length. 'Garrison' hybrid was among the most affected and the change of the cob length was equal to 0.6 cm. The active substance used had an impact on reducing cob length by 0.1 cm in 'GSS 8529'. The influence of dicamba + prosulfuron on the cob length of 'Golda' and 'EX 0871663' hybrids was not significant.

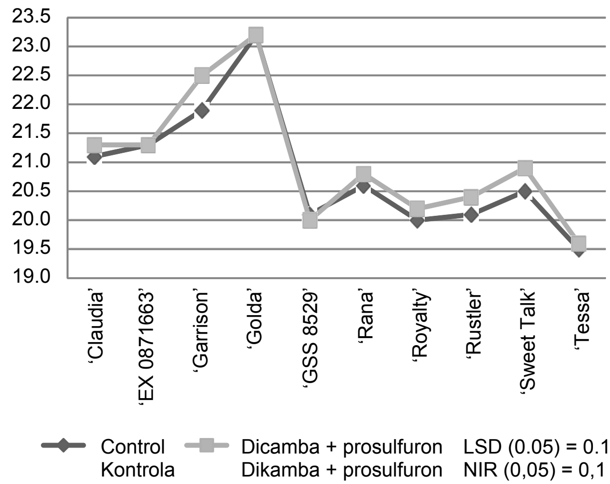

Fig. 3. Cob length by 10 varieties of sugar maize after dicamba + prosulfuron treatment (cm)
Rys. 3. Długość kolb 10 odmian kukurydzy cukrowej pielęgnowanych mieszaniną dikamby i prosulfuronu (cm)

There was no interaction between data about the number of grains in the cob and the number of cobs per hectare and the years of the research (Figs. 4 and 5). The average number of grains per cob on control plots was 619 and the number of cobs per hectare – 65 490, but after applying the herbicide, there were 607 pieces of grains and 64 572 pieces of cobs. The mixture of dicamba + prosulfuron compared to control objects did not influence significantly these two yield parameters.

The studies showed that the mixture of dicamba + prosulfuron contributed to the improvement of some yield parameters in most of the crop varieties, the percentage of first class cob share and cob length. On the basis of their research, JAMES et AL. (2005) show that dicamba can be useful in combating weeds in maize without harming the crop. However, the mixture had negative effect on the cob yield of some sugar maize varieties, the share of first class cobs and cob length. WALIGÓRA et AL. (2008) show that treatment with dicamba caused a decrease in sugar maize yield. This was observed in eight out of 10 varieties. ODHIAMBO and RANSOM (1993) reach similar conclusions based on their experiences. In their studies, dicamba lowered the maize yield only when very high concentrations of the herbicide were used. It could cause toxicity and reduce

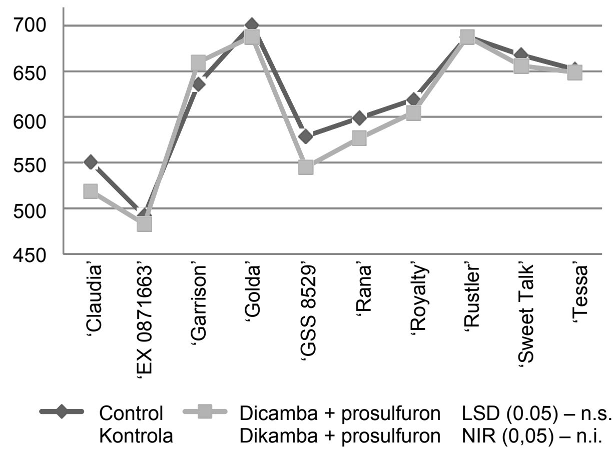

Fig. 4. Number of grains per cob by 10 varieties of sugar maize after dicamba + prosulfuron treatment
Rys. 4. Liczba ziaren w kolbie u 10 odmian kukurydzy cukrowej pielęgnowanych mieszaniną dikamby i prosulfuronu

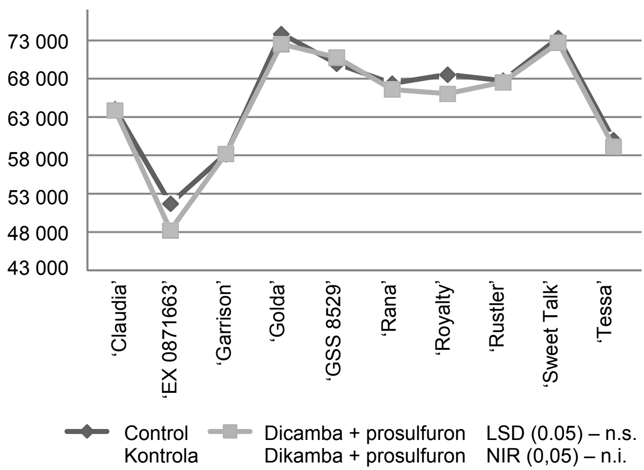

Fig. 5. Number of cobs per 1 ha by 10 varieties of sugar maize after dicamba + prosulfuron treatment
Rys. 5. Liczba kolb z 1 ha u 10 odmian kukurydzy cukrowej pielęgnowanych mieszaniną dikamby i prosulfuronu

root growth in maize (HAHN et AL. 1969). In their experiment, MARKOVIĆ et AL. (2008) examined the effect of prosulfuron on the maize plant. They observed a marginal decline in yield compared to the control objects, but the differences were not significant. However, CIOBANU et AL. (2008) notice a significant drop in maize yield after prosulfuron application. The decrease in yield was significant, amounting to 10%.

Conclusions

1. Mixture of the active substances dicamba + prosulfuron is effective in the cultivation of sugar maize as it combats the following weeds: barnyard grass (*Echinochloa crus-galli* L.), quack grass (*Agropyron repens* L.), lamb's quarters (*Chenopodium album* L.), European field pansy (*Viola arvensis* L.), black bindweed (*Polygonum convolvulus* L.), small-flowered Crane's-bill (*Geranium pusillum* L.) and shepherd's purse (*Capsella bursa pastoris* L.).

2. Researched mixture exerts a transient, phytotoxic effect on three varieties of sugar maize, namely 'Garrison', 'GSS 8529' and 'Rustler'. By the harvest time (fifth sign), these symptoms disappeared.

3. Mixture dicamba + prosulfuron in most cases affected the growth of cob yield, share of first class cobs and cob length. The mixture had no effect on the number of grains per cob and cobs per hectare.

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SKUTECZNOŚĆ CHWASTOBÓJCZA ORAZ SELEKTYWNOŚĆ MIESZANINY SUBSTANCJI AKTYWNYCH DIKAMBA + PROSULFURON W RÓŻNYCH ODMIANACH KUKURYDZY CUKROWEJ (*ZEA MAYS* SSP. *SACCHARATA* KOERN.)

Streszczenie. Celem doświadczenia była ocena skuteczności chwastobójczej oraz selektywności mieszaniny substancji aktywnych dikamba + prosulfuron w kukurydzy cukrowej. Eksperyment prowadzono w Zakładzie Doświadczalno-Dydaktycznym Swadzim w latach 2008-2010, używając 10 odmian kukurydzy cukrowej. Zabieg oprysku herbicydem przeprowadzono w fazie pięciu-sześciu liści kukurydzy cukrowej. Tydzień po zastosowaniu badanej mieszaniny zebrano chwasty, zważono je, a następnie obliczono skuteczność chwastobójczą (%). Uszkodzenia roślin uprawnych określono za pomocą skali od 1 do 9. Po osiągnięciu przez rośliny fazy dojrzałości mlecznej zmierzono plon kolb odkoszulkowanych ($t \cdot ha^{-1}$), udział kolb pierwszej klasy (%), długość kolb (cm), liczbę ziaren w kolbie oraz liczbę kolb z 1 ha. Stwierdzono, że skuteczność chwastobójcza badanych substancji aktywnych w stosunku do siedmiu gatunków chwastów wynosiła 53-60%. Zaobserwowano przemijające fitotoksyczne działanie herbicydu. Badane substancje aktywne spowodowały wzrost plonu kolb, wzrost udziału kolb I klasy oraz długości kolb, nie miały jednak wpływu na liczbę ziaren w kolbie oraz liczbę kolb z 1 ha.

Słowa kluczowe: dikamba, skuteczność chwastobójcza, kukurydza, prosulfuron, wrażliwość

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