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THE EFFECT OF SOME *ALS* INHIBITING HERBICIDES IN CHAMBIC CERNOZEM SOIL

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Abstract

The herbicides with ALS (inhibiting the enzyme acetolactate synthase) are rather unique in their ability to control weeds through both foliar uptake and through root uptake as they are also biologically active in soil. This provides control of both emerged weeds and those that emerge after time of application. Other benefits include low application rates and low mammalian toxicity. Carryover of a herbicide beyond the year of application can be of benefit in controlling weed growth in subsequent years, but can also be of concern in causing injury to sensitive crop species that may be grown in the years following application. The paper present the results concerning the study on the residual effect of some herbicides (inhibiting the enzyme acetolactate synthase - ALS) applied for weed control in sunflower crops in relationship with the climatic conditions. The phytotoxicity and persistence of the herbicides in soil was assessed using the mustard root inhibition bioassay. In earlier stage of mustard vegetation the treatments withimazamox herbicide had a residual effect, but over time this effect was significantly reduced. The chemical composition of the soil was not affected by the applied herbicides. The results indicate that for wheat was not residual effect for any of treatments used.

Key words: *herbicides with ALS, residual effect, phytotoxicity, mustard, bioassay.*

INTRODUCTION

Acetolactate synthase (ALS)-inhibiting herbicides have been used extensively in agricultural production mainly because of their remarkable efficacy at very low application rates. However, it has been recognized that the ALS-inhibitors are the most resistance-selective herbicide group. ALS-herbicides were first introduced in the early 1980s, and since then, rapid increase in incidence of resistance to these herbicides has been reported; more weeds have become resistant to ALS-inhibiting herbicides than to any other herbicide mode of action (Whitcomb, 1999).

The rate of pesticide breakdown in field conditions depends on soil moistureand temperature, which are very important factors in determining the rate of pesticide breakdown. There are different mechanisms which determine the environmental fate of a herbicide such as volatilization, breakdown from sunlight (photolysis), leaching etc. However, the two main mechanisms of herbicide degradation are microbial and chemical hydrolysis. These two processes are dependent on soil water and temperature. However, soil moisture is more important for herbicides that require microbes for its degradation (Streck, 2005). Soil microbesthrive in warm soils, which results in faster degradation. It is estimated that there is a two to three-fold increase in chemical half life with a 10°C decrease in temperature (Walker, 1987).

In field conditions, soil properties such as organic matter content, soil moisture, soil texture, and soil pH play also an important role in the carryover potential ofresidual herbicides (Walker, 1987). With Clearfield® technology, herbicide adsorption to organic matter may reduce its bioavailability and the moisture holdingcapacity of high organic matter soils makes them conducive to increased microbialactivity. The importance of soil organic matter in reducing carryover potential hasbeen shown in studies conducted on sulfosulfuron and flucarbazone (Moyer & Hamman, 2001; Eliason et al., 2002). The effect of clay content on herbicide residues is similar to organic matter in that it tends to adsorb the herbicide as well as improve the water holding capacity. Soil pH is another factor affecting the residual characteristics of some herbicides in field conditions. A low soil pH (less than 7.0) tends to increase the persistence of imidazolinone herbicides such as imazethapyr, imazamethabenz, and imazamox. Imidazolinone herbicides tend to be more adsorbed under acidic (lowsoil pH) conditions, which reduces their availability for microbial degradation (Loux & Reese, 1992). Extended carryover of imidazolinone herbicides in acidicsoils may also be related to their sorption-desorption characteristics.

ALS-herbicides inhibit biosynthesis of branched-chain amino acids and affect primarily root growth of susceptible plants through inhibition of cell division at the root tips. Therefore, measuring root length reduction of sensitive plant species is the most common detection approach used in bioassays for ALS-inhibiting herbicides.

Benefits of the bioassay are that whole-plant bioassays show biological effects of herbicides present, often at levels below chemical detection thresholds. They can be more useful than chemical detection methods due to interactions with soil organic matter, pH, soil moisture and soil texture. Finally, it is the only risk management tool available to growers at this time.

The objective of this study was to determine using bioassay, the persistence of imazamox herbicide inhibiting the enzyme acetolactate synthase (ALS) (applied for weed control in sunflower crops) in relationship with the climatic conditions and different soil caracteristics.

MATERIALS AND METHODS

The experience was carried out at SC Profarma Holding SRL from Fundulea (situated in south-east part of Romania) in the years 2017 and 2018 under non-irrigated conditions on cambic chernozem soil**.**

The experiment was designed by the block method, in three replications, size of the experiment plot was 25 m^2.

Treatments with herbicides based on imazamox were applied to sunflower using technologies and specific resistant hybrids**.**

Soil samples were collected after crop harvest, in three repetitions, from 0-20 cm depth of soil, (Table 1)**.**

To estimate the persistence in soil of studied herbicides was used the bioassay method developed by Eliason et al. (2004) and modified by Petcu et Oprea (2013). It was used mustard (plant sensitive to studied herbicides) and winter wheat (because is known that wheat is sown frequently after sunflower). Seeds were sown at a depth of 2 cm every 2.5 cm along the pot wall. Six seeds of similar size were selected and placed in transparent pots filled with 150 g soil (Figures 1, 2).

Table 1.Calendar and schedule of soil sampling

Date of harvesting soil samples	Treatments
October 12, 2017	**C -** Control, no herbicide
	T1- Pulsar ® 40, dose of 1.2 l/ha
	T2- Generic dose of 1,2 l/ha
	T3- Pulsar Plus, dose of 1.6 l/ha
	T4 - Pulsar Plus, dose of 2 l/ha)
October 14, 2018	**C -** Control, no herbicide
	T1- Pulsar ® 40, dose of 1.2 l/ha
	T2- Generic dose of 1,2 l/ha
	T3- Pulsar Plus, dose of 1.6 l/ha
	T4 - Pulsar Plus, dose of 2 l/ha)

The seeds were carefully placed vertically, embryo downwards and facing the wall to facilitate root growth along the transparent wall.

After sowing, the clear pots were wrapped in aluminum foil and placed in dark-colored paper bags to exclude light from the developing.

The plants were watered with the same amount of tap water avoiding dry and kept at a room temperature of 20-25°C.

Figure 1. Experience with mustardin the firs days

Figure 2. Experiences with mustard

On the ten day after seeding the plants were manually removed from the soil (Figure 3) and the length of root and shoot was measured.

The reduction rate was calculated according to the formula:

RL = (1-Lt/Lo)*100, where:

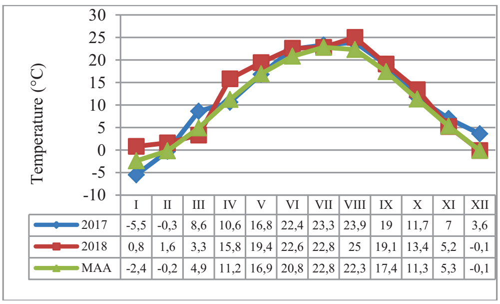
Lt is root length from soil with treatments and Lo is root length from control soil.

Figure 3. Winter wheat plants removed from soil (pots)

RESULTS AND DISCUSSIONS

The average of temperature during April and May 2018 exceeded the normal of the zone with 4.6°C and 2.5°C respectively, while in 2017 in the same period the temperatures were lower by 0.6 and 0.2°C, respectively.

On average, temperatures in 2018 exceeded normal area by 1.6°C and in 2017 only 0.9°C (Figure 4).



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2017	-5,5	-0,3	8,6	10,6	16,8	22,4	23,3	23,9	19	11,7	7	3,6
2018	0,8	1,6	3,3	15,8	19,4	22,6	22,8	25	19,1	13,4	5,2	-0,1
MAA	-2,4	-0,2	4,9	11,2	16,9	20,8	22,8	22,3	17,4	11,3	5,3	-0,1

Figure 4. Monthly average temperature (2017, 2018) and multiannual average temperatures (1960 - 2018)

The years of experimentation were totally different from the viewpoint of quantity and monthly repartitions of rainfall.

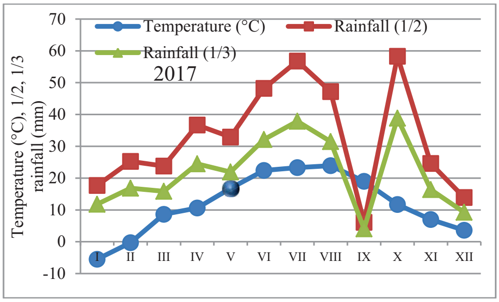


Figure 5. The climate diagram for 2017 (the method for the climate diagram consists in the graphical representation of 1/2 and 1/3 of the total value of recorded rainfall and average temperature)

In 2017 was a moisture deficits in September, as shown in Figure 5. As compared cu 2017, the year 2018 was a year with two water deficits.

First moisture deficits was from April up to May and the second ones was from august to middle of octomber and both of them were combinated also with heat stress (Figure 6).

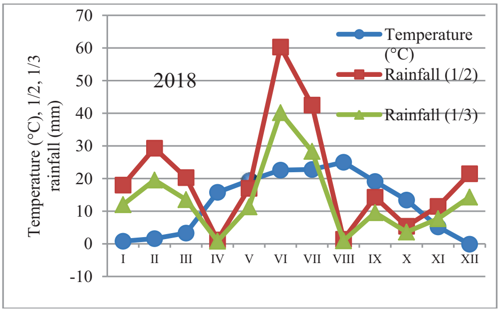


Figure 6. Climato diagram for 2018

Analysis of variances evidentiate that length of mutard roots was very significantly ($P < 0.001$) affected by year of soil sampling and significantly ($P < 0.5$) for the treatments (Table 2).

Table 2.Analyses of variance for length of mutard root

Source of variance	Degree of freedom	Mean square	S2	F factor and significance
Factor A (year)	1	2707	2707	243.9***
Error	2	22.2	11.1	
Factor B (treatment)	4	1065	266	7.37*
A x B	4	321	80	2.22
Error	16	577	36	

***significant differences for P<0.001,* significant differences for P<0.5.

A higher inhibiting effect on the length of root was derived from the T2 and T4 variants in both years of experimentation.
In the 2017 the length of roots from T1 and T3 variants were almost similar to untreated mustard, indicating that there was no detectable herbicide in the soil and the explanation coud be the higher quantity of precipitations registered in this year (Figure 7).

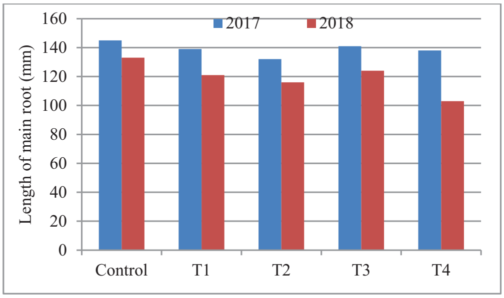


Figure 7. The effect of imazamox on lenght of mustard root

The negative effect on the height of plants was lower in both years of experimentation as compared with the effect on the length of root (Figure 8).

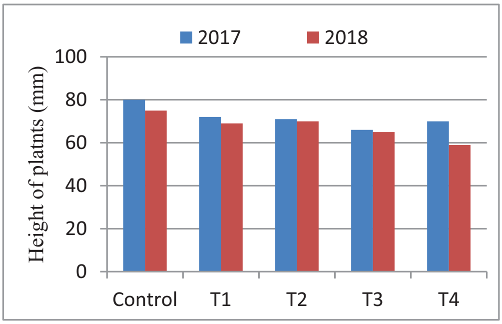


Figure 8. The effect of imazamox on height of mustard plants

Although in earlier stage of mustard vegetation the treatments with imazamox herbicide had a low residual effect on height of plants, but over time this effect was significantly reduced (Figure 9).

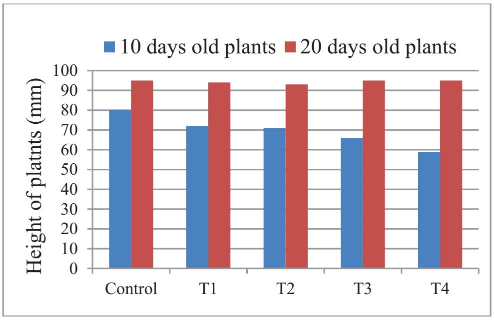


Figure 9. The effect of imazamox on height of mustard plants

The precipitation influence both transport and the herbicides degradation (microbial and chemical hydrolysis) (Streck, 2005; Ghinea et al., 2007).
Data from the literature show that in general, breakdown occurs by soil microbes and breakdown occurs more rapidly and herbicide activity increases as soil pH increases. The soil reaction in our experiences was slightly acidic from 6.06 to 6.36, with little difference between the treatments but a reduction of pH is observed in 2018 in all herbicidal variants (Table 3).
In terms of total nitrogen content, it was noted that soil from experimental plots had 0.141-0.150% total nitrogen (Nt) and organic matter was a few percent higher in 2017 (year without strong hydric stress) (Table 3).
The literature shows that variations in soil pH can influence how long a herbicide will persist. Loux and Reese (1992) (quate by Petcu Victor & Oprea Georgeta, 2013) found that imidazolinone herbicides adsorbed increases as organic matter (OM) increases and as soil pH decreases. All factors increasing microbial activity also increase herbicide degradation (warm, moist soils). Degradation increases in soils with pH above 6.5 (Imi) or 7 (TPS) because herbicide molecules are not adsorbedand are in soil solution for plant uptake and microbial breakdown, (www.cof.orst.edu).

Table 3. The nitrogen and soil reaction. Fundulea, 2017 and 2018

Year	Treatment	N t (%)	Organic matter (%)	Ph
2017	**Control**	**0.145**	**2.98**	**6.36**
	T1	0.143	2.65	6.33
	T2	0.149	2.60	6.35
	T3	0.150	2.75	6.43
	T2	0.149	2.65	6.51
2018	**Control**	**0.141**	**2.65**	**6.25**
	T1	0.140	2.43	6.21
	T2	0.144	2.44	6.12
	T3	0.145	2.30	6.16
	T2	0.141	2.31	6.25

ALS inhibitors are highly plant active through both foliage and root uptake. This ability to be active in the soil and be taken up through the root system is beneficial for the control of weeds that emerge after the date of application. In years of reduced herbicide degradation in the soil due to reduced temperatures or soil moisture, some ALS inhibitors or their metabolites can persist into the following growing seasons (Hall et al. 1999; Hill B. Dal, 1998). This prolonged persistence can potentially injure sensitive crops grown in rotation such as canola and lentils (non-Clearfield® varieties), mustard, or sugar beet (Moyer & Hamman, 2001).

Persistence of phytotoxic levels of a herbicide for more than 1 year can be a problem with some herbicides. Herbicide residues are most likely to occur following years with low rainfall because chemical and microbial activity needed to degrade herbicides are limited in dry soil. Crop damage from herbicide residues can be minimized by applying the lowest herbicide rate required for good weed control, by using band rather than broadcast applications, and by mouldboard plowing before planting the next crop. Moldboard plowing reduces phytotoxicity of some herbicides by diluting the herbicide residue in a large volume of soil, (www.cof.orst.edu).

In order to established if studied herbicides affect the previous crops it was analyzed the reaction of winter wheat plant to herbicides studied.

The results showed no significant differences in terms of main root length (Table 4).

Table 4. Analyses of variance for length of winter wheat root

Source of variance	DF	Mean square	S2	F factor and significance
Factor A (year)	1	28.03	28.03	1.83
Error	2	29.8	14.93	
Factor B (treatment)	4	277	69	4.55
A x B	4	66.13	16.53	1.08
Error	16	243	15.21	

In case of winter wheat, during the dry year 2018 as compared with 2017, the persistence of herbicides studied was higher, the decrease of length of wheat roots being 0.54-8.74% from control compared with that of 2017 when, the winter wheat root lengths varied from 0 to 5.40% from the control (Table 5).

Table 5. The length of winter wheat root

Year	2017	2018	2017	2018
	Length of root (mm)		Rate of reduction (%)	
Control	185	183	100	100
T1	185	182	0	0.54
T2	178	175	3.78	4.37
T3	180	176	2.70	3.82
T4	175	167	5.40	8.74

The explanation is that the humidity and heat accelerates biodegradation, but also facilitates the leaching, while a dry climate, on the contrary, increases persistence as non-biological degradation and biodegradation are less intense.

CONCLUSIONS

The root length bioassay is suitable for assessment of susceptibility/resistance of wild mustard populations to ALS-inhibiting herbicides.

Our study evidentiate that biodegradation of herbicides depends by climatic conditions from year of experimentations and soil properties. On wheat (as in mustard) the reduction in root length as a treatment effect was higher in the dry year. But from a statistical point of view, our results revealed no significant differences between the type of herbicide used and untreated check. This suggests that the herbicides studied do not significantly affect the growth of this plant.

Results from the bioassay should not be interpreted alone. Interpretation needs to include other tools and information such as label recommendations, rainfall restrictions, pH, organic matter, soil texture, and perhaps most importantly, grower and agronomist experience.

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