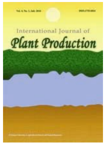

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Evaluation of broadleaf weeds control with some post-emergence herbicides in maize (*Zea mays* L.) in Iran

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Abstract

Registered dose of herbicides may be higher than rate required for controlling weed species depending on growth stages. In order to study the effect of individual post-emergence application of 2,4-D plus MCPA and three sulfonylurea herbicides at four- to six-true leaf stage of weeds, experiments were conducted in 2011 at the greenhouse of Agricultural Faculty of Ferdowsi University of Mashhad, Iran. Treatments included untreated control and several rates of 2,4-D plus MCPA, foramsulfuron, nicosulfuron and nicosulfuron + rimsulfuron on redroot pigweed, common lambsquarters, common purslane and black nightshade. These herbicides were more effective to control redroot pigweed than other weeds (except nicosulfuron + rimsulfuron), thereupon minimum dose required for a satisfactory efficacy of 90% reduction of redroot pigweed aboveground dry matter (ED_{90}) were 375.26, 23.51 and 63.81 g a.i h^{-1} of 2,4-D plus MCPA, foramsulfuron and nicosulfuron, respectively. Nicosulfuron and nicosulfuron + rimsulfuron did not control common lambsquarters effectively. Foramsulfuron had the lowest effect on black nightshade and common purslane, so that minimum dose required for a 90% reduction of black nightshade and common purslane aboveground dry matter were 52.42 and 60.26 g a.i h^{-1}, respectively. Thus, these results showed that tank mixtures with other herbicides effective in controlling broadleaf weeds may be required for satisfactory weed control and reduction in sulfonylurea herbicides doses.

Keywords: Broadleaf weeds; Dose-response curve; Effective dose; Growth stage; Sulfonylurea herbicides.

Abbreviations: 2,4-D-(2,4-dichlorophenoxy) acetic acid; a.i.-active ingredient; ALS-acetolactate synthase; DAT-days after treatment; ED-effective dose; Foramsulfuron-1-(4,6-dimethoxypyrimidin-2-yl)-3-[2-(dimethylcarbamoyl)-5-formamidophenylsulfonyl]urea; MCPA-(4-chloro-2-methylphenoxy) acetic acid; Nicosulfuron-2-[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl] amino] sulfonyl]-*N*,*N*-dimethyl-3-pyridinecarboxamide; Rimsulfuron-*N*-[[4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]-3-(ethylsulfonyl)-2-pyridinesulfonamide; POST-post-emergence.

Introduction

Although, maize (*Zea mays* L.) is a good competitor in exploitation of resources, it needs weed control especially at the beginning of season to prevent significant yield loss. Mahmoodi and Rahimi (2009) stated that weeds reduced maize yield by approximately 77%, when allowed to compete with the crop from planting to harvest. Redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarters (*Chenopodium album* L.), common purslane (*Portulaca oleracea* L.) and black nightshade (*Solanum nigrum* L.) are four common broadleaf weeds found in maize fields in Mashhad, Iran. There are few herbicides available to control broadleaf weeds in maize in Iran. 2,4-D plus MCPA is one of the growth regulator herbicides that is applied for controlling broadleaf weeds in maize in Iran. In addition, foramsulfuron, nicosulfuron and nicosulfuron plus rimsulfuron are dual purpose and ALS-inhibitor herbicides that have been recently registered for control of narrow and some broadleaf weeds in maize fields of Iran (Baghestani et al., 2007).

Reducing the recommended dose of herbicides is one of the important tools in weed management systems. Zhang et al. (2000) stated that registered doses are set to ensure adequate control over a wide spectrum of weed species, weed densities, growth stages and environmental conditions. Several authors have reported that reduced rates of POST herbicides can provide adequate control of broadleaf and grass weed species (DeFelice et al., 1989; Klingaman et al., 1992; Prostko and Meade, 1993). However, application should be performed at early growth stages because herbicide efficacy is commonly reduced as weed increase in size (Lee and Oliver, 1982). Soltani et al. (2005) demonstrated that the herbicide flufenacet plus metribuzin applied at a rate of 670 g a.i. ha^{-1} (170 g a.i. ha^{-1} lower than registered rate) provided greater than 90% control of redroot pigweed, common lambsquarters and common ragweed (*Ambrosia artemisiifolia* L.)

in soybean fields in southwestern Ontario. Belles et al. (2000) have reported that a 50% dose of tralkoxydim controls more than 85% of wild oat (*Avena fatua* L.) in barley (*Hordeum vulgare* L.). Also, Travlos (2012) reported that the best weed control in wheat was achieved with the highest herbicide rate, but lower rates of mesosulfuron + iodosulfuron often provided good control of wild oat (*Avena sterilis* L.), little seed canary grass (*Phalaris minor* Retz.), common poppy (*Papaver rhoeas* L.) and wild mustard (*Sinapis arvensis* L.). Weed management cost can be reduced by applying herbicides at reduced rates during early weed growth stages, too (Dieleman and Mortensen, 1997; Rosales-Robles et al., 1999). Reduced prosulfuron rates showed excellent weed control early in the season and protected grain sorghum yield (Rosales-Robles et al., 2005). Below-labeled herbicide rates in conjunction with cultivation or with the addition of surfactant have proven to be an effective way of reducing herbicide input to agricultural systems (Gebhardt, 1981; Hamill and Zhang, 1995a; Hamill and Zhang, 1995b; Salisbury et al., 1991; Steckel et al., 1990). Therefore, by testing the effectiveness of herbicide over a wide range of rates, growers will have better information to determine the appropriate weed management program that maximizes net returns and minimizes loading of herbicides into the environment (Nurse et al., 2007).

By considering the merits of reduced herbicide rates, there is risk associated with adopting such method (Blackshaw et al., 2006). Roggenkamp et al. (2000) reported that velvetleaf (*Abutilon theophrasti* Medik.) and green foxtail (*Setaria viridis* [L.] Beauv.) control with reduced rates of alachlor and atrazine in maize was quite variable and any economic benefit was small. In these cases, this procedure must be performed along with other weed management practices. Few studies have been done on minimum dose required for optimum control of broadleaf weeds in maize fields of Iran. Therefore, the main objective of the present study was to determine effective dose of maize herbicides over a wide range of rates at four-to six-true leaf stage of weeds and minimizing cost and loading of herbicides into the environment.

Materials and Methods

Site description and procedure

Four experiments were conducted in 2011 at the greenhouse of Agricultural Faculty of Ferdowsi University of Mashhad, Iran (Lat 36° 15' N, Long 59° 28' E; 985 m Altitude). In these experiments, the effect of individual post-emergence application of 2,4-D plus MCPA and three sulfonylurea herbicides in different doses was studied at four- to six-true leaf stage of four important broadleaf weeds in maize fields in Mashhad, Iran. Weed seeds were collected from maize fields and placed in 11 cm diameter glass Petri dishes with a single layer of Wathman No. 1 filter paper. Petri dishes were placed in a seed germinator under a 25-15 °C and 43% relative humidity with a 14 h photoperiod to germinate the seeds. Experiments showed that common purslane and black nightshade seeds have no dormancy, but common lambsquarters and redroot pigweed seeds have. After breaking dormancy of common lambsquarters and redroot pigweed by placing the seeds in sulfuric acid (98%) for 2 minutes, all weed seeds were planted into 200 Multi-Cell plant trays (Length 54 cm, Width 28 cm and Depth 4.2 cm) filled with Black Sphagnum White Peat produced by Terracult company in 70 L bag (NPK fertilizer 14-16-18 + microelements: 0.5 Kg/m^3; Total nitrogen: 70 mg/L; Phosphate: 80 mg/L; Potassium: 90 mg/L; EC 0.5-0.8 mS/cm and a pH of 5.5-6.5). Seedlings were transferred to 0.7 L-plastic pots after emergence. Plants were grown in greenhouse conditions with temperatures maintained at 24/18 °C day/night. Natural sunlight was supplemented with metal halide lamps producing 16 h of photoperiod. After development of the second true leaf, plants with uniform height were selected and thinned to three plants per pot for greenhouse studies. The soil texture was 1:1 (v/v) mixture of leaf mold and silt loam (19.8% sand, 20.1% clay, 56% silt, 4.1% organic matter and a pH of 6.7) and was sterilized at 180 °C for 2.5 hours. No fertilizer was used and the soil moisture was kept near field capacity. Pots were surface watered daily or as needed throughout the experiments to maintain adequate soil moisture for plant growth.

Treatments

Treatments included various rates (20.25, 50.625, 101.25, 202.5, 405, 607.5, 810 and 1012.5 g a.i. h^{-1}) of 2,4-D plus MCPA (U46 Combi Fluid, SL 67.5%, Zhejiang Chemicals Import & Export Corporation, Hangzhou, China) for common lambsquarters and redroot pigweed, rates (20.25, 50.625, 101.25, 202.5, 337.5, 506.25 and 1012.5 g a.i. h^{-1}) of 2,4-D plus MCPA for common purslane and black nightshade, rates (2.25, 4.5, 9, 18, 27, 36 and 45 g a.i. h^{-1}) of foramsulfuron (Equip, OD 2.25%, Bayer Crop Science, Tehran, Iran), rates

(4, 8, 16, 32, 48, 64 and 80 g a.i. h^{-1}) of nicosulfuron (Accent, SC 4%, Inter-China Group Corp., Zhenjiang, Jiangsu, China) and rates (18.75, 37.5, 56.25, 75, 93.75, 112.5 and 131.25 g a.i. h^{-1}) of nicosulfuron plus rimsulfuron (Ultima, WG 75%, Golsam Gorgan Chemicals Corporation, Gorgan, Iran) for all of the weeds. An untreated check was included for each weed. Weeds were sprayed at four- to six-true leaf stage by greenhouse bench sprayer delivering 200 L ha^{-1} at 300 kPa utilizing 8002 flat-fan nozzle tip; boom height was 50 cm. Fourteen days after spraying, control percentages of plants were evaluated by visual rating. Visual observations were recorded every two weeks until 28 days after treatment (DAT). The scale used for injury percent ranged from 0 (no visible injury) to 100% (complete death) as approved by the Weed Science Society of America. All aboveground plant organs were cut 4 weeks after treatment from the soil surface and oven-dried at 70 °C for 48 h and weighed.

Experimental design and Statistical analysis

Experiments comprised of completely randomized designs with several doses of each herbicide and four replications for each dose. The dose-response curves for each herbicide and weed were fitted simultaneously with the three-parameter Gompertz model (function 1) with the lower limit equal to zero using the drc add-on package to the programme R:

$$f(x,(b,d,e))=d\ exp\{-exp\{b(log(x)-e)\}\} \qquad (1)$$

Where d denotes the upper limit of dry matter at zero doses of herbicides, b is the relative slope around e and the e parameter is denoted ED_{50} and it is the dose producing a response half-way between the upper limit d and lower limit c. The ED_{50} parameter can be replaced by any ED level, so the selected model was used to estimate the dose of herbicides required to obtain 80 and 90% weed control when applied individually (ED_{80} and ED_{90} values). The goodness-of-fit was assessed by graphical analyses of residuals and F-test for lack-of-fit (Ritz and Streibig, 2005). Also, optimal Box-Cox transform-both-sides approach was done to variance homogeneity of the response as needed.

Assuming that Z_A and Z_B are the doses of herbicide A (2,4-D + MCPA) and B (Sulfonylurea herbicides) producing for example a 50% effect, i.e. the ED_{50} doses, the relative potency between the herbicides (function 2) was calculated as:

$$R = \frac{Z_A}{Z_B} \quad (2)$$

The relative potency between herbicides A and B expresses the biological exchange rate between herbicides when applied separately (Streibig et al., 1998).

Results and Discussion

Visual observations

Effects of 2,4-D plus MCPA resulted in occurring symptoms such as chlorosis and epinasty of the leaves especially in petioles. Stems also showed bending and twisting, tissue swelling and bursting in response to the herbicide application at higher doses. Symptoms of albinism and chlorosis were observed at the upper portion of the plants when sulfonylurea herbicides used. In addition, leaf internodes were shortened by increasing herbicide dose that resulted in reduced plant height. Black nightshade indicated purple spots at the leaf surface between veins by herbicides application. Common purslane and redroot pigweed showed the highest susceptibility to 2,4-D plus MCPA, so that application of 337.5 and 405 g a.i. ha^{-1} of herbicide resulted in 93.75 and 83.75 percent control 28 days after treatment. Foramsulfuron had the maximum effect on redroot pigweed and common lambsquarters. Nicosulfuron controlled redroot pigweed and common purslane better than other weeds based on visual observations. Nicosulfuron plus rimsulfuron had the best effect on black nightshade and redroot pigweed, so that at recommended dose has been observed 75 and 80% control of weeds 28 days after treatment, respectively. Nicosulfuron + rimsulfuron controlled redroot pigweed and black nightshade by 58 and 97 percent at the rate of 23 + 12 g a.i. ha^{-1} when weeds were 10 cm or less (Arnold et al., 2005). Nicosulfuron had the lowest effect on common lambs quarters, so that plants resumed the growth after application of herbicide (Table 1).

Dose-response studies

Dose-response curves of herbicide applications showed that 2,4-D plus MCPA, foramsulfuron and nicosulfuron were more effective on aboveground dry matter of redroot pigweed at four- to six-true leaf stage. We used reduced doses of these herbicides for sufficient control of weed. Minimum dose required for a satisfactory efficacy of 90% reduction in redroot pigweed aboveground dry matter were 375.26, 23.51 and 63.81 g a.i. $h^{-1}$of 2,4-D plus MCPA, foramsulfuron and nicosulfuron, respectively (Figure 1 (a) and Table 2). Based on results reported by Bunting et al. (2005), foramsulfuron alone and nicosulfuron plus 1.0% (v/v) COC and 2.5% (v/v) 28% UAN both provided excellent control of redroot pigweed (99%) at the rate of 37 and 35 g a.i. h^{-1}, respectively when weeds were between 5 and 10 cm tall. On the other hand, Baghestani et al. (2007) reported that the highest redroot pigweed survival was occurred where nicosulfuron was applied at 40 g a.i. ha^{-1}. However, where nicosulfuron dose was increased to 80 g a.i. ha^{-1}, control of redroot pigweed increased to 84.6%. Our results indicated that rates of herbicides can be less than recommended dose, if controlling operations was done at this growth stage. Nicosulfuron plus rimsulfuron controlled redroot pigweed by 80% reduction in weed aboveground dry matter at the rate of 127.35 g a.i. h^{-1}, but higher rate of herbicide was needed for 90% reduction (Table 2).

Common lambsquarters was controlled at the rate of 573.26 and 38.26 g a.i. h^{-1} of 2,4-D plus MCPA and foramsulfuron, respectively by 90% reduction in aboveground dry matter (Figure 1 (b) and Table 2). Arnold et al. (2005) reported 97 percent common lambsquarters control with a 33 g a.i. ha^{-1} application of foramsulfuron in New Mexico. Nicosulfuron did not improve control of common lambsquarters, so that based on our observations and fitted dose-response curve, recommended dose of nicosulfuron did not result in 50 percent control of weed 28 days after treatment (Tables 1 and 2). This result was in accordance with those reported by Bunting et al. (2005), who reported 32% common lambs quarters control when nicosulfuron was applied at the rate of 35 g a.i. h^{-1}. They also stated that foramsulfuron had an advantage controlling common lambsquarters over nicosulfuron by 81% control at either 32 or 37 g a.i. h^{-1} in Illinois. Nicosulfuron plus rimsulfuron did not affect sufficiently on common lambsquarters at recommended dose by manufacturer in our field study (data not shown). Zand et al. (2009) reported that nicosulfuron plus rimsulfuron at recommended dose resulted in 29.25 percent reduction in aboveground dry matter 30 days after treatment in Varamin.

Table 1. Control percentages of redroot pigweed, common lambsquarters, black nightshade and common purslane based on visual observations at four-to six-true leaf stage.

Herbicide	Rate	AMARE		CHEAL		SOLNI		POROL	
		14 DAT	28 DAT	14 DAT	28 DAT	14 DAT	28 DAT	14 DAT	28 DAT
	g a.i./ha	% Control							
None		0	0	0	0	0	0	0	0
2,4-D + MCPA	20.25	-	-	5	5	7	7	8	12.25
	50.625	12.5	48.75	10	10	10	15	7.75	13.5
	101.25	53.75	71.25	26.25	26.25	17.5	20	11.25	13.5
	202.5	53.75	77.5	42. 5	45	46.25	62.5	43.75	81.25
	337.5	-	-	-	-	62.5	80	87.5	93.75
	405	61.25	83.75	50	52.5	-	-	-	-
	506.25	-	-	-	-	78.75	97.5	95	97.5
	607.5	63.75	87.5	73.75	92.5	-	-	-	-
	810	73.75	91.25	76.25	92.5	-	-	-	-
	1012.5	73.75	91.25	88.75	96.25	93.75	100	100	100
Foramsulfuron	2.25	-	-	5	5	10	19.5	6.5	9.25
	4.5	13.75	31.25	10	12	15	26.25	15	18
	9	18.75	68.75	17.5	18	21.25	43.75	15.5	30
	18	32.5	88.75	27.5	31.25	22.5	50	23.75	56.25
	27	52.5	96.25	42.5	47.5	31.25	57.5	36.25	67.5
	36	52.5	88.75	48.75	76.25	43.75	65	40	73.75
	45	60	97.5	53.75	93.75	56.25	88.75	53.75	81.25
Nicosulfuron	4	-	-	-	-	8.25	10.25	10.5	16.25
	8	16.25	62.5	-	-	15	19.5	11.25	13.5
	16	26.25	63.75	5	6.25	22.5	28.75	25	30
	32	42.5	70	7.5	5	33.75	41.25	31.25	57.5
	48	47.5	77.5	13.75	5	40	56.25	41.25	63.75
	64	50	80	17.5	13.75	48.75	62.5	72.5	86.25
	80	47.5	86.25	16.25	11.25	52.5	73.75	83.75	90
Nicosulfuron +	18.75	40	57.5	-	-	6.75	13.5	-	-
rimsulfuron	37.5	50	70	-	-	16.25	21.25	-	-
	56.25	55	65	-	-	22	32.5	-	-
	75	50	60	-	-	30	48.75	-	-
	93.75	57.5	77.5	-	-	35	56.25	-	-
	112.5	67.5	75	-	-	38.75	63.75	-	-
	131.25	70	80	-	-	45	75	-	-

Note: Visual observations of weeds were made 14 and 28 days after treatment (DAT).
Abbreviations: AMARE, *Amaranthus retroflexus* L. (redroot pigweed); CHEAL, *Chenopodium album* L. (common lambsquarters); SOLNI, *Solanum nigrum* L. (black nightshade); POROL, *Portulaca oleracea* L. (common purslane).

Table 2. Curve slope, ED_{50}, ED_{80} and ED_{90} of 2,4-D plus MCPA, foramsulfuron, nicosulfuron and nicosulfuron plus rimsulfuron on aboveground dry matter of weeds 28 days after treatment (DAT) at four-to six-true leaf stage.

Weed species	Herbicide	Curve slope	Effective dose (g a.i. ha^{-1})					
		b	ED_{50}	SE	ED_{80}	SE	ED_{90}	SE
Redroot pigweed	2.4-D plus MCPA	0.63	55.98	10.02	212.73	31.83	375.26	82.04
(*Amaranthus retroflexus*)	Foramsulfuron	0.92	6.37	0.69	15.93	1.76	23.51	3.5
(AMARE)	Nicosulfuron	0.76	13.24	1.61	39.91	4.11	63.81	8.59
	Nicosulfuron plus rimsulfuron	0.48	22.33	6.70	127.34	29.45	266.94	99.01
Common lambsquarters	2.4-D plus MCPA	0.86	142.18	17.58	378.20	37.54	573.26	70.67
(*Chenopodium album*)	Foramsulfuron	0.67	6.49	1.005	22.54	2.52	38.26	5.31
(CHEAL)	Nicosulfuron	0.53	98.39	23.88	474.50	290.61	926.28	736.39
Black nightshade	2.4-D plus MCPA	0.65	111.43	18.39	400.99	53.01	691.14	120.63
(*Solanum nigrum*)	Foramsulfuron	0.41	2.89	0.69	22.09	4.37	52.42	13.5
(SOLNI)	Nicosulfuron	0.38	3.81	1.17	34.20	6.39	86.91	23.38
	Nicosulfuron plus rimsulfuron	0.59	19.64	3.57	81.45	11.66	149.1	28.23
Common purslane	2.4-D plus MCPA	0.66	98.49	21.58	352.03	58.65	605	128.85
(*Portulaca oleracea*)	Foramsulfuron	0.37	2.37	0.96	22.95	5.83	60.26	22.42
(POROL)	Nicosulfuron	0.53	6.95	1.79	33.97	6.37	66.70	16.47

SE=Standard error.

2,4-D plus MCPA controlled black nightshade at more lower than recommended dose, so that 691.14 g a.i. h^{-1} of this herbicide resulted in 90 percent reduction in aboveground dry matter compared to untreated check. This control obtained at near or higher than labeled recommended dose by other herbicides, so that application of 52.42, 86.91 and 149.10 g a.i. h^{-1} of foramsulfuron, nicosulfuron and nicosulfuron plus rimsulfuron caused to 90 percent reduction in black nightshade dry matter (Figure 1 (c) and Table 2). Application of 2,4-D plus MCPA and nicosulfuron had benefit of reducing rate of herbicides lower than recommended dose at this growth stage of common purslane. Minimum dose required for 90% reduction in common purslane aboveground dry matter was 605 and 66.70 g a.i. h^{-1} of these herbicides, respectively (Figure 1 (d) and Table 2). Dogan et al. (2005) stated that common purslane was controlled satisfactorily by 50 g a.i. ha^{-1} of nicosulfuron at early growth stages (two- to four and five- to eight- true leaf stages). Foramsulfuron did not have an advantage in controlling common purslane over nicosulfuron at recommended dose. Based on regression model and ED_{90}, we need to apply 60.26 g a.i. h^{-1} of foramsulfuron to see this response.

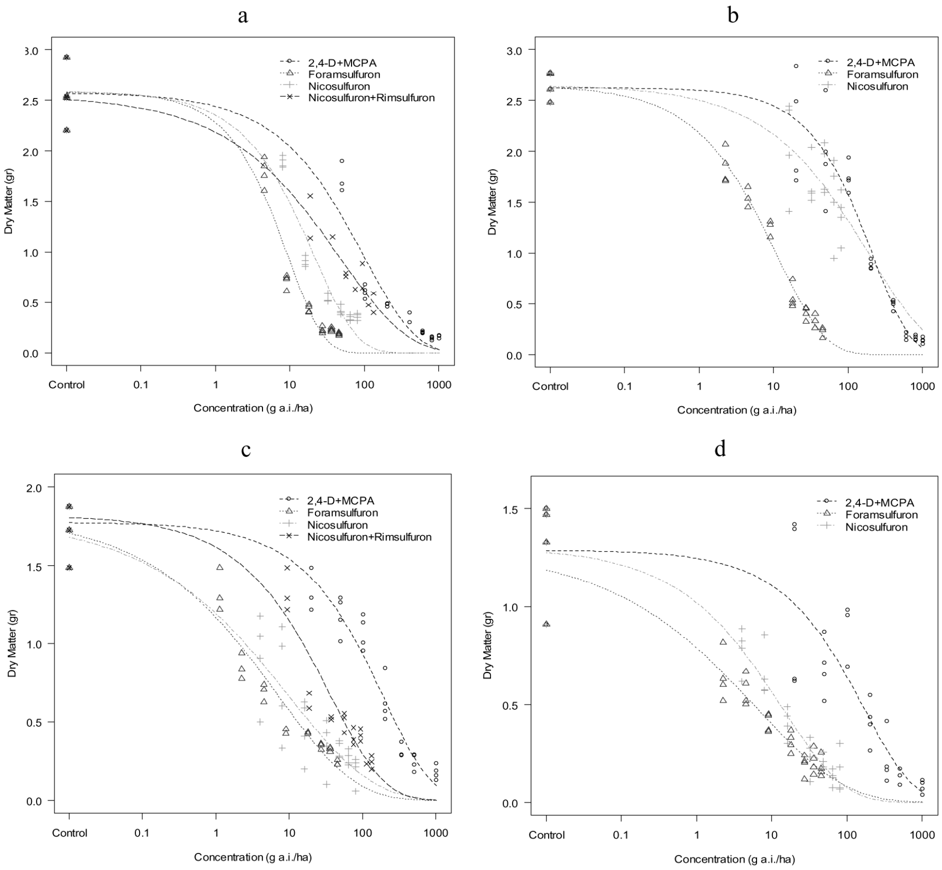

Figure 1. Dose-response curves of redroot pigweed (a), common lambs quarters (b), black nightshade (c) and common purslane (d) aboveground dry matter (g per pot) to 2,4-D plus MCPA and three sulfonylurea herbicides using the three parameter Gompertz model at four-to six-true leaf stage.

Results of this study demonstrated that phenological leaf stage is not the only substantial factor reducing recommended dose of herbicides, but also type of weed species is important. Redroot pigweed, common lambs quarters, black nightshade and common purslane can be effectively controlled by 2,4-D plus MCPA with doses ranging from 375.26 to 691.14 g a.i. ha^{-1} (*ED_{90}*). This confirms the high susceptibility of these species to 2,4-D plus MCPA at this growth stage. This growth stage can be critical period for some weeds providing maximum control and reduction in dry matter using reduced rates of 2,4-D plus MCPA. Less susceptible or unsusceptible weeds such as common lambsquarters related to nicosulfuron, confirm that this herbicide should not be used in weed control operations where such weed is present especially with high densities. Sulfonylurea herbicides such as foramsulfuron and nicosulfuron controlled weeds at near or higher than the maximum recommended dose (except of redroot pigweed) by 90 percent reduction in aboveground dry matter. Based on our results, we have to spray higher doses of sulfonylurea herbicides for controlling some weeds effectively. In these cases, we impose much pressure to these species while adding high rates of herbicides to the environment. Despite few herbicides available for broadleaf weeds control in Iran, it could be lead to tolerance in weeds to these herbicides. In addition, care is needed to avoid situations where the presence of one unsusceptible weed species escaping the treatment would hinder the overall effectiveness of weed control (Covarelli and Pannacci, 2000). Therefore, it is required to use a mixture of these herbicides with other herbicides such as 2,4-D plus MCPA to improve the efficacy, decrease in rate of herbicides, and prevent of herbicide tolerance or resistance. Values of relative potency (R) parameter between 2,4-D plus MCPA and sulfonylurea herbicides can give preliminary information for next experiments by knowing that mixture of 2,4-D plus MCPA with sulfonylurea herbicides is possible on important broadleaf weeds at this growth stage (Table 3). This parameter (R) help us calculate the correct composition of the mixture ratios by adjusting ration and ultimately estimating synergism, additive and antagonism between herbicides at different mixture ratios based on additive dose model (ADM) or other joint action models. Foramsulfuron controlled redroot pigweed more efficiently at this growth stage, so that using doses correspond to half of the maximum recommended dose, caused to 90 percent reduction in aboveground dry matter. This demonstrated that foramsulfuron can be considered as an alternative herbicide for controlling redroot pigweed where this weed is present. Dose-response curve did not show good efficacy of nicosulfuron plus rimsulfuron against weed species. Therefore, this herbicide should not be used in control operations where broadleaf weeds are present. In other words, other herbicides should be used to control broadleaf weeds where this herbicide considers controlling narrow-leaf weeds.

Table 3. Evaluation of relative potency between 2,4-D plus MCPA and sulfonylurea herbicides.

Weed species	Herbicide	Relative potency (R)		
		ED$_{50}$	*ED*$_{80}$	*ED*$_{90}$
Redroot pigweed	2.4-D plus MCPA: Foramsulfuron	8.77 (1.83)†	13.35 (2.48)	15.95 (4.22)
(*Amaranthus retroflexus*)	2.4-D plus MCPA: Nicosulfuron	4.22 (0.91)	5.32 (0.96)	5.88 (1.5)
(AMARE)	2.4-D plus MCPA: Nicosulfuron plus rimsulfuron	2.5 (0.87)	1.67 (0.46)	1.4 (0.6)
Common lambsquarters	2.4-D plus MCPA: Foramsulfuron	21.88 (4.33)	16.77 (2.5)	14.98 (2.78)
(*Chenopodium album*)	2.4-D plus MCPA: Nicosulfuron	1.44 (0.39)	0.79 (0.49)	0.61 (0.49)
(CHEAL)				
Black nightshade	2.4-D plus MCPA: Foramsulfuron	38.48 (11.19)	18.14 (4.32)	13.18 (4.1)
(*Solanum nigrum*)	2.4-D plus MCPA: Nicosulfuron	29.2 (10.2)	11.72 (2.68)	7.95 (2.55)
(SOLNI)	2.4-D plus MCPA: Nicosulfuron plus rimsulfuron	5.67 (1.39)	4.92 (0.95)	4.63 (1.19)
Common purslane	2.4-D plus MCPA: Foramsulfuron	41.53 (19.26)	15.33 (4.66)	10.03 (4.3)
(*Portulaca oleracea*)	2.4-D plus MCPA: Nicosulfuron	14.16 (4.8)	10.36 (2.6)	9.06 (2.95)
(POROL)				

† Standard errors are in parentheses.

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