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WEED MANAGEMENT OF HERBICIDE TOLERANT CROPS, AND THEIR POSITION IN THE HUNGARIAN CROP PRODUCTION SYSTEM

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1. INTRODUCTION, AIMS OF THE RESEARCH

The arable weed flora has changed significantly during the last decades. The number of weed species has reduced. Moreover, several invasive ‘difficult to control’ weeds have become more common in the fields, somewhere with very high abundances.
With the aim of enhancing herbicide efficacy researchers have developed herbicide tolerant (HT) crops which have been produced by transgenic and non-transgenic methods, too. Unambiguously, the HT varieties have resulted in the most highest economic profit among the first generation GM crops worldwide. In Europe and in Hungary the production of GM plants is legally governed and restricted. Therefore, in Europe most of the non- GM HT crops are of increasingly economic importance, and the research has started in this area of science, respectively.
In Hungary the growers can use the weed control technologies in sunflower successfully, which are based on tolerance towards imidazolinone (IMI) and tribenuron-methyl (SU). They are applied increasingly in practice nowadays. In cycloxydim-tolerant (CT) maize the usage of cycloxydim enables super selective chemical control against the monocot species. These facts are very insistent, because the *Poaceae* species spread spectacularly. The development of imidazolinone-tolerant (IMI) rape targets firstly the enlargement of effective post-emergent herbicide choice in rape.

Aims of the research:

● Evaluation of the weed control efficacy of the imidazolinone and the trineuron-methyl tolerant sunflower technologies. Comparing them with each other and with the non-tolerant sunflower weed control methods. Demonstrating their advantages and disadvantages. Special attention must be paid to the control of common ragweed, because of its great importance.

● Describing the phytotoxicity effects on the crops as a result of treatments. Discussing their influence on the crop cultivation with special regard to the new improved hybrids.

● Examination of the opportunities of the effective post-emergent chemical control against the monocot and dicot weeds in the tribenuron-methyl tolerant sunflower with respect to crop phytotoxicity.

● Studying the adaptability of precision technologies through the post-emergent weed control of sunflowers.

● The sunflower volunteer causes herbological problems after growing their culture varieties. One aim of our research is to investigate to what extent the sunflower volunteer germinates in relation to the passed time since sunflowers were previously cultivated.

- Based on dates of bibliography it is well-known that the imidazolinone and/or sulfonyl-urea resistant weeds show cross-resistance in many cases. We search in our experiments to what extent of resistance and/or susceptibility of different types of sunflower volunteers possess against AHAS-inhibitor herbicides.
- Investigation of the maize weed control technology which is based on tolerance to cycloxydim. Description of the possibilities, which are able to give the best weed control efficacy against the annual and perennial monocot species in relation to the time of herbicide application besides the development of maize and weeds, respectively. Paying special attention to weed control efficacy against the Johnson grass.
- Measuring of the degree of tolerance of CT maize to cycloxydim herbicide. Moreover, examination of the tolerance and/or susceptibility of the CT maize to other ACCase inhibitor herbicides in order to find out if growers can use other graminicides for their weed management.
- Investigation of the adaptability of IMI rape weed management system.

2. MATERIALS AND METHODS

2. 1. Herbicide-tolerant (IMI and SU) sunflower

2. 1. 1. Examining the weed control efficacy

The experiments were carried out in 2008, 2009, and 2011. The non-tolerant and the HT weed control technologies were applied next to each other. We evaluated the effect of hoeing in line separately. We performed experiments with IMI sunflowers to eradicate *Cirsium arvense* in an effective way during 2008, where we estimated the hoeing in line (BBCH 12) – imazamox (BBCH 14) – hoeing in line (BBCH 32) treatment.

Applications were made with field sprayer. We appointed 4-4 examined areas in all technologies which contained an untreated check and a treated plot, respectively. On these areas, weed surveys were done after the method of Balázs-Ujvárosi and we assessed the effect of herbicides against the different weed species, respectively. The weed control efficacy was visually assessed on a scale of 0 to 100 (0% = no weed control, 100% =full weed control). All dates were subjected to ANOVA. Means were separated with Student-Newman-Keuls test at $P \leq 0.05$. The significant differences were marked with different letters which followed the values of weed control efficacy through the descriptions of results (this method was applied through the dissertation).

2. 1. 2. Examining the phytotoxicity in imidazolinone-tolerant sunflower

We estimated the phytotoxicity effect on different types of IMI sunflowers which caused the imazamox. The examined hybrids were in 2008 and 2009: LG 56.58 CL, LG 56.63 CL, MV Primis, ES Florimis, NK Alego, NK Neoma (all of them are IMISUN sunflower). In 2011: The previous hybrids, as well as a CLHA-Plus futhermore P64LC09 and XF2411 which were developed by Pioneer Company (the type of tolerance is not known).

Applications were made with field sprayer. We appointed 4-4 examined areas which contained a hoed control and a treated plot, respectively. Visual evaluation of phytotoxicity was done using a scale of 0 to 100 (0=no damage, 100=plant death). The dates of replications were subjected to statistical analysis.

2. 1. 3. Examining the phytotoxicity and opportunities of usage of herbicide mixtures in tribenuron-methyl-tolerant sunflower

We examined SU sunflower hybrids which carry the attribute of tolerance with heterozyge (PR63E82) or homozygote (2009: P63A05, P64A31, P64A29, XF4005-X018; 2011: P64LE13) alleles. Applications were made with a hand sprayer in more replicates. The examined treatments were (1) tribenuron-methyl 22.5 and (2) 34 g ha^{-1}; (3) tribenuron-methyl 22.5 g ha^{-1} + graminicide; (4) tribenuron-methyl 22.5 g ha^{-1} + thifensulfuron-methyl 7.5 g ha^{-1} (only 2011).

The value of phytotoxicity was visually expressed in percentage. In addition we performed 3 (PR63E82, PR63A05, XF4005-X018) and 2 hybrids yield measurements in 2009 and in 2011, respectively. All results were subjected to statistical analysis.

2. 1. 4. Examining the opportunities of adaptation of precision weed control technologies

We carried out the field trials in tribenuron-methyl-tolerant sunflowers. Weed survey was regularly conducted in every 0.5 hectare. The dates of weed surveys were done by interpolation using AgLeader SMS Basic software to show the within field distribution of monocot and dicot weed species. Based on these results we prepared treatment prescription to apply it for the monocot and dicot herbicides.

2. 1. 5. The degree of infestation of weedy volunteer sunflowers after several years of the sunflower cropping

The study was conducted on three sunflower fields where sunflower growing had been performed three, four and five years before. During the field survey one sample plot was regularly designated in every 0.5 ha by means of a GPS device. We determined the cover values (%), the number (plants m^{-2}) and frequency (%) of sunflower volunteers.

2. 1. 6. Examining the opportunities of weed control against the HT volunteer sunflowers.

We tested (2009, 2010, and 2011) the susceptibility of volunteers from different tolerant sunflower hybrids against AHAS-inhibitor herbicides without cultivation of crop. The volunteers were collected from the previous year harvest therefore these were the F2 generation of hybrids. The examined hybrids were: (1) non-tolerant F2 (2) IMISUN F2 (3) CLHA-Plus F2 (excepted 2010) (4) CLHA-Plus/IMISUN F2 (5) heterozygote SU F2 (6) homozygote SU F2 (excepted 2009) (7) IMISUN F4 (only 2011).

The tested treatments were: (1) 15 g ha^{-1} amidosulfuron + 3.75 g ha^{-1} jodosulfuron (2) 4 g ha^{-1} metsulfuron-methyl (3) 10 g ha^{-1} triasulfuron (4) 35 g ha^{-1} tritosulfuron (5) 35 g ha^{-1} tritosulfuron + 0.1 l ha^{-1} fluroxipyr (6) 10 g ha^{-1} aminopyralid + 10 g ha^{-1} pyroxsulam + 5 g ha^{-1} florasulam (7) 10 g ha^{-1} rimsulfuron (excepted 2010) (8) 15 g ha^{-1} rimsulfuron (excepted 2009) (9) 10 g ha^{-1} rimsulfuron + 5 g ha^{-1} thifensulfuron-methyl (10) 12.5 g ha^{-1} prosulfuron + 7.5 g ha^{-1} pirimisulfuron (11) 22.5 g ha^{-1} tribenuron-methyl (12) 48 g ha^{-1} imazamox (13) 7.5 ha^{-1} thifensulfuron-methyl (14) 10 g ha^{-1} thifensulfuron-methyl (only 2011) (15) 15 g ha^{-1} triflusulfuron-methyl.

In 2010 we examined in cropped maize the efficacy of rimsulfuron, rimsulfuron + thifensulfuron-methyl, thifensulfuron-methyl, foramsulfuron herbicides against naturally germinated SU and IMISUN, futhermore unnaturally infested non-tolerant volunteers, respectively. During 2011 in cropped sunflower we investigated the weed control efficacy of imazamox, imazamox + hoeing in line, tribenuron-methyl, tribenuron-methyl + hoeing in line treatments against naturally germinated IMISUN and SU and sowed by us CLHA-Plus and non-tolerant volunteers, respectively. The efficacy of imazamox, thifensulfuron-methyl, bentazone herbicides against IMISUN, SU, CLHA-Plus and non-tolerant sunflower volunteers were studied in cropped soybean in 2010. In addition, the availability of 2,4-DB (earlier permitted) was estimated in soybean.

Applications were done with hand sprayer in several replicates. We assessed the efficacy of treatments applied to the different types of sunflower volunteers. All results were subjected to statistical analysis.

2. 2. Cycloxydim-tolerant maize

2. 2. 1. Examining the weed control efficacy

We estimated weed control effect of the technology in 2009, 2010 and 2011, where the bentazone + dicamba herbicide for dicot weeds was used at BBCH 13 stage of maize. The efficacy of cycloxydim (150 g ha^{-1}) was evaluated with two applications: (1) early post (2) late post.

The CT technology was examined under high infestation of *Cynodon dactylon* in 2009 and 2010. The examined treatments were: (1) 200 (early post) + 100 (late post) g ha^{-1} (2) 200 (early post) + 200 (late post) g ha^{-1} (3) 300 g ha^{-1} (late post) (4) 400 g ha^{-1} (late post).

In 2009 we assessed the cycloxydim efficacy against *Phragmites australis*. The treatments were: (1) 400 g ha^{-1} (early post) (2) 400 g ha^{-1} (normal post) (3) 400 g ha^{-1} (late post) (4) 200 (early post) + 200 (normal post) g ha^{-1} (5) 200 (early post) + 200 (late post) g ha^{-1} (6) 300 (erly post) + 100 (late post) g ha^{-1} (7) 300 (early post) + 200 (late post) g ha^{-1}.

The herbicide effect against Johnsongrass was examined in 2010 and 2011, where we evaluated the two following cycloxydim treatments: (1) 400 g ha^{-1} (normal post) (2) 200 (early post) + 200 g ha^{-1} (late post).

Applications were done with hand sprayer in more replications. All results were subjected to statistical analysis.

2. 2. 2. Examining the phytotoxicity and cross-resistance

We carried out field trials in 2010 and 2011 to measure the tolerance of CT maize against the cycloxydim and other graminicides, respectively. The tested treatments were in 2010: cycloxydim (150, 400 and 800 g ha^{-1}), quizalofop-p-tefuryl (40, 120 and 240 g ha^{-1}), haloxyfop-r-methylester (55, 215 and 430 g ha^{-1}); in 2011: the previous treatments and propaquizafop (75, 150 and 300 g ha^{-1}), fluazifop-p-buthyl (120, 375 and 750 g ha^{-1}). Treatments were post-emergently made at BBCH: 15-17 stage of maize. During the experiments a standard area was included into each treatments, where weed control was performed using a combination of 160 g ha^{-1} dicamba + 50 g ha^{-1} topramezone.

The value of phytotoxicity was visually expressed in percentage, moreover the treated plots were harvested. All results were subjected to statistical analysis.

2. 3. Imidazolinone-toelrant rape

The weed control efficacy was examined through the next treatments in 2009/2010: 40 g ha^{-1} imazamox, in 2010/2011: (1) 835 g ha^{-1} metazachlor + 210 g ha^{-1} quinmerak, (2) autumn applied 40 g ha^{-1} imazamox, (3) spring applied 40 g ha^{-1} imazamox. The phytotoxicity effect of imazamox was assessed on the following hybrids in 2009/2010: X08W985I, X08W984I, X08W982I; in 2010/2011: PX100CL, PX200CL.

3. RESULTS AND DISCUSSIONS

3. 1. Herbicide-tolerant (IMI and SU) sunflower

3. 1. 1. Examining the weed control efficacy

By using the conventional pre-emergent methods – when the environmental effects were suitable – we were able to control the monocot and also some dicot species successfully. Although, they had also only partial effect against the common ragweed. The efficiency were estimated at 95.5^{b}%, 83.5^{d}%, 92.8^{c}%, 97.5^{b}% in 2008 and at 97^{c}%, 85^{b}%, 94^{b}%, 93^{b}% in 2011 against *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Chenopodium album*, *Datura stramonium*. On the contrary, there was no precipitation in 2009 so the treated plots became full of weeds. The flumioxazon showed weak weed control effect. We got a much better weed control effect with the cultivation of IMI and SU sunflowers in all cases. Moreover, both technologies could suppress common ragweed. We noted the decreased efficacy of imazamox against the *Chenopodium album* in dry weather conditions. The efficacy of imazamox were possessed 97.3^{b}%, 99.8^{a}%, 93.8^{b}%, 94.8^{b}%, 98^{ab}% in 2008; ø , 99^{a}%, 95^{a}%, 96.2^{a}%, ø , in 2009; 98.5^{ab}%, 99.3^{a}%, 98.3^{a}%, 73.5^{d}%, 99.8^{a}% in 2011 against the *Echinochloa crus-galli*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Chenopodium album*, *Datura stramonium.* The tribenuron-methyl showed in 2008: 98.3^{a}%, 90^{c}%, 98.5^{a}%, 100^{a}%, in 2009: 98^{a}%, 90.3^{b}%, 99.7^{a}%, 100^{a}% and in 2011: 100^{a}%, 97^{a}%, 95^{ab}%, 100^{a}% efficacy against the premited species (excepted barnyardgrass). The inter-row cultivation improved the weed control efficiency in all cases. We were able to do successful weed management against *Cirsium arvense* with the hoeing in line – imazamox – hoeing in line treatment.

3. 1. 2. Examining the phytotoxicity in imidazolinone-tolerant sunflower

Temporary visual phytotoxicity symptoms evolved on the IMISUN hybrids after the treatments. However, we did not see this phenomenon on the newly improved IMI sunflowers (CLHA-Plus, Pioneer IMI).

3. 1. 3. Examining the phytotoxicity and opportunities of usage of herbicide mixtures in SU sunflower

The 2., 3., and 4. treatments caused high crop damages on the heterozygote SU hybrids, they yield were in 2009: 3.48^{a}, 1.16^{b}, 0.62^{b}, in 2011: 3.34^{a}, 2.4^{b}, 2.23^{b}, 2.69^{b} tonne ha^{-1}. None of them resulted in crop injury on homozygote varieties.

3. 1. 4. Examining the opportunities of adaptation of precision weed control technologies

Our results have indicated that the full sunflower fields need to be sprayed with herbicides for monocot and also dicot species.

2. 1. 5. The degree of infestation of weedy volunteer sunflowers after several years of the sunflower cropping

The volunteer sunflower germinated in great quantities in the fields, where sunflowers were grown three years ago (15% cover; 2.56 plants m^{-2}). Its importance decreased during the fourth (5% cover; 0.73 plants m^{-2}) and the fifth (0.95% cover, 0.33 piece m^{-2}) year after the cultivation of sunflowers.

3. 1. 6. Examining the opportunities of weed control against the HT volunteer sunflowers.

The IMISUN sunflowers showed moderate cross-resistance to SU herbicides. Application of metsulfuron-methyl, tribenuron-methyl, thifensulfuron-methyl (in 2009: 75.6^{c}%, 27.8^{e}%, 84.4^{b}%, in 2010: 72.2^{b}%, 37.7^{d}%, 43.7^{c}%, in 2011: 52.3^{e}%, 24.5^{g}%, 24.8^{g}%) and triflusulfuron-methyl (10.8^{h}%) resulted weak efficacy. The types of CLHA-Plus sunflowers were extremely susceptible to sulfonyl-ureas (excepted rimsulfuron). High level of tolerance of SU sunflower volunteers were observed against the metsulfuron-methyl, rimsulfuron + thifensulfuron-methyl, thifensulfuron-methyl, imazamox (efficacy against homozygote SU F2 in 2010: 26.7^{d}%, 23.3^{d}%, 6^{ef}%, 9,3^{e}%; in 2011: 16.5^{f}%, 17.3^{f}%, 16.8^{f}%, 17.8^{f}%) and triflusulfuron-methyl (12.3^{f}%). They showed lower resistance to triasulfuron and rimsulfuron (efficacy

against homozygote SU F2 in 2010: 43.7^{b}%, 35.7^{c}%; in 2011: 25.3^{e}%, 30.5^{de}%). The homozygote types had higher level of resistance than the heterozygotes in all cases.
Growers have to pay attention to the presence of resistant sunflower volunteers by our applied weed management program in cereal crops, and as far as possible they should not use the herbicides which contain only sulfonyl-ureas. From cropped sunflower the chemical control methods could eradicate only the non-tolerant volunteers in HT hybrids and the CLHA-Plus varietas in SU sunflowers. The weed control efficacy was not holistic in other cases. The application of hoeing in line reduced significantly the cover of weedy sunflower. Probably, the resistant volunteers will cause the major herbological problem for soybean and other pulses crops. In this case the weak weed suppression ability of pulses connects to the great tolerance to imazamox and thifensulfuron-methyl of IMISUN and SU sunflower volunteers, respectively. Growers have to apply plus treatments against them. For this aim, the bentazone, the 2,4-DB and their combinations may be effective. The 2,4-DB causes phytotoxicity effects on soybean, but their usage is possible. The CLHA-Plus sunflowers offer a significant solution, because they are killed well by thifensulfuron-methyl.

3. 2. Cycloxydim-tolerant maize

3. 2. 1. Examining the weed control efficacy

We received the best weed control effect on the annual weed species in CT maize, when we separated the treatments against monocot and dicot species, respectively. Treatment to control dicot species had to be applied at maize BBCH 13 stage in order to free the crop from the mass competitiveness of weeds. When we treated against the monocot weeds in the same time, some species which germinating later were not contacted with the herbicide. Weed control effect was in 2009: 92.3^{b}%, 96.8^{b}%, 86^{b}%; in 2010: 88^{b}%, 97.5^{a}%, 90^{b}%; in 2011: 92^{b}%, 99.3^{a}%, 89^{b}% against *Echinichloa crus-galli*, *Panicum miliaceum*, *Setaria verticillata.* Most monocots were developed at the time of the late post-emegent treatment however the application of 150 g ha^{-1} cycloxydim killed them safely. The weed control efficacy against the aforementioned species in 2008 was: 98.5^{a}%, 99.5^{a}%, 96.8^{a}%; in 2009: 98^{a}%, 99.3^{a}%, 97.3^{a}%; in 2011: 99^{a}%, 99.8^{a}%, 97.8^{a}%. Due to good weed control effect on foliar uptake of bentazone + dicamba and the slower soil persistance of dicamba complements well the graminicide thus the maize field may be free from both monocot and dicot species.
The usage of cycloxydim creates opportunities for eradication of *Cynodon dactylon* and *Phragmites australis* in maize. The most effective solution was observed the early (200 g ha^{-1}) then late (200 g ha^{-1}) post-emergent application of cycloxydim. The

normal post-emergent treatment was able to kill the *Sorghum halepense*, but unambiguously the shared application of them gave the most prominently effect (in 2010: 98.3^{a}%, in 2011: 97^{a}%).

3. 2. 2. Examining the phytotoxicity and cross-resistance

The CT maize had high level of tolerance to cycloxidim. Their yield was on the standard plots in 2010: 8.1^{a}; in 2011: 10.29^{a} tonne ha^{-1}, and on the plots where used 800 g ha^{-1} cycloxydim in 2010: 8.04^{a}; in 2011: 10.55^{a} tonne ha^{-1}. In our experiments the lower rates of other types of graminicides did not reduce the yield, while application of higher dosage did. On the plots where quizalofop-p-tefuryl was used the yield was at dosage of 40 g ha $^{-1}$ in 2010: 7.99^{a} and in 2011:10.38^{a} tonne ha^{-1}, at dosage of 240 g ha^{-1} in 2010: 5.92^{c} and in 2011: 3.49^{c} tonne ha^{-1}.

3. 3. Imidazolinone-tolerant winter rape

The weed control technology in IMI rape showed obviously better effect than in non-tolerant rape could be achieved. Good results were received against typical weeds of rape, including the *Cruciferae* species, respectively. The efficacy of the 1. 2. 3. treatments against *Descuriania Sophia* was 48.8^{c}%, 93.8^{b}%, 100^{a}% in 2011. In the cropping year the applied technology have to depend on the weather and the weed flora of field, respectively. The treatments did not cause phytotoxicity on the rape.

4. NEW SCIENTIFIC RESULTS

1. Our examinations confirm, that the growing of herbicide tolerant sunflowers may result effective weed control therefore the risk of crop cultivation reduces to low level (in contrast to the non-tolerant sunflowers). We can declear that good weed control effect is achieved with one well timed postemergent treatment. Imazamox and tribenuron-methyl kill *Amrosia artemisiifolia* to 4 –leaf- stage, but the developed plants at this stage are able to regrow. The effect of imazamox against *Chenopodium album* may decrease in dry weather. Hoeing in line increases more the efficiency of weed control and reduces the weed cover, respectively. The weed control against *Cirsium arvense* may be successful in IMI sunflowers, when we apply the hoeing in line (BBCH 12) – imazamox (BBCH 14-16) – hoeing in line (BBCH 30-32) treatment.

2. According to our examinations the yellow flash and growth depression of plants do not evolve on new improved CLHA-Plus and also imidazolinon-tolerant sunflowers from Pioneer company after imazamox treatment. As a result of high damage on heterozygote tribenuron-methyl tolerant sunflowers, it does not have any possibilities of increasing the dosage of tribenuron-methyl, the applied it in tank mix with thifensulfuron-methyl and graminicides, respectively. The homozygote tribenuron-methyl tolerant hybrids tolerate all of the previous treatments without crop injuries.

3. Because the sunflowers are cropped with wide linespacing it shows huge weed densities by monocot and also dicot species in their early stage of development. Therefore their precision postemergent weed control is not feasible so at their cultivation the full area has to be sprayed.

4. Our experiment has indicated that sunflower volunteer infests in great quantities and it is the dominant species of weed flora in the third year after sunflower cropping. It has a reduced dominance in the fourth year and its importance becomes even smaller in fifth year after their cropping. The distribution of weedy sunflowers is uniform within the field.

5. The property of herbicide resistance remains also in herbicide-tolerant sunflower volunteers, accordingly it is an inheritable ability. It is confirmed in the dissertation, that certain types of herbicide-tolerant varieties show different level

of resistance and/or cross-resistance to the AHAS-inhibitors. The IMISUN sunflowers are effectively eradicated by amidosulfuron + jodosulfuron, tritosulfuron, rimsulfuron, prosulfuron + pirimisulfuron, additionally triasulfuron and rimsulfuron + thifensulfuron-methyl has moderately good efficacy. In contrast, the application of metsulfuron-methyl, tribenuron-methyl, thifensulfuron-methyl, and triflusulfuron-methyl show only a weak weed killer effect. The property of herbicide resistance is expressed in IMISUN volunteers in several years after their cropping, however it may reduce a little. The CLHA-Plus varietes have prominent susceptibility to sulfonyl-ureas (excepted rimsulfuron). The volunteers from tribenuron-methyl tolerant hybrids are able to be killed accordingly by amidosulfuron + jodosulfuron, tritosulfuron, prosulfuron + pirimisulfuron. It possesses reliable cross resistance to metsulfuron-methyl, rimsulfuron + thifensulfuron-methyl, thifensulfuron-methyl, triflusulfuron-methyl and imazamox. Lower level of cross-resistance is showed against triasulfuron and rimsulfuron, respectively. The homozygote types have higher resistance than the heterozygote forms in all cases. The only usage of AHAS-inhibitors causes reduced efficacy against IMISUN and SU volunteers in maize in sunflower and in soybean, respectively. In contrast, the sulfonyl-ureas can get rid of CLHA-Plus sunflowers.

6. Based on our results the best weed control effect on the annual weeds may be achieved, when the herbicide against dicotyledons is sprayed at maize three- leaf-stage and applied against the monocotyledons is done at the five -to -seven –leaf-stage of maize. It is a new opportunity, that with the usage of cycloxydim *Cynodon dactylon* and *Phragmites australis* can be killed with high degree. Cycloxydim is extremely effective against Johnsongrass with application of shared treatment.

7. We have proved that the multiple dosage of cycloxydim does not cause injury on cycloxydim-tolerant maize. In contrast, it possesses just moderate cross-resistance to other ACCase-inhibitor herbicides, so these results exclude the use of them in CT maize.

8. In accordance with our examinations the extreme weed control effect can be achieved by the application of technology which based on imidazolinone-tolerance in winter rape hybrids. The effect of imazamox may be convenient during the autumn and the early spring applications, without causing crop phytotoxicity.

5. LIST OF PUBLICATIONS

Rewieved papers published in scientific journal

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