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Evaluation of Broadleaf Weeds Control with Selectivity of Post-Emergence Herbicides in Sugar Beet (*Beta vulgaris* L.)

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Abstract

The reduction of herbicide applications is a main research priority in recent years. In order to study the effect of individual post-emergence application of sugar beet broad-leaf herbicides at four to six true-leaf stage of weeds, experiments were conducted during 2013. Treatments included untreated control and several rates of desmedipham + phenmedipham + ethofumesate, chloridazon and clopyralid on *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Chenopodium album*. A completely randomized layout with three replications was used for each herbicide. Three weeks after spraying (WAS), plants were harvested and measured their dry weight. These herbicides were more effective to control *Portulaca oleracea* than other weeds, thereupon minimum dose required for a satisfactory efficacy of 90% reduction of *Portulaca oleracea* aboveground dry matter (ED_{90}) were 299.22, 1138.31 and 129.44 g a.i ha^{-1} of desmedipham + phenmedipham + ethofumesate, chloridazon and clopyralid, respectively. *Solanum nigrum* was more affected by clopyralid application (132.40 g a.i ha^{-1}), and did not make significant difference in *Portulaca oleracea*. Chloridazon had lower effect for control of *Chenopodium album* due to existence of powdery covering on abaxial side of the leaves. Biomass ED_{50} or ED_{90}, based on log-logistic dose–response curves, for *Chenopodium album* was considerably higher than other species. These results showed that tank mixtures with other herbicides may be required for satisfactory weed control and reduction in applied herbicides doses.

Keywords: dose-response curve, effective dose, growth stage, reduced herbicide dose, weed control

Introduction

Sugar beet is a low growing crop and many weeds grow taller than sugar beet (Odero *et al.,* 2008). Competition from uncontrolled annual weeds that emerge within 8 weeks of sowing or within 4 weeks of the crop reaching the two-leaf stage can reduce root yields by 26-100% (Cioni and Maines, 2011). *Portulaca oleracea* L. (Common purslane), *Solanum nigrum* L. 'Black nightshade', *Amaranthus retroflexus* L. (Redroot pigweed) and *Chenopodium album* L. (Common lambsquarters) are four common broadleaf weeds found in sugar beet fields in Mashhad, Iran. There are few herbicides available to control broadleaf weeds in sugar beet in Iran. Clopyralid is a selective post-emergence herbicide that is a member of the pyridinecarboxyli acid family that has activity on a number of annual and perennial broadleaf weeds (Norsworthy and Smith, 2005) in sugar beet in Iran. In addition, desmedipham + phenmedipham + ethofumesate, phenylcarbamates + benzofuranyl alkanesulfonate herbicides are widely used for post-emergence broad-leaved weed control in sugar beet (Deveikyte and Seibutis, 2006; Markovska *et al.,* 2012). Chloridazon, a pyridazinone herbicide, is also used as a pre- and post-emergence herbicide in sugar beet (Deveikyte and Seibutis, 2006). Desmedipham, phenmedipham and chloridazon, are photosystem II (PSII) inhibitors, mostly absorbed not only by roots, but also by foliage (Cioni and Maines, 2011). Ethofumesate is fatty acid and lipid biosynthesis inhibitor which readily absorbed by emerging shoots and roots, and translocated readily to the foliage. Post-emergence applied ethofumesate is poorly absorbed by maturing leaves with a well developed cuticle (Jonson *et al.,* 1989).

Reducing the recommended dose of herbicides is one of the important instruments in weed management systems. Reduced herbicide applications could be achieved either by reducing the dosages or the number of treatments. In many cases, reduced dosages could provide adequate control of weeds down to 25-33% of recommended dosage without yield reductions (Cioni and Maines, 2011). In a few studies using the recommended dose, Barros *et al.* (2007) obtained a weed control efficiency of only 20-40%, whereas a weed control efficiency of 70% or higher was achieved in 50% of the studies with herbicide doses of only 20% of the label recommendation. Numerous researchers have observed that herbicide rates below those recommended can provide suitable weed suppression without affecting crop yields negatively (Zhang *et al.,* 2000). However, application should be carried out at early growth stages because herbicide efficacy is commonly reduced as weed increase in size (Cioni and Maines, 2011). Barros *et al.* (2007) found that using lower doses than recommended dose of mesosulfuron-methyl + iodosulfuron-methyl-sodium and mefenpyr-diethyl herbicides had well efficiency to annual grass weeds such as *Avena sterilis* L. and *Lolium rigidum* G. control. Also, Belles *et al.* (2000) reported that a 50% dose of tralkoxydim consistently achieved in excess of 85% *Avena fatua* L. (wild oat) control in *Hordeum vulgare* L. (barely). Weed management cost can be reduced by applying herbicides at reduced rates during early weed growth stages, as well, which resulting financially and environmentally beneficial to both to the grower and the consumer (Doyle and Stypa, 2004). Kirkland *et al.* (2001) investigated the effect of reduced herbicide rate on the efficacy of Everest. Reducing the rate to 2/3 the label resulted in 32% higher wild oat biomass compared to the full rate; however, there was no detrimental effect on crop yield.

Low-labeled herbicide rates in joining with competitive cropping and adjuvants for increase herbicide uptake and translocation to be an effective way of reducing herbicide input to agricultural system (Blackshaw *et al.,* 2006). In addition, inter-row cultivation in row crops and high crop density are other factors that enhance the likelihood of success with reduced herbicide doses (Blackshaw *et al.,* 2006). Therefore, by testing the impressiveness 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). Another researcher has also shown that it is possible to reduce herbicide doses in sugar beet (Lajos and Lajos, 2000; Zargar and Rostami, 2011). Dexter (1994) reported that half-rate of phenmedipham and/or desmedipham applied twice at a 5-7 days interval controlled weeds better and caused less sugar beet injury than a single full-rate application, and allowed application to smaller than four-leaf sugar beet. Ordero *et al.* (2008) stated that micro-rate applications in reduce dosage with ethofumesate were more controlled *Chenopodium album* and *Setaria viridis* compared with post-emergence herbicide programs alone, and sugar beet root yields were 6.97 mg/ha increased. Also, Dale *et al.* (2006) observed that the "micro-rate" application of desmedipham plus phenmedipham or desmedipham plus phenmedipham plus ethofumesate were reduced by 80%, when applied as micro-rate three to five times for *Chenopodium album* and *Amaranthus* spp. control.

Based on these results, the objectives of this study were to determine effective dose of sugar beet herbicides over a wide range of rates at four to six true-leaf stage of weeds by various parameters derived from the dose-response curve and evaluate the possibility of broadleaf weeds control with reduced rates of herbicides.

Materials and methods

Plant materials

Seeds of *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Chenopodium album* were collected from sugar beet fields in Mashhad, Iran, and were grown in 2 L pots filled with mixture of a sandy-loam soil, sand and peat (1:1:1wt/wt/wt) containing all necessary macro-and micro-nutrients. The experiments were conducted during a three-month period from April 2013 to June 2013 at the research greenhouse in Faculty of Agriculture, Ferdowsi University of Mashhad, Iran (Lat 36° 15' N, Long 59° 28' E; 985 m Altitude). The photoperiod was 16:8 h light:dark and temperature ranges were approximately 14/16 °C at night and 20/25 °C during the day. Four high-pressure sodium vapor lamps (Osram Sylvania, Lynn, MA, USA, 400 W, 22500 lumens) were installed 2 m above the plants to accommodate the photoperiod as mentioned above. Plants were tinned to four plants per pot at the cotyledon stage.4

Treatments and chemicals

There were four independent experiments for three herbicides, whose dose–response curves consisted of seven doses plus an untreated control. The dose ranges of desmedipham + phenmedipham + ethofumesate (Betanal Progress- OF®, 274 mg L^{-1}, Bayer Crop Science) were: 0, 51.38, 102.75, 205.5, 308.25, 411, 616.5 and 822 mg active ingredient (a.i.) ha^{-1}, chloridazon (Pyramin®, 650 g L^{-1},BASF A/S) were: 0, 81.25, 162.5, 325, 650, 1300, 1950 and 2600 g a.i. ha^{-1} and clopyralid (Lontrel® 300 mg L^{-1}, Golsam Gorgan Chemicals Corporation, Gorgan, Iran) were: 0, 15, 30, 60, 90, 120, 180 and 240 mg a.i. ha^{-1} for *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Chenopodium album*.

Spraying was performed by overhead trolley sprayer (Matabi 121030 Super Agro 20 l sprayer; Agratech Services-Crop®, Spraying Equipment, Rossendale, UK), 8002 flat-fan nozzle at 300 kPa and a spray volume of 200 L ha^{-1}. The plants were treated at 21 days (at the four- to six-true leaf stage) after transplanting. A completely randomized layout with three replications was used for each herbicide; the untreated pots had twelve replications.

Seven days after spraying, control percentages of plants were evaluated by visual rating. Visual observations were recorded every two weeks until 21 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. Three weeks after treatment (WAT), plants were harvested, oven-dried at 70 °C for 48 h and their dry weight measured.

Statistical analysis

If a significant dose effect was found, data were described by a log-logistic dose–response model against dose (Devilliers *et al.,* 2001):

$$U = \frac{d}{1+\exp[b(\log(z)-\log(ED50))]} \qquad (1)$$

Where U is the dry matter at dose z, d is the upper limit where the dose is zero, ED_{50} denotes the dose required reducing dry matter by half and b is proportional to the slopes of the curves around ED_{50}. The ED_{50} parameter can be replaced by any ED level (ED_x), so the selected model was used to estimate the dose of herbicides required to obtain 50% and 90% weeds control (ED_{50} and ED_{90} values) when applied individually. The goodness-of-fit was assessed by graphical analyses of residuals and the tests for lack of fit of the models, and the biomass data were Box-Cox transformed to obtain variance homogeneity (Streibig *et al.*, 1993). Data were analyzed by R statistical software (R Development Core Team, 2011) and the R extension package drc.

Assuming that Z_A and Z_B are the doses of herbicide A (PSII inhibitor herbicides) and B (Clopyralid) producing for example a 50% effect, i.e. the ED_{50} doses, the relative potency between the herbicides were calculated as:

$$R = Z_A / Z_B$$

The relative potency between herbicides A and B expresses the biological exchange rate between herbicides when applied separately (Streibig *et al.,* 1993).

Results and discussion

Visual observations

Desmedipham + phenmedipham + ethofumesate and chloridazon resulted to necrosis and chlorosis in *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Chenopodium album* due to interrupted and failures to photosynthesis function. Symptoms of chlorosis and epinasty of the leaves especially in petioles, and bending and twisting, tissue swelling and bursting stems were in response to the clopyralid application at higher doses. *Portulaca oleracea* and *Solanum nigrum* showed the highest susceptibility to desmedipham + phenmedipham + ethofumesate, so that application of 308.25 g a.i. ha^{-1} of herbicide resulted in 100 percent control 21 days after treatment (Tab. 1). Sweeney *et al.* (2008) described that post herbicides in sugar beet are effective only when applied to weeds less than 2 cm in height and repeated applications are usually needed because weeds continue to emerge until the time of canopy closure in late June or early July (Dexter, 1994; Dale and Renner, 2006). Strategies that reduce weed emergence early in the season would be beneficial to growers that must manage weeds in noncompetitive crops, such as sugar beet.

Chloridazon controlled *Solanum nigrum* and *Amaranthus retroflexus* better than other weeds based on visual observations. Clopyralid had the maximum effect on *Solanum nigrum* and *Portulaca oleracea*. *Chenopodium album* was insignificantly affected by desmedipham + phenmedipham + ethofumesate, chloridazon and clopyralid application, especially at lower doses (Tab. 1).

Dose–response assays

A summary of the dose response curve regressions for dry matter of *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus*

Tab. 1. Control percentages of *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Cheno podium album* based on visual observations at four- to six-true leaf stage

		POROL		SOLN		AMARE		CHEAL	
Herbicide	Rate	7 DAT	21 DAT	7 DAT	21 DAT	7 DAT	21 DAT	7 DAT	21 DAT
	g a.i./ha				% Control				
None	0	0	0	0	0	0	0	0	0
Desmedipham	51.38	6	23.34	2.67	21.67	4.33	11.34	3.34	9.67
+	102.75	7.67	25	5	65	6.67	15.34	5.76	13
phenmedipham	205.5	43.34	95	10	91.66	10	20	9.45	16.67
+	308.25	70	100	11.67	100	16.67	28.35	14.65	25
ethofumesate	411	100	100	11.34	100	28.34	91.37	23.34	38.67
	616.5	100	100	30	100	45	91.37	40	90.93
	822	100	100	31.67	100	63.75	90.63	46.67	90.93
Chloridazon	81.25	5	10	5	10	3.39	6.67	2.67	4.67
	162.5	6.67	15.34	6.67	13	4	7.69	3.34	6.95
	325	8.34	21.67	6.67	15.67	6.57	11.66	5.34	10.67
	650	13.34	25	11.67	23.34	7.66	16.68	6.34	13.44
	1300	18.34	90.27	16.67	90.67	8.35	90.47	7.34	35
	1950	25	89.78	18.34	91.67	20	89.47	10	90.97
	2600	30	91.96	25	92.12	21.67	85.91	11.67	86.57
Clopyralid	15	5	7.67	1.67	10	1.67	10	0	4.67
	30	6	15	5	16.34	3.34	16.67	1.67	6.95
	60	10	23.34	6.67	25	5.34	15	2.67	10.67
	90	15	46.67	13.34	51.67	8.33	21.67	5	13.44
	120	20	48.34	15	58.47	16.67	26.67	11.67	20
	180	30	93.34	23.34	96.67	23.34	91.67	13.34	90.17
	240	31.67	89.67	25	90.66	25.34	89.32	15	85.47

Note: Visual observations of weeds were made 7 and 21 days after treatment (DAT)
Abbreviations: POROL, *Portulaca oleracea* L. (common purslane); SOLNI, *Solanum nigrum* L. (black nightshade); AMARE, *Amaranthus retroflexus* L. (redroot pigweed); CHEAL, *Chenopodium album* L. (common lambsquarters)

retroflexus and *Chenopodium album*, for the four experiments is shown in Fig. 1.

Dose-response curves of herbicide applications showed that desmedipham + phenmedipham + ethofumesate and clopyralid were more effective on aboveground dry matter of *Portulaca oleracea* 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 *Portulaca oleracea* aboveground dry matters were 299.22 and 129.44 g a.i. ha^{-1} of desmedipham + phenmedipham + ethofumesate and clopyralid, respectively (Fig. 1 (c) and Tab. 2). Norsworthy and Smith (2005) found post treatments *Portulaca oleracea* with phenmedipham and clopyralid at 0.55 and 0.10 kg ai/ha respectively, were resulted sufficient control of it. Fennimore and Rachuy (2005) reported that desmedipham/ phenmedipham and ethofumesate applications provided acceptable control of *Portulaca oleracea* and *Amaranthus retroflexus* as well. Our results showed that rates of herbicides can be less than recommended dose, if controlling operations was done at this growth stage. Chloridazon controlled *Portulaca oleracea* by 80% reduction in weed aboveground dry matter at the rate of 574.71 g a.i. ha^{-1}, but twice the amount rate of herbicide was needed for 90% reduction, approximately (Tab. 2).

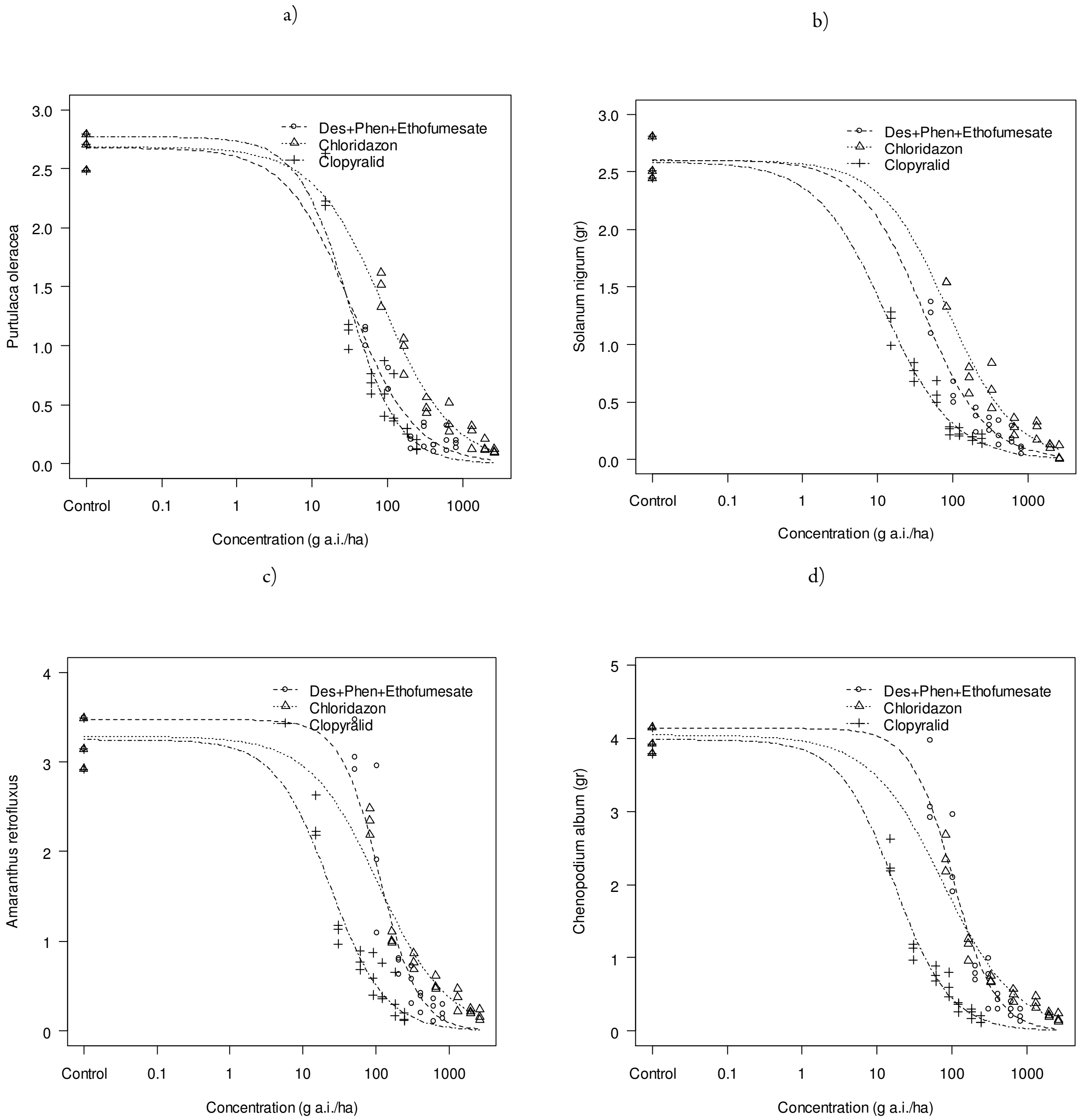

Fig. 1. Dose-response curves of *Portulaca oleracea* (a), *Solanum nigrum* (b), *Amaranthus retroflexus* (c) and *Chenopodium album* (d), aboveground dry matter (g per pot^{-1}) to clopyralid and PSII inhibitor herbicides using the three parameter logistic model at four- to six-true leaf stage

Desmedipham + phenmedipham + ethofumesate controlled *Solanum nigrum* at lower than recommended dose, so that 316.60 g a.i. ha^{-1} of this herbicide resulted in 90 percent reduction in aboveground dry matter compared to untreated check. This control obtained at higher dose by other herbicides in *Solanum nigrum* dry matter than *Portulaca oleracea*, so that application of 1149.16, 132.40 g a.i. ha^{-1} of chloridazon and clopyralid caused to 90 percent reduction (Fig. 1 (c) and Tab. 2). Application of these herbicides had benefit of reducing rate of herbicides lower than recommended dose at the four to six true-leaf stage of *Solanum nigrum*. Dexter (1998) stated that desmedipham and phenmedipham (betanex) and desmedipham + phenmedipham (betamix) and desmedipham + phenmedipham + ethofumesate (progress) had good effectiveness for eastern *Solanum nigrum* control. Kaya and Buzluk (2006); Kaya (2012) described that sugar beet post-emergence herbicides such as phenmedipham + desmedipham + ethofumesate, chloridazon and clopyralid resulted in very good *Solanum nigrum* L. control and those affect were increased when combination with hand and tractor hoeing treatments.

Application of phenmedipham + desmedipham + ethofumesate and clopyralid had benefit of reducing rate of herbicides lower than recommended dose at this growth stage of *Amaranthus retroflexus*. Minimum dose required for 90% reduction in *Amaranthus retroflexus* aboveground dry matter were 343.96 and 137.29 g a.i. ha^{-1} of these herbicides, respectively (Fig. 1 (d) and Tab. 2). Rola and Rola (1992) revealed that good control of *Amaranthus retroflexus* L. was obtained with desmedipham + phenmedipham [Betanal Compact] in sugar beet. Herceg (2002); Abdollahi and Ghadiri (2004) showed that phenmedipham + desmedipham + ethofumesate applied alone at 0.23 + 0.23 + 0.23 kg ai/ha, provide good control of *A. retroflexus*.

Chenopodium album was controlled at the rate of 427.77 g a.i. ha^{-1} of phenmedipham + desmedipham + ethofumesate by 90% reduction in aboveground dry matter (Fig. 1 (b) and Tab. 2). Toth and Peter (1997) found that phenmedipham, or phenmedipham / desmedipham, or phenmedipham / ethofumesate had poor effect on *Chenopodium album* L. control at the five to six true-leaf stage, but this control was raised when phenmedipham/ ethofumesate combined with triflusulfuron and metamitron. Hakoyama *et al.* (1997) stated that phenmedipham or lenacil + chloridazon were not affected *Chenopodium album* L. in sugar beet fields at six true-leaf stage. Based on our observations and fitted dose-response curve, *Chenopodium album* was less affected by chloridazon and clopyralid application, so that applied doses values for *Chenopodium album* control were higher than for other weeds in 21 days after treatment (Tab. 1 and 2). Devikyte and Seibutis (2006) depicted chloridazon had low efficacy to *Chenopodium album* control, but that performance was improved when applied with phenmedipham + desmedipham + ethofumesate. Zargar and Rostami (2011), showed that best results of *Chenopodium album* L. and *Amaranthus retroflexus* L. control were achieved in using herbicide was metamitron (Goltix) + phenmedipham +

Tab. 2. Summary of dose–response regressions of dry matter at days after treatment (DAT) (four- to six-true leaf stage) for each species and experiment. Asymptotic standard errors are in parentheses. In all four experiments the test for lack of fit was not significant, indicating that the logistic model was able to describe the data better than an ordinary ANOVA

Weed species	Herbicide	D[a]	Curve slope	Effective dose (g a.i. ha^{-1})			Lack of fit test (5%)
			b	ED_{50}	ED_{80}	ED_{90}	
Common purslane	Desmedipham+ phenmedipham+ ethofumesate	2.55	1.03	35.08 (7.29)[b]	135.65 (16.64)	299.22 (42.39)	0.48 (NS)[c]
(*Portulaca oleracea*)	Chloridazon	2.83	1.19	187.67 (16.68)	574.71 (38.22)	1138.31 (107.67)	0.98 (NS)
(POROL)	Clopyralid	3.66	1.13	18.72 (2.84)	63.41 (6.56)	129.44 (14.59)	0.57 (NS)
Black nightshade	Desmedipham+ phenmedipham+ ethofumesate	2.68	1.02	37.47 (5.66)	144.02 (13.38)	316.60 (33.81)	0.11 (NS)
(*Solanum nigrum*)	Chloridazon	2.52	1.26	198.35 (24.77)	595.59 (54.65)	1149.16 (140.53)	0.38 (NS)
(SOLNI)	Clopyralid	2.48	0.94	12.66 (2.55)	55.67 (7.92)	132.40 (15.52)	0.97 (NS)
Redroot pigweed	Desmedipham+ phenmedipham+ ethofumesate	4.66	1.44	75.56 (12.1)	196.60 (21.58)	343.96 (36.24)	0.78 NS)
(*Amaranthus retroflexus*)	Chloridazon	3.72	1.22	201.58 (21.92)	626.35 (57.99)	1215.74 (125.65)	0.22 (NS)
(AMARE)	Clopyralid	3.64	1.13	19.74 (2.59)	67.12 (7.22)	137.29 (20.04)	0.09 (NS)
Common lambsquarters	Desmedipham+ phenmedipham+ ethofumesate	4.13	1.55	93.21 (11.12)	223.11 (18.69)	427.77 (31.11)	0.69 (NS)
(*Chenopodium album*)	Chloridazon	4.01	1.19	387.79 (60.88)	790.32 (57.95)	1361.83 (134.13)	0.56 (NS)
(CHEAL)	Clopyralid	3.98	1.18	17.09 (2.55)	55.38 (5.53)	149.16 (10.69)	0.27 (NS)

[a] The upper limit when the dose is zero. [b] Standard errors are in parentheses. [c] NS: not significant at the 5% level

Tab. 3. Evaluation of relative potency between PSII + lipid biosynthesis inhibitor and clopyralid herbicides

Weed species	Herbicide	Relative potency (R)		
		ED_{50}	ED_{80}	ED_{90}
Common purslane	Desmedipham+ phenmedipham+ ethofumesate : Clopyralid	1.87 (0.28)[a]	2.14 (0.78)	2.31 (0.59)
(*Portulaca oleracea*)	Chloridazon : Clopyralid	10.03 (2.57)	9.06 (2.43)	8.79 (1.27)
(POROL)				
Black nightshade	Desmedipham+ phenmedipham+ ethofumesate : Clopyralid	2.96 (0.71)	2.59 (0.42)	2.39 (0.62)
(*Solanum nigrum*)	Chloridazon : Clopyralid	15.67 (2.43)	10.69 (3.75)	8.56 (2.94)
(SOLNI)				
Redroot pigweed	Desmedipham+ phenmedipham+ ethofumesate : Clopyralid	3.83 (1.83)	2.93 (0.69)	2.51 (0.84)
(*Amaranthus retroflexus*)	Chloridazon : Clopyralid	10.21 (2.83)	9.33 (3.92)	8.86 (3.67)
(AMARE)				
Common lambsquarters	Desmedipham+ phenmedipham+ ethofumesate : Clopyralid	5.45 (1.48.)	4.03 (1.04)	2.87 (0.85)
(*Chenopodium album*)	Chloridazon : Clopyralid	22.69 (6.49)	14.27 (4.93)	9.13 (2.73)
(CHEAL)				

[a]Standard errors are in parentheses

desmedipham + ethofumesate (Betanal progress). Dale *et al.,* (2006) revealed the control of *Chenopodium album* L. and *Amaranthus* spp. by desmedipham + phenmedipham and desmedipham + phenmedipham + ethofumesate without any effect on sugar beet plants.

The reason for this apparent discrepancy could be attributed to the different phenological stages of plant development at the time of treatment, and type of weed species as well. This is illustrated by the relative potency between the herbicides (Tab. 3). *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Chenopodium album* can be effectively controlled by desmedipham + phenmedipham + ethofumesate with doses ranging from 299.22 to 427.77 g a.i. ha^{-1} (ED_{90}). This approved the high susceptibility of these species to desmedipham + phenmedipham + ethofumesate 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 desmedipham + phenmedipham + ethofumesate. Less susceptible or higher ED_x values *Chenopodium album* related to desmedipham + phenmedipham + ethofumesate, chloridazon and clopyralid because of existence powdery covering on abaxial side of the leaves, resulted to decline the penetration of herbicide in to plant tissue (Taylor *et al.,* 1981), hence, confirm that these herbicides should not be used in weed control operations where such weed is present especially with high densities.

PSII inhibitor herbicide such as chloridazon controlled weeds at higher doses more than other herbicides (except of *Portulaca oleracea*) by 90 percent reduction in aboveground dry matter. It could be due to lesser solubility and more deposit chloridazon in sprayer tank. Based on our results, we have to spray higher doses of chloridazon for controlling some weeds effectively. In this occasion, we impose much pressure to these species while adding high rates of herbicides to the environment. Also, due to few herbicides available for broadleaf weeds control in Iran, it could be lead to tolerance in weeds to these herbicides. On the other hand, sugar beet herbicides seldom have a wide enough weed control spectrum or sufficient residual activity to control all weeds and tank mixes of different herbicides are commonly used in order to provide a broad spectrum of weed control (Cioni and Maines, 2011). Therefore, it is required to use a mixture of this herbicide with other herbicides such as desmedipham + phenmedipham + ethofumesate to improve the efficacy, decrease in rate of herbicides, and prevent of herbicide tolerance or resistance.

Conclusion

As a conclusion, desmedipham + phenmedipham + ethofumesate were more potent than that of chloridazon and clopyralid against *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Chenopodium album* based on our experiments. ED_{50} and ED_{90} values for desmedipham + phenmedipham + ethofumesate were lesser compared with chloridazon and clopyralid against *Portulaca oleracea*, *Solanum nigrum*, *Amaranthus retroflexus* and *Chenopodium album* at the four to six true-leaf stage. The lowest dose was required for 50% or 90% reduction in dry matter of *Portulaca oleracea* than other weeds species by application of desmedipham + phenmedipham + ethofumesate, chloridazon and clopyralid (Tab. 1). This is again illustrated by the relative potency between the herbicides (Tab. 3) desmedipham + phenmedipham + ethofumesate rather than chloridazon and clopyralid for these adequate weed control in sugar beet.

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