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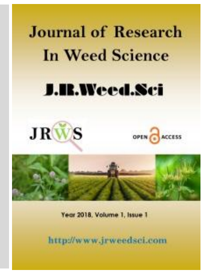

Negative Effects of Residual Herbicides on Sensitive Crops: Impact of Rimsulfuron Herbicide Soil Residue on Sugar beet

Mohammad Mehdizadeh[1,*], Fatemeh Gholami Abadan[2]

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Abstract

This study was designed to assess the effect of rimsulfuron soil residues (0, 0.11, 0.58, 1.1, 2.4, 3.6 and 5.8 µg a.i. kg^{-1}soil) on sugar beet (*Beta vulgaris* L.) plant with bioassay method. Plant response of roots and shoot dry weight per pot were described by A log-logistic model using R software as a function of rimsulfuron doses logarithm by non-linear regression and used to calculate the doses for 10, 50 and 90% inhibition of plant root and shoot dry weight (ED_{10}, ED_{50} and ED_{90}). Sugar beet was susceptible to rimsulfuron soil residues in all concentrations and biomass loses increased linearly as the concentration of rimsulfuron increased in the soil up to 0.11 µg/kg soil. The root biomass was more sensitive than shoot biomass where the ED_{50} calculated for root and shoot biomass was 0.123 and 0.202 µg. kg^{-1} soil, respectively. The same results were obtained for ED_{10} and ED_{90}. From the results of the study, it is concluded that sugar beet is very sensitive and suitable species for using as a bio indicator in bioassay experiments for determine the side-effects of rimsulfuron at low concentration rates. By determining the concentration of rimsulfuron soil residues and the side-effect on sensitive crops, the agricultural managers could have some flexibility in crop rotations program if sensitive crop such as sugar beet is to be planted in the field that previously treated with sulfonylurea herbicides.

Keywords: Inhibition, phytotoxic, rotation, sensitivity, side-effect

1- Faculty of Agricultural and Natural Resources, Department of Agronomy and Plant Breeding, University of Mohaghegh Ardabili. Ardabil. Iran. 2- Department of Biology, Islamic Azad University Tehran Medical Branch,Tehran. Iran.

* Corresponding author mehdizade.mohammad@gmail.com

1. Introduction

Rimsulfuron 1-(4,6-dimethoxypyrimidin-2-yl)-3-(ethylsulfonyl-2-pyridylsulfonyl) urea is one of the acetolactate synthase (ALS) inhibiting herbicides which has excellent selectivity in some crops for control of annual and perennial grasses and broadleaf weeds (Jhala et al. 2012). Sulfonylurea herbicides are very popular in all over the world due to ideal crop tolerance and weed control along with very low application rates and low mammalian toxicity (Rainbird et al. 2018). However, application of these herbicides in agro ecosystems, even at low rates (5-100 g ha $^{-1}$), led to public concern about undesirable impacts on environment such as persistence and activity of their residues in agricultural soils (Grahovac et al. 2017) as well as contaminants of soil and water sources (Springer et al. 2016) and phytotoxic effects on rotational crops (Mehdizadeh et al. 2017). Residual phytotoxicity has become a major problem in the cultivation of subsequent plants. In this regard, continuous control of residues of these agrochemicals in soil from one growing season to another is of great importance in agriculture management since remaining even very low concentrations of these substances can still affect the growth of post-rotating susceptible plants. Usually herbicide bioavailability has been evaluated using bioassays with either root extension or the whole plant (Pannacci et al. 2006). Mehdizadeh et al. (2016) found that sulfosulfuron and tribenuron methyl soil residues had phytotoxic effects on oilseed rape, barley, corn and sugar beet at very low concentration levels such as 0.06 and 0.1 μg a.i. kg^{-1} soil. In contrast to common physical or chemical methods, bioassay method as a direct measurement of bioavailable compounds in the soil can assess activity and phytotoxicity of pesticides (Streibig, 2006). Boydston (2007) studied the impact of rimsulfuron herbicide on potato cultivars and reported 39% injury to Umatilla Russet when rimsulfuron was applied at 26 g ha^{-1}. The objective of this study was to determine the effect of rimsulfuron soil residues on sugar beet plants with bioassay method.

2. Materials and Methods

Greenhouse bioassay experiment conducted to study the determination of sugar beet (*Beta vulgaris* L.) sensitivity to rimsulfuron herbicide soil residue at different concentrations (0, 10, 25, 50, 70, 90 and 100 g a. i. ha^{-1}). Soil samples collected from a field with no history of sulfonylurea herbicides application. Standard concentrations of rimsulfuron (0, 0.11, 0.58, 1.1, 2.4, 3.6 and 5.8 μg a.i. kg^{-1}soil) were created from the stock solution, which these concentrations were represented a range doses of herbicide in application rate of 30 g a. i. ha^{-1}. Each concentration of herbicide separately sprayed and thoroughly mixed with soil samples. Then 20 cm diameter plastic pots filled with a modified soil with three replications for each concentration. Ten sugar beet seeds were distributed uniformly in 5 regular positions on the surface soil and they were thinned to 5 seedlings per pot after germination. The pots were kept under controlled environmental conditions (temperatures of 20/15°C and 16/8 hours light and dark cycle) and shoot and root biomass were harvested 30 days after emergence.

Plant response of roots and shoot dry weight per pot (Y) were described by A log-logistic model using R software with drc package as a function of rimsulfuron doses, x.

$$Y = c + \frac{d - c}{1 + \exp\{b(\log(x) - \log(e))\}}$$

Where d is the upper asymptote (maximum biomass per pot), which is close to the untreated control, b denotes the slope of the curve around the ED_{50}, which denotes the dose that inflicts a 50% biomass reduction relative to d. The log-logistic model fitted well to the plant response for rimsulfuron. The ED_{10} and ED_{90} were calculated on the original fit.

3. Results and Discussion

Our study was designed to assess sensitivity of sugar beet to rimsulfuron applied at 6 different doses. The responses of sugar beet root and shoot biomass well described by logistic model with acceptable limits for rimsulfuron. Sugar beet seed emergence was not influenced by rimsulfuron. The model parameter estimates are shown in Table 1. Sugar beet was susceptible to rimsulfuron soil residues in all concentrations and the injuries caused reduced shoot and root dry weight. Sugar beet (ED_{50}= 0.123 and 0.202 µg. kg^{-1} soil for root and shoot dry weight, respectively) showed the high sensitivity of this crop to rimsulfuron. It is obvious that sugar beet biomass loses increased linearly as the concentration of rimsulfuron increased in the soil up to 0.11 µg/kg soil. The explanation of these results is that, at high concentration of rimsulfuron above 0.11 µg/kg soil, the compounds are available in the soil solution for plant uptake and accordingly considerable growth inhibition of the tested plant was observed. Whereas at low concentrations, the herbicide tend to be distributed in the soil or may consumed as a food source by microbial soil population, consequently, a moderate reduction of growth inhibition may be observed. This suggestion is supported by the results of Mehdizadeh (2016), where he found slightly reductions of oilseed rape biomass due to application of triasulfuron concentration below 25 g a. i. ha^{-1}.

Table 1- Parameters of the logistic model that describe the relationship of shoot and root dry weight as a function of herbicide doses.

Plant Part	b	d	ED µg kg^{-1} soil		
			ED_{10}	ED_{50}	ED_{90}
Shoot	1.17 (0.15)*	0.109 (0.005)	0.031(0.01)	0.202(0.038)	1.31 (0.303)
Root	1.28 (0.18)*	0.07 (0.002)	0.022 (0.007)	0.123(0.017)	0.68 (0.15)

*Standard Error

Sulfonylurea herbicides are highly active in agricultural soils even in very low concentrations. Parrish et al. (1995) reported that application of 1.5 μg L^{-1} sulfosulfuron was caused 20% barley growth inhibition in a bioassay method. Some crops have been reported injured and yield reduced by the residual effects of sulfonylurea herbicides oilseed rape, lucerne, sugar beet, flax, sorghum, and peas (Moyer, 1995; Shinn et al. 1999). Hernandez-Sevillano et al. (2001) found that sulfosulfuron and triasulfuron concentrations between 8 and 3 μg. L^{-1} reduced sunflower root length by 50% in soil bioassays carried out in growth chamber. As shown in table 1, the root biomass was more sensitive than shoot biomass where the EDs were slightly smaller for root than for shoot biomass. Santin-Montanya et al. (2006) reported that the root length of tested plants was the most sensitive response used in bioassay with sulfosulfuron.

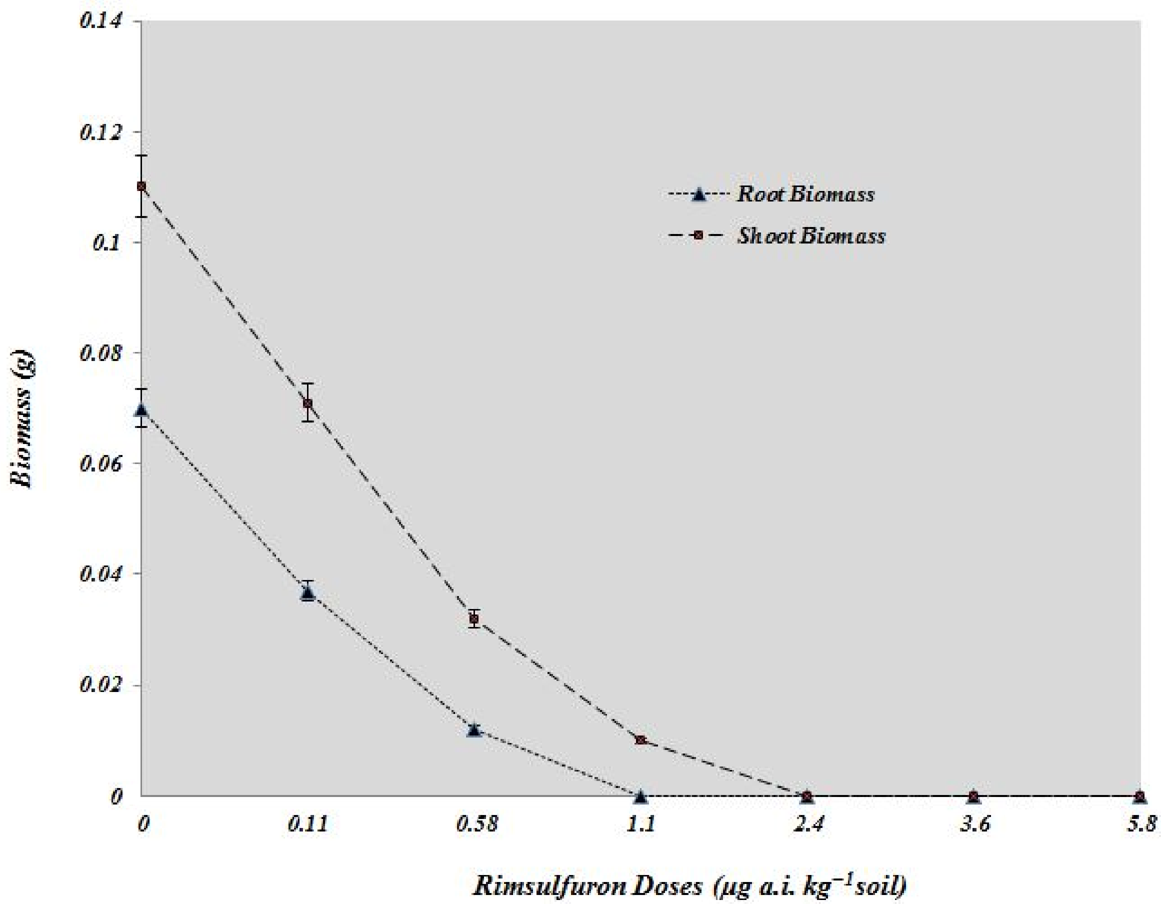

Figure 1- Sugar beet shoots and root biomass response to rimsulfurom doses.

Choosing what herbicide to use, and what species to plant is dependent on many factors such as site, cost, and management objectives. More information about the sensitivity of plant species to herbicides may give us additional tools to aid in successful plantings. Root and shoots biomass was moderately heavy damage to completely killed (36 to 100 percent injury) from the low to the high rates of rimsulfuron applied on sugar beet. By possibly knowing the level of rimsulfuron residues in the soil and the effect on particularly sensitive crops, producers could have some flexibility in crop rotations if sensitive crop such as oilseed rape is to be planted following sulfonylurea herbicides application in previous crops.

Acknowledgments

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Conflict of interest

The authors confirm that there are no known conflicts of interest associated with this study and there has been no significant financial support for this work that could have influenced its outcome.

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