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ORIGINAL ARTICLE

Chemical control of broadleaf weeds in autumn-sown rainfed chickpea

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Abstract

Weed control is the most important constraint of autumn-sown chickpea production. Field experiments were conducted at three sites to evaluate the yield response of autumn-sown rainfed chickpea and weed control with PRE pendimethalin, POST pyridate, PRE isoxaflutole, preemergence (PRE) and postemergence (POST) of imazethapyr through hand-weeded, untreated and weed free checks. The results showed that pyridate was the safest option for weed control in chickpea. The highest grain yield of chickpea was obtained with application of pyridate followed by isoxaflutolein three sites. Imazethapyr and metribuzin caused higher visual injuries than the other treatments. Furthermore, the applications of pyridate, isoxaflutole, metribuzin, and pendimethalin, as well as PRE and POST imazethapyr were found to reduce the total weed densities (averaged for three locations) by as much as 76, 75, 75.4, 43, 64, and 64.5% within 30 days after treatments, respectively.

Keywords: *Cicer arietinum* L., imazethapyr, isoxaflutole, pyridate

Introduction

Chickpea is the second highest consumed edible pulse crop worldwide. Due to the slow plant growth, it is a poor competitor with weeds. It is commonly grown as a rotational crop in the western and northwestern parts of Iran. Chickpea increases soil N and breaks disease cycles of graminaceous crops. In recent years, crop prices have risen due to an increase in input costs (Mohammadi *et al.* 2005).

One of the main reasons for the low yield of rainfed chickpea is weed interference (Ahmadi *et al.* 2013). Increasing the period of weed interference with chickpea reduces seedling dry weight (Ahmadi and Rahimian 1997). Obviously, achieving the highest chickpea production and efficient harvesting requires careful attention to weed interference and the use of appropriate management methods to remove or reduce the interference (Plancqaert *et al.* 1990; Mousavi *et al.* 2007;). Mohammadi *et al.* (2005) suggested that weed interference up to 12, 24 and 36 days after chickpea germination and weed infested control (full season weed control) reduced dry weight of weeds by 8.88, 31.27, 38.2 and 51.3%, respectively, compared to weed free control. Chickpea yield reduction has been reported up to 90% due to the presence of weeds (Knott and Halila 1988) and in some cases up to 94% (Knights 1991; Saxena *et al.* 1996). From 34 to 87% losses caused by weeds in various farming systems (spring and autumn chickpea) has been estimated. The biomass of the autumn crop was more than two and a half times higher than winter and spring crops (Mousavi *et al.* 2007). Grain yield losses are reduced by broadleaf weeds much more than by grasses because of their similar growth patterns (Solh and Pala 1990). Therefore it is essential to control weeds to achieve maximum grain quality, yield, economic returns and facilitate harvest.

Mousavi *et al.* (2010) stated that weed density in autumn chickpea is two and a half times higher than spring chickpea. Stinking chamomile (*Anthemis cotula* L.), wild safflower (*Carthamus oxyacantha* M.B.), corn cleaver (*Galium tricornutum* Dandy.), field bindweed (*Convolvulus arvensis* L.), chicory (*Cichorium intybus* L.), hairy vetch (*Vicia villosa* Roth.), *Centaurea* spp. and cowherb (*Vaccaria pyramidata* Medik.) are among the most problematic in Kermanshah province (Chalechale *et al.* 2014; Ahmadi and Mousavi 2017).

Weed management consists mainly of herbicides (Rao 2000; Baghestani *et al.* 2005). Augmented labor wages have led to costly methods of mechanical weed control besides hand-weeding, which traditionally has been practiced in developing countries. However, since chickpea is grown under semiarid conditions, it is recommended that cultivation be avoided in order to preserve soil moisture (Solh and Pala 1990). Herbicides that have provided effective broadleaf weed control with little or no injury include several dinitroanilines (trifluralin, pendemethalin, etc.), triazines (metribuzin and simazine) (Solh and Pala 1990), imidazolinones (imazethapyr), aryl triazinone (sulfentrazone) and isoxazole (isoxaflutole) (Lyon and Wilson 2005; Mousavi *et al.* 2010), fomesafen (Mousavi *et al.* 2010) and pendimethalin (Sanjeev *et al.* 2015). Herbicides with a wide spectrum of weed control and chickpea tolerance are very few. Pyridate and linuron are the only registered herbicides for chickpea in Iran. However, linuron is not currently used (Zand *et al.* 2010). Pyridate is the most common herbicide used to control broadleaf weeds in Iran (Akbari *et al.* 2010). However, it is used less frequently due to its higher price. In recent years, several studies have been carried out in Iran in an attempt to replace the appropriate herbicide with pyridate. The most important herbicides proposed are as follows: isoxaflutole, fomesafen, flumetsulam, metribuzin, imazethapyr and pendimethalin. Mousavi *et al.* (2010) found that preemergence (PRE) application of fomesafen, with relatively good control of weeds (88%), did not have any obvious phytotoxicity effect on the chickpea, but this herbicide is not available in Iran. Veisi *et al.* (2017) also suggested that flumetsulam provided poor weed control. Herbicides such as imazethapyr, metribuzin and pendimethalin have been evaluated for use in legumes (Vasilakoglou *et al.* 2013; Singh *et al.* 2016; Tiwari and Meena 2016). Isoxaflutole controls grass and broadleaf weeds in soybean, corn and chickpea and has been found to control many annual broadleaf weeds in chickpea (Datta *et al.* 2009). The herbicides used in this study are less expensive than pyridate. The purpose of this project was to identify the most effective herbicides in controlling broadleaf weeds and increase the yield of autumn-sown rainfed chickpea in western Iran. Another objective was to determine which herbicide can replace pyridate with a lower cost but similar efficiency.

Materials and Methods

Field experiments were carried out at three research stations in Kermanshah (46.50° E, 34.16° N), Kurdestan (47.8° E, 35.40° N) and Lorestan (48.33° E, 33.46° N) provinces, Iran, during 2015–2016. The different sites were selected based on varying climatic conditions and different weeds. Table 1 displays the chickpea variety and describes the sites (soil PH, organic carbon, clay, sand and silt content).

Experiments were conducted using a randomized complete-block design with four replications. Plots were eight rows wide (0.3 m spacing between rows) by 10 m long. Fields were prepared conventionally (moldboard plowing, disking, and land leveling) before planting. Fertilizers were applied based on soil test recommendations. Different spectrums of weed species were observed at each location.

Treatments consisted of: a) preemergence applications of pendimethalin (Stomp), metribuzin (Sencor) and imazethapyr (Pursuit) at 0.82, 0.28, and 0.5 kg a.i. · ha^{-1}, respectively, b) postemergence application of pyridate (Lentagran), isoxaflutole (Merlin flex) and imazethapyr at 0.12, 1, and 0.5 kg a.i. · ha^{-1}, respectively and c) hand-weeded control. Herbicide

Table 1. The chickpea varieties and climates, soil textures, and schedule of events at the different experimental locations during 2015–2016

Location	Climate	Variety	Soil texture	Sand	Silt	Clay	Soil PH	Organic carbon [%]
Kermanshah	semi-dry	Adel	silt clay	12	46	42	7.8	0.73
Kurdestan	semi-dry cold	Adel	clay	19	31	45	7.42	0.74
Lorestan	semi-humid	Adel	silt clay loam	11	49	40	7.11	0.8

treatments were applied with a backpack sprayer using a spray volume of 300 l · ha^{-1} at 250 kPa. Preemergence herbicides were sprayed in November (2 days after planting). Postemergence herbicides were applied at two to four leaf stages of weeds.

Half of each plot was sprayed and the other half was used as a running check (Baghestani *et al.* 2007). Percent reductions in the weed populations and biomasses were recorded separately for each weed species after dropping two quadrats (1 m^2) into each half of the treated and untreated plots 4 weeks after the postemergence (POST) treatments. After cutting all the weeds at the soil surface, they were separated according to species and oven-dried at 75°C for 48 h (weed biomasses). Approximately 4 weeks after treatments, crop injury was recorded visually as described by the European Weed Research Committee (EWRC) (Sandral *et al.* 1997). Visual ratings of herbicide injury were assessed on a 1 to 9 scale where 1 – no visible injury; 2 – very slight effects, some stunting and yellowing just visible; 3 – slight effect, stunting and yellowing, effects reversible; 4 – substantial chlorosis and/or stunting, most effects probably reversible; 5 – strong chlorosis/stunting, thinning of stand; 6 – increasing severity of damage; 7 – increasing severity of damage; 8 – increasing severity of damage; 9 – death of all plant tissues. The grain yield was determined after harvest.

Meteorological data (mean monthly temperature and total rainfall) were collected from a nearby station (Fig. 1).

All the data were analyzed using the analysis of variance in SAS portable 9.1 statistical software. The arcsine and square root transformations would be applied to the percent reductions in the weed biomasses and populations if the assumptions were not sufficiently satisfied. Combined analysis of data collected from three sites showed that the effect of location is significant ($p < 0.01$). Based on Duncan's Multiple Range Test at $p = 0.05$ level, the significance of the differences between the means of the treatments was determined.

Results and Discussion

Crop injury

The measurements of the injuries to the chickpea plants 4 weeks after the treatments revealed their similar responses to the EWRC-based herbicide treatments across the sites. Posemergence imazethapyr at the three locations caused significant crop injuries. Visual symptoms of injury caused by imazethapyr were stand thinning and stunting. Metribuzin caused significant crop injury compared to the untreated or hand-weeded checks in Kurdestan and Kermanshah (strong chlorosis and stunting) (Table 2), while in Lorestan stunting and yellowing were observed with reversible effects. The least crop injury was achieved with pyridate, pendimethalin and isoxaflutole applications. In Kermanshah and Lorestan, pyridate and isoxaflutole caused minor visual crop injuries (very slight yellowing). Reversible yellowing and very slight effects were noted on chickpea treated with isoxaflutole and pyridate, respectively, in Kurdestan.

Weed control

In Kermanshah *C. arvensis* was not controlled well by the herbicides due to permanent rhizomes. Nevertheless, it was controlled by isoxaflutole 66%, probably due to its contact property as well as the activity of this herbicide in the soil (Table 3). All herbicides, except for pendimethalin, reduced *Conringia orientalis* and *Anthemis cotula* density from 85.83 to 100% and 95 to 100%, respectively, compared to the non-treated control. *Cephalaria syriaca* and *Carthamus oxyacantha* were also controlled between 90.6 and 100% by metribuzin, pyridate, isoxaflutole and PRE imazathapyr applications. *Galium tricornutum* density was reduced from 81.43 to 88.54% by using pendimethalin, pyridate and isoxaflutole. Among all treatments, metribuzin and pendimethalin could not provide acceptable biomass

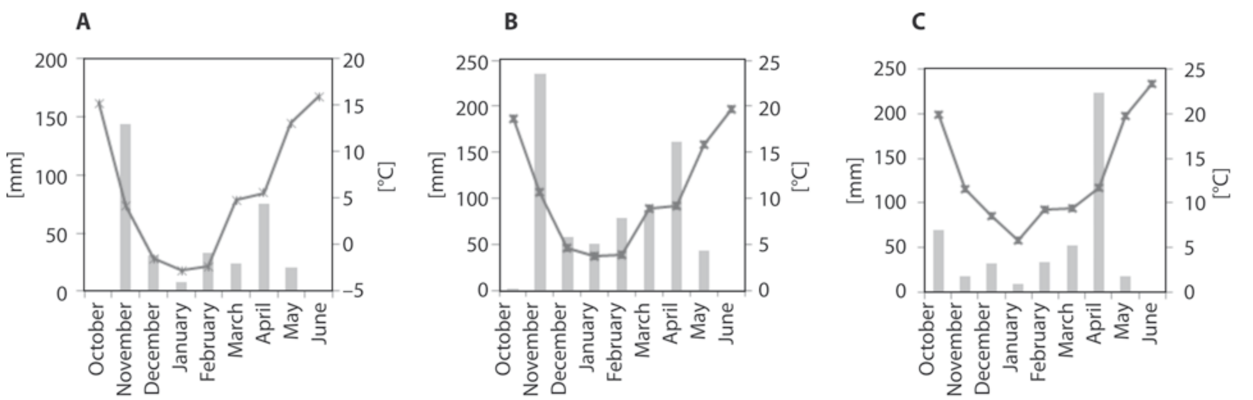

Fig. 1. Monthly mean temperature (°C; solid line) and total rainfall (mm; bold bar) recorded from each location during 2015–2016. Kurdestan (A), Kermanshah (B) and Lorestan (C)

Table 2. Herbicide injury based on a 1 to 9 scale: 1 – no visible injury and 9 – death of all plant tissues, 4 and 6 weeks after the treatments (EWRC – European Weed Research Council)

Herbicide treatments	Timing	Rate [kg a.i. · ha^{-1}]	Visual crop injury [%]					
			Kermanshah		Kurdestan		Lorestan	
			4 weeks	6 weeks	4 weeks	6 weeks	4 weeks	6 weeks
Pendimethalin	PRE	0.82	1.5 c	1 d	2 d	1.5 d	2.5 b	1.5 c
Metribuzin	PRE	0.28	5 a	5.5 a	6 a	6.5 a	3 b	3 b
Pyridate	POST	1.2	1.5 c	1 d	1.25 e	1 e	1.75 c	1 d
Isoxaflutole	POST	0.1	1.75 c	1.5 d	2.75 c	2 c	1.5 c	1.2 d
Imazethapyr	PRE	0.05	3.25 b	3.5 c	4.5 b	4.75 b	5.5 a	5 a
Imazethapyr	POST	0.05	4.75 a	4.5 b	5 b	5 b	5.25 a	5 a
Non-treated check	–	–	–	–	–	–	–	–

PRE – preemergence, POST – postemergence; means within the same column followed by the same letter are not significantly different according to Duncan`s multiple Range Test (p = 0.05)

and population reduction in *G. tricornutum* (Table 3). Generally, pendimethalin had no beneficial effect on weed reduction (except *C. orientalis*), while other herbicides effectively reduced all weed species density (73 to 88%), except for metribuzinon *G. tricornutum*.

In Kurdestan the highest percent reductions of *Polygonum aviculare* density (90.66–93.75%) were observed with pendimethalin and isoxaflutole applications, while the other treatments led to less than 80% reduction (Table 4). Pyridate could not satisfactorily control *P. aviculare*. Metribuzin, pyridate, isoxaflutole and POST imazethapyr applications for *C. syriaca* resulted in at least 95% reduction in the mentioned population. The reduction in *G. tuberosum* density ranged from 68.75 to 90% where the plots were treated with PRE imazethapyr, pyridate, and metribuzin (Table 4). Pendimethalin and isoxaflutole had the least effect on *G. tuberosum.*

In general, the maximum total weed density reduction was recorded with metribuzin (78.25%) followed by pyridate (69.65%) and isoxaflutole (71%). The poorest controls were achieved with pendimethalin, PRE and POST imazethapyr treatments.

In Lorestan maximum reduction in the *G. tricornutum* population (92%) was observed by isoxaflutole, while pendimethalin provided a reduction of 38.9% for the *G. tricornutum* population (Table 5). Lyon and Wilson (2005) reported that pendimethalin provided a poor weed control when it was applied without a tank-mix partner. Percent reductions of *V. pyramidata* population with isoxaflutole, metribuzin and pyridate applications were the highest, ranging from 78.9 to 83.87%, while the other herbicides caused less than 62.44% control. Pyridate, isoxaflutole and PRE imazethapyr significantly provided at least 72% control for the *C. oxyacantha* population. The lowest reduction in density was achieved with the application of metribuzin and pendimethalin (Table 5). The results indicated that pyridate and isoxaflutole significantly reduced weed (total and dominant species) populations and dry weights in the field.

Chickpea yield

Chickpea yields were significantly different with herbicide applications in all locations. In Kermanshah province, yields were higher with pyridate, isoxaflutole and the hand weeding check (Table 6). The lowest grain yield was recorded in metribuzin, followed by the non-treated check and pendimethalin. The maximum plant heights in chickpea were found for hand weeding and the weed free check, while metribuzin, followed by PRE and POST imazethapyr, resulted in the lowest plant height.

In Kurdestan, application of pyridate resulted in the highest grain yield. However, for grain yield there was no significant difference between isoxaflutole, pyridate and two hand weeding (Table 6). Of the different treatments, the lowest grain yield was found with metribuzin due to metribuzin crop injury (Table 2). Pendimethalin, PRE and POST imazethapyr had the lowest yield. This was most likely due to poor weed control (pendimethalin) and chickpea injury (PRE and POST imazethapyr) since these treatments did not differ significantly from the untreated check. In Kurdestan, the highest chickpea plant height was observed with pyridate and isoxaflutole followed by PRE imazhetapyr and pendimethalin (Table 6).

In Lorestan, pyridate was found to have the highest positive effect for grain yield of chickpea followed by isoxaflutole, while the application of metribuzin, pendimethalin, PRE and POST imazhethapyr resulted in the lowest grain yields (Table 6). There was no significant effect on grain yield with metribuzin, pendimethalin, PRE imazethapyr, POST imazethapyr and the

Table 3. The effect of different herbicides on the percent reductions of the weed population and biomass 4 weeks after the POST treatments at Kermanshah

Treatments [kg a.i. · ha^{-1}]	Rate	Timing	Population reduction [%]							Dry weight reduction [%]						
			Anthemis cotula	*Conringia orientalis*	*Cephalaria syriaca*	*Carthamus oxyacantha*	*Convolvulus arvensis*	*Galium tricornutum*	Total	*Anthemis cotula*	*Conringia orientalis*	*Cephalaria syriaca*	*Carthamus oxyacantha*	*Convolvulus arvensis*	*Galium tricornutum*	Total
Pendimethalin	0.82	PRE	47.41 b	79.17 b	31.25 c	47.92 c	24.88 b	51.43 b	51.44 b	74.76 b	93.77 a	55.45 c	59.5 c	38.63 c	54.05 b	65.94 b
Metribuzin	0.28	PRE	100 a	85.83 ab	90.63 ab	95.83 ab	52.79a b	46.25 b	87.83 a	100 a	95.91 a	94 ab	96.7 a	61.29 ab	54.61 b	85.52 a
Pyridate	1.2	POST	95 a	95 ab	100 a	97.92 a	41.97 ab	88.54 a	77.6 a	97.4 a	98.56 a	100 a	98.35 a	51.96 abc	90.44 a	82.2 a
Isoxaflutole	0.1	POST	96.5 a	94.5 ab	94.25 a	90.08 ab	66.10 a	87.57 a	80.97 a	97.09 a	96.75 a	97.84 a	87.08 ab	67.13 a	89.5 a	86.39 a
Imazethapyr	0.05	PRE	98.08 a	100 a	96.88 a	90.63 ab	43.85 ab	76.04 a	78.32 a	98.87 a	100 a	97.95 a	93.19 ab	53.57 abc	79.73 a	82.92 a
Imazethapyr	0.05	POST	95.3 a	86.46 ab	80 b	72.92 b	31.28 b	75.69 a	72.64 ab	97.18 a	93.76 a	86.81 b	77.78 b	43.78 bc	79.05 a	79.1 a

PRE – preemergence, POST – postemergence; means within the same column followed by the same letter are not significantly different according to Duncan`s multiple Range Test (p = 0.05)

Table 4. The effects of the different herbicides on the percent reductions of the weed populations and dry weights in Kurdestan 4 weeks after the POST treatments

Treatments	Rate [kg a.i. · ha^{-1}]	Timing	Population reduction [%]				Dry weight reduction [%]			
			Polygonum aviculare	*Cephalaria syriaca*	*Galium tuberosum*	Total	*Polygonum aviculare*	*Cephalaria syriaca*	*Galium tuberosum*	Total
Pendimethalin	0.82	PRE	90.66 a	47.92 b	15.18 b	36.56 c	71.01 ab	59.08 b	23.39 b	34.01 c
Metribuzin	0.28	PRE	73.93 ab	100 a	90 a	88.25 a	60.58 b	100 a	90.97 a	80.6 a
Pyridate	1.2	POST	64.58 b	100 a	87.22 a	69.65 ab	61.47 b	100 a	88.46 a	70.29 ab
Isoxaflutole	0.1	POST	93.75 a	100 a	40.92 b	70.99 ab	98 a	100 a	45.8 b	68.34 ab
Imazethapyr	0.05	PRE	80.36 ab	36.7 c	68.75 a	50.38 bc	74.52 ab	34.55 c	71.77 a	58.91 bc
Imazethapyr	0.05	POST	86.48 ab	95 a	34.99 b	56.77 bc	74.13 ab	96.07 a	41.28 b	52.96 bc

PRE – preemergence, POST – postemergence; means within the same column followed by the same letter are not significantly different according to Duncan`s multiple Range Test ($p = 0.05$)

Table 5. The effects of the different herbicides on the percent reductions of the weed populations and dry weights in Lorestan 4 weeks after the POST treatments

Treatments	Rate [kg a.i. · ha^{-1}]	Timing	Population reduction [%]				Dry weight reduction [%]			
			Vaccaria pyramidata	*Galium tricornutum*	*Carthamus oxyacantha*	Total	*Vaccaria pyramidata*	*Galium tricornutum*	*Carthamus oxyacantha*	Total
Pendimethalin	0.82	PRE	32.11 c	38.89 b	54.98 bc	40.48 c	23.93 c	57.93 b	52.15 b	34.33 b
Metribuzin	0.28	PRE	78.9 ab	41.67 b	46.4 c	50.19 ab	75.63 ab	49.05 b	53.08 b	42.52 ab
Pyridate	1.2	POST	83.87 a	76.67 a	87.84 a	78.1 a	83.16 a	86.57 a	89.84 a	70.03 a
Isoxaflutole	0.1	POST	80.7 ab	92.59 a	72.21 abc	73.97 a	92.62 a	73.18 ab	72.94 ab	77.06 a
Imazethapyr	0.05	PRE	42.4 b	39.09 b	77.49 ab	64.48 ab	44.6 b	79.77 a	78.66 ab	49.87 b
Imazethapyr	0.05	POST	62.44 ab	50 b	59.65 bc	61.73 b	55.3 b	59.65 b	59.65 b	66.59 ab

PRE – preemergence, POST – postemergence; means within the same column followed by the same letter are not significantly different according to Duncan`s multiple Range Test ($p = 0.05$)

Table 6. The effect of different herbicides on chickpea traits in three locations

Treatments	Rate [kg a.i. · ha^{-1}]	Timing	Kermanshah		Kurdestan		Lorestan	
			grain yield [kg · ha^{-1}]	height [cm]	grain yield [kg · ha^{-1}]	height [cm]	grain yield [kg · ha^{-1}]	height [cm]
Pendimethalin	0.82	PRE	908.5 d	37.8 c	859.5 cd	30.8 bc	1 368.5 cd	9.35 ab
Metribuzin	0.28	PRE	855 d	34.5 d	550 e	25.2 d	1 288 cd	9.69 ab
Pyridate	1.2	POST	1 397.1 a	42.8 b	1 338.2 ab	35.55 ab	1 850.8 ab	9.23 ab
Isoxaflutole	0.1	POST	1 302.6 ab	40.08 bc	1 028.2 bc	34.35 ab	1 647.1 b	9.16 ab
Imazethapyr	0.05	PRE	1 295.8 b	33.35 d	900.5 cd	30.85 bc	1 182.9 d	9.84 ab
Imazethapyr	0.05	POST	1 030.8 c	33.15 d	846 cd	25.75 c	1 342.7 cd	10.62 a
Weed free check	–	–	1 417.7 a	49.75 a	1 441 a	39.45 a	2 244.8 a	9.21 ab
Non-treated check	–	–	880.6 d	33.25 d	611.5 d	28 c	1 290.1 cd	7.85 b
Two hand weeding	–	–	1 394.3 a	48.2 a	1 337 ab	34.5 ab	2 121 a	10.6 a

PRE – preemergence, POST – postemergence; means within the same column followed by the same letter are not significantly different according to Duncan`s multiple Range Test ($p = 0.05$)

non-treated check in Lorestan (Table 6). There was no significant difference between herbicide treatments in terms of plant height.

Discussion

Herbicide efficacy on weeds and crop injury can vary greatly depending on many factors. Environmental factors such as temperature, relative humidity, and soil moisture differentially affect the uptake, translocation, and activity of different herbicide chemistries (Varanasi *et al.* 2016). The efficacy of PRE herbicides for weed control is affected by various environmental factors such as soil properties and rainfall as well as physicochemical properties of the herbicide that are related to its behavior in the field (Green and Strek 2001).

In this study, application of metribuzin in Kurdestan and Kermanshah caused more damage to chickpea compared to Lorestan (Table 2). Metribuzin is highly soluble in water and excess rainfall can cause puddling resulting in injurious concentrations of metribuzin in fields (Pilcher *et al*. 2017). Lewis *et al.* (2016) stated that metribuzin is highly water-soluble and has moderate to very high leaching potential. Johnson *et al.* (2017) suggested that heavy rainfall soon after herbicide application to peas, lentils and chickpeas can result in yield reduction. Abugho *et al.* (2015) found that PRE sulfentrazone and flumioxazin can cause soybean injury when high rainfall occurs close to the time of applications. Comparisons of climate between the three locations (Fig. 1) indicated that heavy rainfall (1 month after treatments inN ovember) may cause metribuzin leakage into the soil and damage chickpea in Kurdestan (143.6 mm) and Kermanshah (235 mm). At Lorestan less injury was due to less rainfall (17.2 mm), which resulted in lower levels of weed control and grain yield than in the other two locations tested. Furthermore, low temperatures in Kurdistan (4.2°C) led to a decrease in chickpea growth and subsequently reduced herbicide metabolism in plants. Lindsey *et al.* (2019) observed that winter applications could impose greater injury due to slower growth and lower metabolic processes that can detoxify herbicides. Metribuzin injury to soybeans was greater in years when more rainfall and cooler temperatures occurred following herbicide application (Moomaw and Martin 1978).

In three locations, application of pendimetalin resulted in low grain yields, which could be due to poor weed control in the fields. This is confirmed by low weed populations and biomass reductions with this treatment (total weeds), which suppressed the growth and development of chickpea plants by competing for moisture, light and nutrients. Pendimetalin, had a low effect on the control of weed species (except for *P. aviculare*). These results were similar to those obtained by previous studies (Lyon and Wilson 2005; Uygur *et al.* 2010). Tank-mix combinations of pendimethalin and other PRE herbicides may increase the spectrum of weed control. The results of other studies indicate that weed control by pendimethalin + hand weeding (Arya 2004; Sanjeev *et al.* 2015) and pendimethalin + pyridate (Yousefi and Alizade 2006) have better results than using pendimethalin alone. Lyon and Wilson (2005) reported that pendimethalin provided poor weed control when it was applied without a tank-mix partner.

Yield reduction in imazethapyr (PRE and POST) plots were due to crop injury. These results are confirmed by Poonia and Pithia (2013), and Hoseiny-Rad and Jagannath (2011), while Taran *et al.* (2013) showed that POST imazethapyr increased chickpea yield. Goud *et al.* (2013) reported that high concentrations of imazethapyr affect growth and yield of chickpea and lower concentrations were inefficient for effective weed control. Application of imazethapyr changed the plant architecture and plants became bushy with small leaves which ultimately affected the chickpea grain yield (Khope *et al.* 2011). Although metribuzin and imazathapyr effectively controlled broadleaf weeds, they had lower yields than pyridate and isoxaflutole due to damage to the chickpea (Table 2).

Pyridate and isoxaflutole in the three experimental sites caused the highest yield and weed reduction. Furthermore, they caused minor visual crop injuries. Lyon and Wilson (2005) reported that isoxaflutole caused minor chlorosis. Jafarzadeh and Shimi (2004) found that POST pyridate and isoxaflutole, increased the yield by 52% in autumn-sown chickpea. Mousavi *et al.* (2010) reported that isoxaflutole and fomesafen controlled whole weeds satisfactorily, while Johnson *et al.* (2007) stated that no rates or timing of isoxaflutole could control *Polygonum convolvulus* L. or *Vaccaria hispanica* (Mill.) Rauschert.

In conclusion, isoxaflutlole reduced the average amounts of weeds (75%) which resulted in a 48% increase of yield in the three studied areas. Furthermore, isoxaflutlole caused no significant difference in terms of broadleaf weed reductions and increasing yield with pyridate. Hence, isoxaflutlole can be a less expensive alternative to pyridate. It is suggested that future research could include more herbicides and combinations of herbicides in order to increase their impact on the broad spectrum of weeds (especially pendimethalin). Also, by reducing the amounts of herbicides such as metribuzin and imazathapyr in combination with other herbicides, it would be possible to prevent their damage to the chickpea.

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