Crop Protection 42 (2012) 345–350

Contents lists available at SciVerse ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Evaluating the efficacy of pre- and post-emergence herbicides for controlling *Amaranthus retroflexus* L. and *Chenopodium album* L. in potato

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ARTICLE INFO

Article history:
Received 12 July 2011
Received in revised form
17 May 2012
Accepted 5 June 2012

Keywords:
Weed control
Herbicide injury
Crop safety

ABSTRACT

Field studies were conducted from 2008 to 2010 to evaluate the control of *Amaranthus retroflexus* and *Chenopodium album* and tolerance of potato (*Solanum tuberosum* cv. Agria) to ethalfluralin, trifluralin, pendimethalin, rimsulfuron, EPTC and oxadiargyl applied pre-emergence (PRE) and post-emergence (POST) at seven rates. The experiments showed that trifluralin applied PRE, rimsulfuron applied PRE or POST and oxadiargyl applied POST provided the best control of *A. retroflexus*. Rimsulfuron and oxadiargyl applied POST and pendimethalin applied PRE were the best control options for *C. album*. Except for trifluralin and pendimethalin the susceptibility of the two weed species to the herbicides was similar. Trifluralin was more effective against *A. retroflexus* than *C. album* while the opposite was true for pendimethalin. Applied POST oxadiargyl was more effective than applied PRE. In contrast no differences were observed between PRE and POST applications for metribuzin, rimsulfuron and EPTC. Crop injury to rimsulfuron applied PRE or POST, trifluralin and pendimethalin was negligible while the other herbicides injured the potato crop. Metribuzin, oxadiargyl and ethalfluralin tended to cause more damage than EPTC. The results suggest that rimsulfuron and trifluralin would be the best options for weed control of *A. retroflexus* and *C. album* in Iranian potato fields.

1. Introduction

Potato (*Solanum tuberosum*) is one of the most important and widely grown root crops in the world and approximately 190,000 ha of potatoes are grown annually in Iran. Effective weed control is essential to ensure high yields and good quality. Weed competition can reduce yield, size, and quality of potato tubers (Eberlein et al., 1997; Nelson and Thoreson, 1981; VanGessel and Renner, 1990; Wall and Friesen, 1990a, 1990b). In Iran, manual weeding carried out during ridging is the most common method of weed control. However, manual weed control is labour-intensive and costly and has a significant bearing on the overall cost of production. Currently metribuzin is the only herbicide registered for use in potato production in Iran and it is commonly used both preemergent (PRE) and postemergent (POST) (Zand et al., in press).

Metribuzin is a standard component of many weed management programmes in potato because it is effective on many broadleaf weeds and grasses (Ackley et al., 1996a; Robinson et al., 1996). Heavy reliance on metribuzin has, however, resulted in an increase in the frequency of metribuzin tolerant weed species such as hairy nightshade (*Solanum sarachoides* Sendt.) and also resulted in the selection of metribuzin-resistant biotypes e.g. of *Chenopodium album* and *Amaranthus retroflexus* (Eberlein et al., 1994). In addition, the use of metribuzin POST is restricted because many potato cultivars are sensitive to foliar applications of this herbicide with short-season red or white-skinned potato cultivars being the most susceptible (Friesen and Wall, 1980). Also, three consecutive days of sunny weather are required prior to application of metribuzin POST to avoid crop injury (Friesen and Wall, 1980). Additionally because of the short residual effect metribuzin is not effective against late emerging weed species, especially *C. album* and *A. retroflexus*.

The objective of our research was to evaluate the response of *C. album* and *A. retroflexus* and the tolerance of potato to

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0261-2194/$ – see front matter
http://dx.doi.org/10.1016/j.cropro.2012.06.004

a dose range of metribuzin, rimsulfuron, EPTC, oxadiargyl, ethalfluralin, trifluralin and pendimethalin applied PRE or POST emergence.

2. Materials and methods

Trials were conducted in 2008, 2009 and 2010 in the North western part of Iran near Ardabil (longitude 48′ 20″, latitude 19′ 38″, altitude1350 m). The soil type was a Delco loam (coarse-loamy, mixed, mesic, xerollic calciorthids) with 1.4% organic matter and a pH of 8.0. Tuber pieces of the variety Agria were planted at 25-cm intervals, within rows spaced 75 cm apart. The ridges were hilled at approximately 10% emergence (standard grower practice). Plot size was 3 m (4 rows) by 4 m. The experimental designs were a randomized complete block with four replications. Plots were irrigated as needed throughout the growing season to maintain minimum available soil water content of 65%. The following herbicides were used: metribuzin (700 g ai/kg, Sencor™, Bayer Persian AG, Tehran, Iran), ethalfluralin (360 g ai/L, Sonalan™, Dow AgroSciences, Indianapolis, IN-46268, USA), trifluralin (480 g ai/L, Treflan™, Dow AgroSciences, Indianapolis, IN-46268, USA), pendimethalin (400 g ai/L, Stomp™, BASF Iran AG, Tehran, Iran), rimsulfuron (250 g/kg, Titus™, DuPont, Wilmington, DE, 19805, USA), EPTC (800 g/L, EPTC, Eradican™, Golsam, Tehran, Iran) and oxadiargyl (400 g/L, Topstar™, Giah Company, Tehran, Iran). Herbicides were applied using a CO_2-pressurized backpack sprayer fitted with 8002 VS flat fan nozzles delivering a volume rate of 160 L/ha at 250 kPa. Pre-plant applications were made before potato planting while post-emergence applications were made when potato plants were 15 cm tall. The weed flora was dominated by *C. album* (22.3 plants/m^2 on average) and *A. retroflexus* (27.8 plants/m^2 on average). The two weed species were at the cotyledon to 2–3 leaf stage at the post-emergence application time.

2.1. Experiment 1

The experiment was carried out in 2008 and 2009. Seven herbicides each applied at seven dose rates from zero to dose rates exceeding commercial recommendations. An overview of the herbicide treatments is given in Table 1. Crop tolerance, determined by assessment of visible injury, foliar discolouration and reduced plant health was assessed on a 0–100% scale where 0 = no injury and 100 = plant death. Visible injury of PRE and POST treatments was assessed 1 and 3 weeks after crop emergence (WAE) and 1 and 3 weeks after treatment (WAT), respectively. Tubers were harvested from the centre two rows of each plot 2–3 weeks after desiccation, using a single row plot harvester. Visual estimates of weed control were assessed on a scale from 0 to 100%, with 0 = no control and 100% = complete control.

Table 1
Herbicides used in experiment 1.

Herbicide	Rate (g ai/ha)	Time of application
Metribuzin[1]	0, 210, 280, 560, 700, 875and 1000 g/ha	Pre and Post emergence
Ethalfluralin[2]	0, 1, 2, 3, 4, 5 and 6 L/ha	Pre emergence
Trifluralin[3]	0, 1, 1.5, 2, 2.5, 3 and 4 L/ha	Pre emergence
Pendimethalin[4]	0, 0.5, 1, 1.5, 2, 4 and 6 L/ha	Pre emergence
Rimsulfuron[5]	0, 5, 10, 20,30, 40 and 50 g/ha	Pre and Post emergence
EPTC[6]	0, 2, 3, 3.5, 4, 4.5 and 5 L/ha	Pre and Post emergence
Oxadiargyl[7]	0, 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 L/ha	Pre and Post emergence

2.2. Experiment 2

The experiment was conducted in 2010. The objective of this experiment was to narrow down the herbicide doses required to control *C. album* and *A. retroflexus*. Each herbicide, except metribuzin, was applied at 3 rates while metribuzin was only applied at one rate. The trial was conducted at two locations and within each experiment the treatments were replicated 4 times (Table 2). Crop injury and weed control percent were assessed as in the 2009 experiment.

2.3. Statistical analysis

Visual estimates of weed control recorded in experiment 1 were expressed as 100% effect and analysed using non-linear regressions (PROC NLIN, SAS[8] Institute). A three parameter log-logistic model was fitted to the data (Kudsk and Mathiassen, 2007; Ritz, 2010):

$$U_{ij} = \frac{D}{1 + \exp(2b_i(\log(ED_{50i}) - \log(z_{ij})))} \quad (1)$$

where U_{ij} denotes percent weed control at the *j*th dose of the *i*th herbicide (z_{ij}); D denote the upper asymptote of percent weed control at infinite doses. The simultaneous fit within year for both weed species and the applications assumed common upper limit, D for all response curves while the ED_{50} and b parameters were estimated for each dose response curve.

By re-parameterising Eqn. (1) the ED_{50} parameter can be replaced by ED_{90} that is of more practical relevance than ED_{50}.

$$U_{ij} = \frac{D}{1 + \exp(2b_i(\log(ED_{90i}) + 1.099/b_i - \log(z_{ij})))} \quad (2)$$

Within each experiment non-linear regression models were fitted simultaneously to the dose response curves of the PRE and POST treatments for each weed species. A Transform-Both-Sides method was applied to stabilize the variance (Streibig et al., 1993). A test for lack-of-fit and visual assessment of the plots of observed and predicted values were used to assess the assumption that the response of the herbicides and herbicide mixtures could be described by Eqns. (1) and (2) (Seefeldt et al., 1995). The test for lack of fit compares the Mean Square Error of the analysis of variance with the Mean Square Error of the non-linear regression, i.e. the variation between replicates with the variation between observed and predicted values.

An analysis of variance was performed on the visual estimates of weed control recorded in Experiment 2 and all data on visual injury using PROC GLM (SAS[8] Institute). Due to the lower number of doses in Experiment 2 it was not possible to fit dose response curves to the data. All data were arcsine transformed to ensure variance homogeneity. Non-transformed data are shown in the tables. No significant year by treatment or location by year interaction was found with these data; hence the data were pooled over years and locations.

Table 2
Herbicides and herbicide rates used in experiment 2.

Herbicide	Rate (g ai/ha)	Time of application
Metribuzin	490	Pre emergence
Trifluralin	960, 1200 and 1440	Pre emergence
Pendimethalin	600, 800 and 1600	Pre emergence
Rimsulfuron	7.5, 10 and12.5	Pre and Post emergence
Oxadiargyl	160, 200 and 240	Pre and Post emergence

3. Results and discussion

3.1. Experiment 1

3.1.1. Weed control

Tests for lack of fit rejected the hypotheses that Eqns. (1) and (2) could be fitted to the data whereas visual assessment of the non-linear regressions revealed a very good agreement between observed and predicted values, as illustrated in Fig. 1 for *C. album* exposed to PRE applied herbicides. In the present experiments the Mean Square Errors of the analyses of variances tended to low which could explain why the assumption of log-logistic dose response curves was rejected. The low Mean Square Errors of the analyses of variance can be attributed to visual assessments and not biomass being used as response variable (standard errors on visual assessments tend to be lower than on biomass data) and the fact that for some herbicides the observed values were located at the upper end of the dose response curve where variation is less than around the ED_{50} (see Fig. 1). Visual assessments of the plots revealed a rather good agreement between observed and predicted values and with acceptable standard errors of ED_{50} and ED_{90}.

Despite an uneven distribution of the doses along the dose response curve for metribuzin, ethalfluralin and trifluralin it was possible to fit dose response curves to all treatments and to estimate ED_{50} and ED_{90} doses (Tables 3 & 4). The estimated ED_{50} and ED_{90} did not vary significantly between years suggesting that the performance of the herbicides was not strongly influenced by application variables such as climate.

A comparison of the performance of the herbicides on *A. retroflexus* and *C. album* revealed similar susceptibility of the two weed species to metribuzin PRE and POST, ethalfluralin, rimsulfuron PRE, EPTC PRE and POST and oxadiargyl POST. In contrast, *A. retroflexus* was more susceptible to trifluralin and rimsulfuron POST than *C. album* while the opposite was true for pendimethalin and oxadiargyl PRE. Applied PRE the ED_{90} dose of pendimethalin, EPTC and oxadiargyl on *A. retroflexus* exceeded the maximum dose applied while this was only observed for EPTC on *C. album*. For POST treatments only the ED_{90} dose of EPTC applied to *A. retroflexus* exceeded the maximum dose.

Metribuzin PRE and POST provided effective control of both weed species at the three highest doses and estimated ED_{90} doses varied from 202 to 276 g/ha for *A. retroflexus* and 179–252 g/ha for *C. album*, respectively. Our results were similar to those of previous studies, e.g. Robinson et al. (1996) and Renner and Powell (1998).

Tonks et al. (2000) reported 82% and 78% control of *A. retroflexus* and *C. album* of 1050 g/ha ethalfluralin applied PRE and similar results were reported by Ransom and Ishida (1998), i.e. a somewhat lower activity than observed in the present experiments (ED_{90} doses ranging from 572 to 709 g/ha). Hutchinson et al. (2005) reported that pendimethalin PRE at 1100 g/ha controlled *A. retroflexus* by 53% and *C. album* by 75% confirming our results. In contrast, triazine-resistant *C. album* was controlled by 91–100% by pendimethalin PRE at 1100 g/ha (Chomas and Kells, 2004).

Rimsulfuron PRE and POST at the highest dose of 12.5 g/ha provided 100% control of *A. retroflexus* and 95–98% control of *C. album* (95%). ED_{90} doses ranged from 4.99 to 6.15 g/ha for *A. retroflexus* and 7.30–9.58 g/ha for *C. album*. Our results are in agreement with the findings of Hutchinson et al. (2005), Renner and Powell (1998), Ackley et al. (1996b) and Robinson et al. (1996) but not with Eberlein et al. (1994) who reported lower effects particularly on *C. album*.

EPTC PRE applied at the maximum dose of 4000 g/ha provided less than 90% effect on both weed species while the same dose applied POST resulted in effects around or slightly higher than 90%. The estimated ED_{90} doses were higher than 4000 g/ha except for EPTC POST on *C. album*. In a previous experiment EPTC applied at 3400 g/ha controlled *A. retroflexus* and *C. album* at 70% and 81%, which is comparable to the effect levels recorded in the present experiments (Hutchinson et al., 2005).

Generally only minor differences were found between PRE and POST applications except for oxadiargyl where POST applications were significantly more effective than PRE applications. This could suggest that foliar activity is not contributing

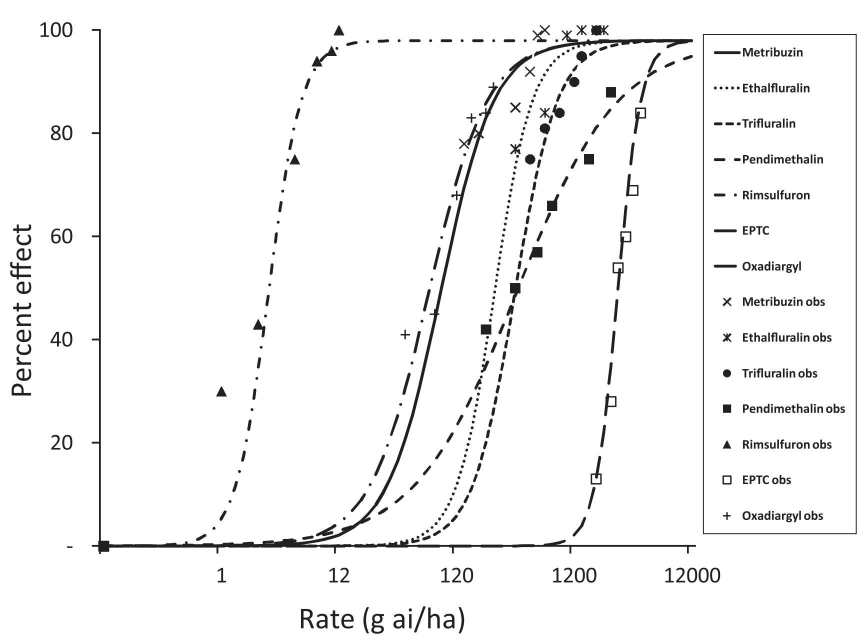

Fig. 1. Estimated dose response curves and observed responses for 7 herbicides applied pre-emergence to *Amaranthus retroflexus* (Experiment 1, 2009 trial). Data shown as percent effect.

Table 3
Estimated regression parameters of 7 herbicides applied PRE and POST to *Amaranthus retroflexus* L and *Chenopodium album* L (Experiment 1, 2008 trial). Responses variable is 100-percent weed control. Doses are in g ai/ha. Figures in parentheses are approximate standard errors.

Herbicide	*Amaranthus retroflexus* PRE			*Chenopodium album* PRE		
	$D = 95.8$ (3.2)			$D = 95.8$ (3.2)		
	ED_{50}	ED_{90}	*b*	ED_{50}	ED_{90}	*b*
Metribuzin	96 (19)	276 (15)	−2.20 (0.19)	85 (10)	253 (14)	−2.14 (0.19)
Ethafluralin	274 (27)	608 (32)	−2.89 (0.27)	277 (31)	709 (40)	−2.47 (0.25)
Trifluralin	408 (37)	970 (41)	−2.69 (0.26)	538 (57)	1838 (157)	−1.89 (0.23)
Pendimethalin	480 (74)	4320 (936)	−1.06 (0.14)	252 (26)	872 (56)	−1.87 (0.15)
Rimsulfuron	3.3 (0.2)	6.2 (0.2)	−3.73 (0.30)	3.8 (0.3)	9.6 (0.5)	−2.53 (0.25)
EPTC	2936 (107)	4800 (279.2)	−4.73 (0.71)	2776 (97)	4336 (174)	−5.21 (0.67)
Oxadiargyl	130 (10)	358 (43)	−2.30 (0.35)	65 (7)	222 (17)	−1.90 (0.21)
	Amaranthus retroflexus POST			*Chenopodium album* POST		
Metribuzin	77 (11)	202 (15)	−2.41 (0.26)	79 (9)	197 (12)	−2.53 (0.22)
Rimsulfuron	2.9 (0.2)	5.0 (0.2)	−4.25 (0.38)	3.4 (0.3)	7.7 (0.4)	−2.83 (0.26)
EPTC	2808 (112)	4136 (162)	−6.00 (0.89)	2592 (87)	3720 (91)	−6.40 (0.70)
Oxadiargyl	34 (5)	114 (9)	−1.91 (0.21)	30 (4)	95 (6)	−2.00 (0.18)

significantly to the overall activity of the tested herbicides. Metribuzin and EPTC are considered residual herbicides and a limited foliar activity is not surprising. On the other hand several studies have shown that rimsulfuron is absorbed by the foliage and translocated to other plant parts (Ackley et al., 1999; Mekki and Leroux, 1995) hence it was to be expected that the performance of POST applications would be higher than that of PRE applications but they are almost similar. A likely explanation is that rimsulfuron was applied without a tank adjuvant as adjuvants have been shown to promote rimsulfuron activity (Tonks and Eberlein, 2001; Green, 2002).

3.1.2. *Crop tolerance*

Initial injury 1 WAE by metribuzin PRE and POST was up to 24% (Table 5). Three WAE injuries had increased for metribuzin PRE while the potato crop had partly recovered from metribuzin POST. Of the 7 herbicides tested in the experiment metribuzin caused the highest levels of crop injury. Similar levels of injury were found in previous studies (Robinson et al., 1996; Renner and Powell, 1998; Ivany, 2002).

Maximum initial injury of ethalfluralin 1 and 3 WAE was 18 and 13%, respectively indicating that the potato crop recovered from the early injury (Table 5). Tonks et al. (2000) reported findings similar to ours, but also reported that cool, cloudy weather before or after application reduced potato tolerance to ethalfluralin. Initial injury 1 and 3 WAE following application of trifluralin was less than for ethalfluralin ($\leq$4%) suggesting that potato is more tolerant to trifluralin than ethalfluralin. No crop damage was observed when trifluralin was applied at rates from 480 to 1200 g/ha. Initial injury at both 1 and 3 WAE with pendimethalin was intermediate between ethalfluralin and trifluralin. Pendimethalin injury decreased slightly after 3 weeks. No injury ($<$5%) was observed during the growing season following pre- or post-emergence application of rimsulfuron. Boydston (2007) also found that rimsulfuron applied at 18 or 26 g/ha controlled weeds without potato injury and similar results were reported by other researchers (Eberlein et al., 1994; Ivany, 2002; Haidar et al., 2005).

Potato injury 1 WAE by EPTC ranged from 1 to 15% (PRE) and 3 to 20% (POST) (Table 5). EPTC applied POST caused chlorosis, especially in young leaves, and reduced potato height. Injury decreased after 3 weeks. Potato injury from oxadiargyl was similar to that of metribuzin ranging from 1 to 23% but 3 weeks after application the potato crop had recovered.

Table 4
Estimated regression parameters of 7 herbicides applied PRE and POST to *Amaranthus retroflexus* L and *Chenopodium album* L (Experiment 1, 2009 trial). Response variable is 100-percent weed control. Doses are in g ai/ha. Figures in parentheses are approximate standard errors.

Herbicide	*Amaranthus retroflexus* Pre-emergence			*Chenopodium album* Pre-emergence		
	$D = 95.6$ (3.4)			$D = 95.6$ (3.4)		
	ED_{50}	ED_{90}	*B*	ED_{50}	ED_{90}	*b*
Metribuzin	96 (11)	277 (16)	−2.20 (0.20)	81 (10)	244 (14)	−2.11 (0.19)
Ethafluralin	270 (26)	572 (30)	−3.10 (0.29)	274 (28)	659 (35)	−2.64 (0.259)
Trifluralin	408 (37)	941 (40)	−2.77 (0.27)	494 (56)	1786 (151)	−1.81 (0.229)
Pendimethalin	464 (70)	3496 (656)	−1.15 (0.15)	248 (23)	752 (42)	−2.09 (0.159)
Rimsulfuron	3.2 (0.2)	6.1 (0.3)	−3.59 (0.30)	3.7 (0.3)	8.9 (0.4)	−2.63 (0.249)
EPTC	2944 (105)	4616 (239)	−5.15 (0.77)	2744 (99)	4424 (193)	−4.87 (0.63)
Oxadiargyl	77 (8)	247 (21)	−2.00 (0.24)	69 (6)	191 (11)	−2.29 (0.22)
	Amaranthus retroflexus Post-emergence			*Chenopodium album* Post-emergence		
Metribuzin	72 (11)	203 (15)	−2.24 (0.23)	71 (9)	179 (11)	−2.53 (0.23)
Rimsulfuron	2.8 (0.2)	5.0 (0.2)	−4.10 (0.34)	3.6 (0.3)	7.3 (0.3)	−3.29 (0.29)
EPTC	2752 (106)	4096 (148)	−5.87 (0.80)	2544 (91)	3801 (102)	−5.82 (0.64)
Oxadiargyl	36 (5)	112 (7)	−2.06 (0.21)	31 (3)	84 (5)	−2.34 (0.19)

Table 5
Visible injury on potato following application of metribuzin, ethalfluralin, trifluralin, pendimethalin, rimsulfuron, EPTC and oxadiargyl (Experiment 1, average of two experiments).

Treatment	Rate (g ai/ha)	1 WAE[a]–1 WAP		3 WAE–3 WAP	
		PRE	POST	PRE	POST
Metribuzin	0	0	0	0	0
	147	3 c[b]	6 d	9 c	1 d
	196	14 b	6 d	11 c	2 c
	392	14 b	14 c	15 b	4 b
	490	17 a	15 c	19 a	4 b
	613	19 a	18 b	21 a	4 b
	700	18 a	24 a	21 a	10 a
Ethalfluralin	0	0	–	0	–
	360	2 e	–	1 d	–
	720	5 d	–	2 d	–
	1080	8 c	–	4 c	–
	1440	10 c	–	5 c	–
	1800	15 b	–	8 b	–
	2160	18 a	–	13 a	–
Trifluralin	0	0	–	0	–
	480	0	–	0	–
	720	0	–	0	–
	960	0	–	0	–
	1200	2 c	–	0	–
	1440	4 b	–	2 b	–
	1920	8 a	–	4 a	–
Pendimethalin	0	0	–	0	–
	200	0	–	0	–
	400	0	–	0	–
	600	2 d	–	1 d	–
	800	4 c	–	2 c	–
	1600	7 b	–	3 b	–
	2400	10 a	–	5 a	–
Rimsulfuron	0	0	0	0	0
	1.25	0	0	0	0
	2.5	0	0	0	0
	5	0	0	0	0
	7.5	0	0	3 a	0
	10	0	0	3 a	1 a
	12.5	0	0	3 a	1 a
EPTC	0	0	0	0	0
	1600	0	0	0	0
	2400	0	0	0	1 c
	2800	1 d	3 d	0	1 c
	3200	3 c	8 c	1 c	2 c
	3600	9 b	14 b	4 b	4 b
	4000	15 a	20 a	7 a	8 a
Oxadiargyl	0	0	0	0	0
	40	0	2 e	0	0
	80	2 e	3 e	1 c	1 e
	120	4 d	7 d	1 c	2 d
	160	11 c	13 c	8 ab	6 c
	200	14 b	19 b	7 b	10 b
	240	17 a	23 a	10 a	14 a

[a] Abbreviations: WAE: week after crop emergence; WAP: week after treatment.
[b] Means with the same letter within a column (For each herbicide) were not significantly different at $P \leq 0.05$.

3.2. Experiment 2

Overall the effects on *A. retroflexus* and *C. album* tended to slightly lower in Experiment 2 compared to Experiment 1 but the ranking of the herbicides was the same with rimsulfuron providing the highest level of control on both weed species (Table 6). As in experiment 1 pendimethalin was more active against *C. album* than *A. retroflexus*, oxadiargyl POST provided better control than oxadiargyl PRE while no differences were observed between rimsulfuron PRE and POST (Table 7).

Visual assessment of crop injury revealed that rimsulfuron applied PRE or POST, trifluralin and pendimethalin were the treatments causing least injury while crop injury following application of oxadiargyl PRE and POST and metribuzin PRE was higher as observed in Experiment 1 (Table 6).

Table 6
Control of *Amaranthus retroflexus* and *Chenopodium album* by various herbicides (Experiment 2, average of two trials).

Treatment	Rate (g ai/ha)	*Amaranthus retroflexus*		*Chenopodium album*	
		PRE	POST	PRE	POST
Metribuzin	613	87 cd[a]	–	89 ab	–
Rimsulfuron	7.5	89 bcd	93 a	79 efgh	82 def
	10	92 ab	95 a	86 cd	87 bcd
	12.5	95 a	95 a	90 abc	95 a
Oxadiargyl	160	76 g	82 ef	78 fgh	87 bcd
	200	79 fg	90 abc	84 cde	93 ab
	240s	85 de	95 a	87 bcd	94 a
Trifluralin	960	79 fg	–	65 i	–
	1200	85 de	–	73 h	–
	1440	95 a	–	80 efg	–
Pendimethalin	600	51 j	–	75 gh	–
	800	60 i	–	79 efgh	–
	1600	68 h	–	94 a	–

[a] Means with the same letter within a column (for each herbicide) were not significantly different at $P \leq 0.05$.

Table 7
Visible injury on potato following application of various herbicides (Experiment 2, average of 2 trials).

Treatment	Rate (g ai/ha)	1 WAE[a]-1 WAP		3 WAE-3 WAP	
		PRE	POST	PRE	POST
Metribuzin	613	12 d[b]	–	13 a	–
Rimsulfuron	7.5	0	0	1 g	0
	10	0	0	2 f	0
	12.5	0	0	2 f	1 g
Oxadiargyl	160	10 e	12 d	6 d	5 e
	200	12 d	17 b	5 de	8 c
	240	8 c	20 a	15 c	12 b
Trifluralin	960	0	–	0	–
	1200	1 h	–	0	–
	1440	2 g	–	1 g	–
Pendimethalin	600	1 h	–	0	–
	800	3 g	–	1 g	–
	1600	5 f	–	2 f	–

[a] Abbreviations: WAE: week after crop emergence; WAP: week after treatment.
[b] Means with the same letter within a column (for each herbicide) were not significantly different at $P \leq 0.05$.

4. Conclusions

Metribuzin was effective against both weed species but caused more crop damage than the other herbicides. Among the seven herbicides tested, EPTC was the least effective against *A. retroflexus* and *C. album* but caused some crop at the highest doses. Ethalfluralin and trifluralin provided good control of the two weed species but ethalfluralin caused some crop injury. The effect of pendimethalin on *A. retroflexus* was inadequate whereas *C. album* was controlled very effectively. Rimsulfuron applied PRE or POST controlled both weed species very effectively and caused no crop injury, while the effect of oxadiargyl was inadequate on *A. retroflexus* and crop injury was comparable to that of metribuzin. Except for metribuzin none of the tested herbicides are currently registered for use in potato in Iran, but our results suggests that particular trifluralin and rimsulfuron could be valuable tools for weed control in Iranian potato fields with high infestations of *A. retroflexus* and *C. album*. More research is, however, needed to elucidate differences in the susceptibility of the most common Iranian potato cultivars and also the possible influence of climatic conditions, which can vary significantly in Iran, before recommendations on the use of these herbicides can be published.

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