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Effect of some adjuvants application on enhancing sulfosulfuron herbicide performance on *Phalaris minor*- Poaceae

Mohammad Mehdizadeh [1*] and Mohammad-Taghi Alebrahim[2]

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ABSTRACT

Nowadays environmental pollution by pesticides application is a major concern for health. Efficiency of many herbicides can be increased by adding adjuvants to the spray solution. Therefore greenhouse study was conducted during 2014 to determine the efficacy of three adjuvants (Citogate, Castor oil and Canola oil) at concentrations of 0.1 and 0.2 (%v/v) with 5, 10, 20, 30 and 40 g a.i\ha of sulfosulfuron herbicide on littleseed canary grass. Results showed that the adjuvants enhanced the efficacy of sulfosulfuron in decreasing the dry weights of littleseed canary grass. Performance of herbicide was increased with enhancing its concentrations. Measured ED_{50} and ED_{90} concentrations of sulfosulfuron in control were 16.74 and 32.22 g a.i\ha, respectively. Whereas the values for Citogate 0.2 (%v\v), was 5.86 and 13.34 g a.i\ha, respectively. The addition of Citogate and Castor oil had the highest and lowest effect on sulfosulfuron efficacy against Littleseed canary grass. In conclusion, the study revealed that Citogate concentrations had powerful effects on herbicide efficacy followed by Canola oil.

INTRODUCTION

The contribution of agricultural chemicals to the world's agricultural economy is tremendous and increasing by providing protection against damages caused by various insects, diseases, and weeds. Over the past 40 years, modern herbicides have largely replaced human, animal and mechanical weed control (Powles and Yu 2010). One of the most important cereal threaten weeds in Iran is Littleseed canary grass (*Phalaris minor* Ritz.) that reduces yield of wheat through competing for resources such as water, nutrient and light (Baghestani et al. 2007). sulfosulfuron that belongs to sulfonylureas herbicides, controls weeds by inhibiting the acetolactate synthase enzyme (ALS), thus preventing formation of certain plant proteins resulting in eventual plant death. This herbicide is one of the most effective and widespread herbicides to control the grass weeds in Iran (Baghestani et al. 2008) which might result in evolution of resistance in grasses due to high selective pressure imposed by this group of herbicides (Devine and Shimabukuro 1994). Moreover, environmental side-effects due to the high usage of the ALS inhibitors are probable. Therefore, optimizing the application techniques must be used to overcome these problems. A solution to the above-mentioned negative impacts of continuous application of ALS herbicides is to use adjuvants and specially vegetable oils adjuvants. These chemical compounds decrease the application dose of herbicides (Sharma and Singh 2000). Application of adjuvants can increase the efficacy of herbicides through several methods such as: change the surface characteristics of herbicide droplets, affect the bioavailability of the herbicide molecules, and alter the diffusion coefficient of the herbicide molecule (Holloway 1993; Reiderer et al. 1995). Adjuvants can reduce the surface tension of herbicides droplets; thereby increase the chance of spray droplets to sit on the plant surface. Moreover, they can increase the droplets spread on leaf surface and enhance the foliar activity of post-emergence herbicides (Rashed-Mohassel et al. 2009) due to an increase in the penetration of herbicides into the cuticular waxes. There are many factors that affect the suitability of an adjuvant (Zolinger 2000). Based on their type, adjuvant can directly/indirectly affect

1-PhD student in Weed Science, Department of Agronomy and Plant Breeding, Mohaghegh Ardabili University of Ardabil, Iran.
2- Assistant Professor of Weed Science, Department of Agronomy and Plant Breeding, Mohaghegh Ardabili University of Ardabil, Iran.
*Email: Mehdizade.mohammad@gmail.com

the formulations efficacy-related factors including atomization, deposition, retention, absorption and translocation (Zabkiewicz 2000). Hammami et al (2013) found that the addition of emulsifiable vegetable oils improved sethoxydim effectiveness significantly. Many researchers have expressed that adjuvant efficiency depends on the interaction among herbicide, adjuvant and plant target area features (Bunting et al. 2004). The objective of this study was to test and evaluate the ability of three different adjuvants on increasing the performance of sulfosulfuron against littleseed canary grass (*Phalaris minor* Ritz.).

MATERIAL AND METHODS

The seeds of Littleseed canary grass (*Phalaris minor* Ritz.) were collected from plants in the fields and preserved in a refrigerator (at 4 ± 1°C). To increase seed germination, the seeds were dehulled and placed in petri dishes on a single layer of Whatman no. 1 filter paper. Then, 10 mL of 0.2% KNO3 solution was added to each petri dish for breaking dormancy (Rashed-Mohassel et al. 2010). The seeds were placed in an incubator at alternating temperatures of 20/15°C and relative humidity of 45/65% under 16/8 hour light and dark cycle. After germination, ten seedlings with uniform radical length (8-10 mm) were selected and planted 1 cm deep in 1.5 L plastic pots (pots with 12 cm diameter) that were filled with a mixture of sand, clay loam soil and vermiculate (1:1:1). The pots were placed in a greenhouse with a light/dark period of 16/8 hour at 25/15°C. A lamp was used to supply additional light and extend the day length. The plants were irrigated every three days and thinned to five per pot at one-leaf stage.

Experiment was conducted in a Completely Randomized Design with a factorial arrangement of treatments and three replications during year 2014. Factor A was different sulfosulfuron concentrations including 5, 10, 20, 30 and 40 g a.i\ha applied against littleseed canary grass. Factor B was included castor oil (*Ricinus communis* L.), canola oil (*Brassica napus* L.) and Emulsifiable oil Citogate (a non-ionic surfactant, 100% alkylarylpolyglycol ether) at 0.1 and 0.2 % (v/v). Herbicide was sprayed at three to four leaves stage by using a sprayer equipped with a Flat-fan nozzle, delivering 300 L\ha spray solution at 250 kPa. Thirty days after spraying, the number of survived plants per pot and dry (dried at 70°C for 48 hours) biomass was recorded. The response of dry matter (U) to herbicides dose (z) was assumed by a log-logistic model that was described by Nielsen et al (2004):

(Equation 1)

$$Uij = C + \frac{D-C}{1+\exp[bi(\log(Zij)-\log(ED50i))]}$$

where Uij denotes the fresh or dry matter at the *j*th dose of the *i*th herbicide preparation; D and C denote the upper and lower limit of the fresh or dry weight at zero and at infinite doses; ED_{50i} denotes the required dose of herbicide, *i*, to give 50% littleseed canary grass control; and b_i is proportional to the slope of the curve around the ED_{50i}. The logistic response-dose model was fitted to the experimental data. Theoretically, whether the response curves are parallel or not, horizontal displacement between curves described by relative potency:

(Equation 2)

$$RP = \frac{ED_{50f}}{ED_{50f+v}}$$

where ED_{50f} denotes the ED_{50} of herbicide formulation alone; and ED_{50f+v} denotes the ED_{50} of herbicide formulation along with each surfactants. If R = 1, the addition of surfactants would not have any effect on herbicide response. But if R was higher or lower than 1, the herbicide accompanied by surfactants would be more or less potent than herbicide alone, respectively. The data was subjected to analysis of variance using the Mstat-C software. Mean comparisons were performed using Duncan Multiple Range Test (DMRT) at 0.05.

RESULT AND DISCUSSION

The results showed that increasing in sulfosulfuron concentration up to 40 g a.i\ha enhanced its efficacy (Table 1). This herbicide controlled weed effectively at higher doses (40 g a.i\ha). When sulfosulfuron was combined with Citogate and vegetable oils, littleseed canary grass control was considerably increased, consequently all adjuvant-added to herbicide showed superior performance in reducing the dry weight of littleseed canary grass (Table 1). Citogate was the most effective adjuvant as its addition to sulfosulfuron at 40 g a.i\ha led to the highest control of littleseed canary grass. It was clearly indicated that sulfosulfuron has a vigorous receptivity for surfactants which might be related to weaker penetration of this herbicide into littleseed canary grass leaf when applied without adjuvants. In an experiment conducted by Hunsche and Noga (2008) it was proved that linseed oils adjuvants showed an increace in efficiency of fungicide mancozeb. With this study, it was shown that the application rate of sulfosulfuron could be reduced when an adjuvant was added. Furthermore, it can be concluded that a higher content of adjuvants affected the herbicidal efficacy in a positive way. Only with an appropriate adjuvant, herbicides can develop their maximum efficacy even at lower than recommended doses.

Table 1. Effects of sulfosulfuron with and without adjuvants on littleseed canary grass dry weight (g\pot).

Herbicide Rate (g a.i\ha)	No Adjuvants	Citogate		Canola oil		Castor oil	
		0.1	0.2	0.1	0.2	0.1	0.2
4	2.20^{a*}	1.20^{a}	1.06^{a}	1.32^{a}	1.11^{a}	1.55^{a}	1.22^{a}
10	1.64^{b}	0.80^{b}	0.65^{b}	1.11^{ab}	0.75^{ab}	1.26^{ab}	0.87^{ab}
20	0.86^{c}	0.42^{c}	0.30^{c}	0.62^{c}	0.42^{c}	0.74^{c}	0.58^{c}
30	0.33^{d}	0.21^{d}	0.12^{d}	0.29^{d}	0.20^{d}	0.51^{cd}	0.36^{d}
40	0.10^{e}	0.08^{e}	0.04^{e}	0.12^{e}	0.08^{e}	0.21^{e}	0.14^{e}

* Treatment means within each column followed by the same letter, do not differ significantly at the 5% level

The ED_{50} and ED_{90} values of sulfosulfuron were significantly reduced and the Relative Potency (RP) values was significantly increased when Citogate and vegetable oils were added to this herbicide (Table 2). These results Showed that the adjuvants enhanced the efficacy of sulfosulfuron. The ED_{50} and ED_{90} measured parameters estimated by dose–response model based on littleseed canary grass dry weight for sulfosulfuron without adjuvant were 16.74 and 32.22 g a.i\ha, respectively (Table 2). Based on the ED_{50} and ED_{90} values given in Table 2, all three adjuvants considerably improved the efficiency of sulfosulfuron. Based on ED_{50} values, the lowest effect was observed in Castor oil and the highest was obtained from Citogate.

The fact that modified vegetable oils improve herbicide efficacy is already known and was reviewed by Gauvarit and Cabanne (1993). Giysopoulos et al. (2014) showed that the use of vegetable oil mixtures with diquat herbicide indicating significant enhancement of diquat efficacy on grasses. An increased spreading of spray droplets on target plants and an enhanced penetration of active ingredients into leaves seem to be the reasons for the herbicide enhancing action of vegetable oils (Liu 2004). Since many oil-based adjuvants act well as penetration enhancers, it can be assumed that the addition of these adjuvants can enhance herbicide efficiency (Stock and Briggs 2000).

Since it is known that the efficacy of sulfonylureas can be reduced by precipitation within a few hours after application (Russell et al. 2002) an increased performance of those herbicides might have been achieved by the addition of the vegetable oils. In this study, the addition of Citogate and vegetable oils increased the efficacy of sulfosulfuron in reducing littleseed canary grass biomass. The improvement of the tested sulfosulfuron by this adjuvants may be associated with a theory that says the solubilizing, softening or disordering nature of cuticular waxes by the methylated seed oils (Hazen 2000). Also this is known that the adjuvants are likely to improve the permeability of the herbicide active ingredient (Johnson et al. 2002) which provides an opportunity to reduce herbicide application dose (Zabkiewicz 2000). It seems that the tested adjuvants led to more cuticular penetration and stomata infiltration and subsequently, allowed better sulfosulfuron absorption and translocation. All three adjuvants increased considerably the efficiency of sulfosulfuron compared with herbicide alone. Rashed-Mohassel et al. (2011) reported that reduction in the surface tension of herbicide solution by the vegetable oils. Therefore this is an important factor to atomize herbicide droplets and allowing remaining it on foliage (Ejim et al. 2007), also an increase in the penetration dose of active ingredient via disordering of the cuticular waxes is a more important factor in improving the efficiency of herbicides (Rashed-Mohassel et al. 2011). Other researchers have demonstrated that the vegetable oils improved weed control by 2,4-D, phenmedipham (Muller et al. 2002), glyphosate (Gauvrit et al. 2007), metoxuron, sethoxydim, and quizalofop (Ruiter et al. 1997). Vegetable oils such as castor and canola oil probably disrupt and solubilize cuticular waxes (Zabkiewicz, 2000) and consequently, facilitate the penetration of the active ingredient (McMullan and Chow 1993). The benefits of using these oils (e.g. castor and canola) in enhancing the foliage activity of herbicides have

Table 2. Measured ED50 and ED90 doses of sulfosulfuron alone and with the presence of adjuvants in the control dry weight of littleseed canary grass

Experimental Treatments	ED_{50} (g a.i\ha)	ED_{90} (g a.i\ha)	Relative Potency (RP)
sulfosulfuron (control)	16.74	32.22	1
sulfosulfuron + Citogate (% 0.1)	6.22	14.41	2.69
sulfosulfuron + Citogate (% 0.2)	5.86	13. 34	2.86
sulfosulfuron + Canola oil (% 0.1)	8.37	17.15	2
sulfosulfuron + Canola oil (% 0.2)	7.75	16.6	2.16
sulfosulfuron + Castor oil (% 0.1)	9.05	18.97	1.85
sulfosulfuron + Castor oil (% 0.2)	8.54	18.13	1.96

been well documented (Bunting et al. 2004). Sharma and Singh (2000) have shown that an increase in the permeability of the herbicide through disordering the cuticular waxes is a more important factor than reduction the surface tension of herbicide droplets in improving the foliar activity of glyphosate on *Bidens frondosa* and *Panicum maximum*. Therefore, these results emphasize the dependency of adjuvant performance on herbicide properties and plant species.

CONCLUSION

Selecting proper herbicide adjuvants is a key factor in chemical weed management because this factor reduces herbicide rates. The phytotoxic effects of vegetable oils compared to mineral oils on plants are very low and they decomposed rapidly in the environment. It seems that the application of vegetable oils could be an efficient method for optimizing herbicide performance on contorting of *Phalaris minor*, especially Canola oil. The use of vegetable oils seems to be an efficient alternative to other commonly used synthetic adjuvants.

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