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Study of respond wheat (*Triticum aestivum* L.) to rate and time application Chevalier®

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Field experiments were conducted at five locations of principle wheat production regions of Iran to evaluate the efficiency of Chevalier in controlling weedy barleys in 2006-2007 growing seasons. Chevalier was applied either postemergence (POST) or prepalant incorporated (PPI) at 0, 20.25, 30.75, 40.5, 51, 60.75 and 71.25 g a.i./ha using a randomized complete blocks design with four replications. Chevalier at recommended rate (20.25 g a.i./ha) failed to provide an acceptable control of weedy barleys. However, control of weedy barleys increased with application rate particularly at rates higher than 40.5 g a.i./ha. Generally, PPI applied Chevalier resulted in markedly greater control levels than those of a POST application and complete control of *H. murinum* was achieved with PPI applied Chevalier at all rates higher than 20.25 and 30.75 g a.i./ha, respectively. In most cases, wheat yield increased with application rate without any crop injury. The highest wheat yield increase (186%) also obtained with PPI application at 71.25 g a.i./ha.

Key words: Chevalier®, application rate, application timing, weedy barleys control, wheat yield

Introduction

Wild barley species including wild barley (*Hordeum spontaneum* Koch.), mouse barley (*H. murinum* L.) and smooth barley (*H. glaucum* Steud.) have been reported as troublesome grass weeds in irrigated wheat farms of Iran (Montazeri, 2005), however, the magnitude of impact has not yet fully understood. They have been adapted to a wide range of climate conditions and are documented weeds of 16 provinces in Iran (Ashrafi *et al*., 2009; Montazeri, 2005). In addition to wild species of barely, volunteer barley (*H. vulgare* L.) can further be considered as a problematic weed. It is often grown in rotation with winter wheat and depending on environmental conditions and barley variety it may volunteer and overwinter in the following winter wheat crop,

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causing significant yield loss. Adequate control of these barley species has not yet warranted with current herbicides registered for wheat in Iran. Selective herbicides to control barley species are lacking due to close morphological and physiological similarities of barley species to wheat crop. However, preliminary studies conducted by Baghestani *et al*. (2007) showed the possibility of weedy barleys control with Chevalier [mesosulfuron-methyl + iodosulfuron-methyl-sodium] (6% water dispersible granule [WG]).

Chevalier is a sulfonylurea herbicide being developed for selective control of broadleaved and grass weeds in wheat (Parrish *et al*., 1995). Sulfonylurea herbicides inhibit plant metabolism by inhibiting acetolactate synthase (ALS) [acetohydroxyacid synthase AHAS], a crucial enzyme for biosynthesis of branched-chain amino acids isoleucine, leucine and valine (Anonymous, 1996). It selectively controls grass weeds such as *Elytrigia repens* (Blank, 1997), *Avena fatua* (Sanders *et al*., 1997; Baghestani *et al*., 2007), *Bromus* spp. (Geier and Stahlman, 1996; Hageman *et al*., 1996), *Phalaris minor* (Ashrafi *et al*., 2009; Chhokar and Malik, 2002; Baghestani *et al*., 2007), volunteer barley (Shinn *et al*., 1999) and wild barleys (Baghestani *et al*., 2007) in winter wheat. Chevalier also controls broad-leaved weeds including *Stellria media*, *Amaranthus* spp. and *Thlaspi arvense* (Olson *et al.*, 1999), *Chorispora tenella*, *Conringia orientalis* and *Anchusa italica* (Ashrafi *et al*., 2009; Baghestani *et al*., 2007). Wild barley species differ in their response to Chevalier. For example, application of Chevalier at label recommended rate (20.25 g a.i./ha) provided satisfactory control of *H. murinum* but failed to reduce *H. spontaneum* population (Baghestani *et al*., 2007). In the study of Shinn *et al*. (1999), however, applying sulfosulfuron at 18, 26 or 35 g a.i./ha provided 83-98% control of *H. vulgare* (volunteer barley). Time of application may also alter the efficacy of Chevalier in controlling grass weeds. Chevalier applied preemrgence (PRE) or in fall postemergence (POST) provided better control of *B. tectorum* than when applied spring POST (Blackshaw and Hamman, 1998). Similar results reported by Ashrafi *et al*. (2009), Rahnavard *et al*. (2009), Geier *et al*. (1998), Ball and Walenta, (1997) and Koscelny *et al*. (1997). Even though control with Chevalier may vary depending on application rate (e.g. Ball and Walenta, 1997; Stahlman *et al*., 1996), it seems that wheat crop is sufficiently tolerant to sulfosulfuron application rates. Parrish *et al*. (1995) reported that winter wheat exhibited excellent tolerance to PRE and POST applications of Chevalier at rates up to 100 g/ha. Winter wheat was not visibly injured nor the grain yield decreased by sulfosulfuron at rates up to 60 (Blackshaw and Hamman, 1998) or 70 g/ha (Shinn and Thill, 1997). Ball and Walenta, (1997) observed a small height reduction in winter wheat with Chevalier applied POST at 35 g/ha, but yield was not reduced. However, Lyon *et al.* (2003) noted that winter wheat treated with Chevalier at 139 g/ha yielded less than nontreated wheat.

The objective of this study was to determine the response of weedy barleys and winter wheat to various Chevalier rates either applied PPI or POST under conditions typical of major wheat production regions of Iran.

Materials and methods

Field experiments were conducted in 2006-2007 growing seasons at five locations of principle wheat growing regions of Iran to evaluate the efficiency of Chevalier (65% WG) in controlling three wild barley species (including *H. spontaneum* and *H. murinum*). Experimental sites and barley species presented at each site-year are shown in Table 1. At all site-years Chevalier was applied at 0, 20.25, 30.75, 40.5, 60.75 and 71.25 g a.i./ha either postemergence (POST) (at Eslamshahr, Karaj,) or preplant incorporated (PPI) (at Karaj). Nonionic surfactant (Citowett at 0.25% v/v) was added to all Chevalier treatments and a weedfree check was also included. Field applications were made with a backup sprayer delivering 200 L/ha of spray solution at 220 kPa through a flat fan spray tip. POST Chevalier was applied at wheat tillering stage (Zadoks 20; Zadoks *et al.*, 1974) to 3-4 leaved barley species. PPI Chevalier was applied before wheat planting and immediately soil incorporated. Plots were artificially infested with seeds of a given barley species proposed for each location before applying Chevalier treatments.

Seedbed preparation consisted of moldboard plowing and tandom disking followed by land leveler smoothing in autumn. A field cultivator prepared the final seedbed with a row spacing of 18 cm. Plots were 3 m wide by 10 m long and one-half of each plot remained as nontreated control (Zand *et al*., 2007). Where Chevalier applied POST, barley densities by species were measured prior to, 2, 3 and 4 weeks after treatment (WAT) from a 0.5 m^2 fixed quadrate located in the treated area of each plot. For a particular barley species, percent of reduction in density was then calculated based on its initial density measured prior to treatment. Those weeds and barley seedlings emerging at sampling intervals were hand removed and omitted from the analysis. Dry matter was obtained by placing two 0.25 m^2 quadrates within both treated and nontreated halves of each plot at 2, 3 and 4 WAT. Barley plants were then cut at soil level and oven dried for at 75^{o}C for 72 h. Biomass values from treated area were divided by those of nontreated and multiplied by 100 to give biomass reduction percentages. Where Chevalier applied PPI, weed density was determined from two 0.25 m^2 quadrates placed within treated area at mid-tillering and early jointing stages of wheat crop. At the later stage weed biomass was also measured similarly to the procedure used for POST treatments. Wheat grain was harvested at maturity. All data were subjected to the analysis of variance (ANOVA) using SAS statistical software (SAS Institute, 1996), where assumptions of a parametric analysis (random, homogeneous, normal distribution of error) were met. If not, ANOVA was performed on arcsin squareroot transformed data and converted back to the original scale for presentation of results. Comparison of treatment means were made using Fisher's protected LSD test at *P=0.05*. Data were not combined over locations or years since wheat cultivars and field operations were different at each location. Furthermore, not all barley species were presented at all test sites nor subjected to both POST and PPI treatments jointly (Table 1).

Table 1. Barley species subjected to POST and/or PPI[a] Chevalier rates at each site-year.

Site-year	Post application		2006-2007	PPI application	
	H. spontaneum	*H. murinum*		*H. spontaneum*	*H. murinum*
Karaj	*	-		-	-
Eslamshahr	*	-		-	-

Location	Wheat cultivar	Planting date	Plant density (P m^{-2})	Seeding method	Spraying date	Harvest date
Karaj	Pishtaz	26/10/2006	400	By hand	15/03/2007	9/07/2007
Eslamshahr	Zarrin	25/10/2006	3500	By hand	14/03/2007	1/07/2007

Results and discussion

Weedy barleys control

The results of experiments are discussed for each barley species separately and we would represent those measurements taken at 4 WAT.

Hordeum spontaneum experiment

At all test sites, percent of reduction in *H. spontaneum* density never exceeded 52%, when Chevalier applied POST (Table 2). With exception to Karaj, at all other locations *H. spontaneum* density reductions increased as Chevalier POST application rate increased. At Eslamshahr, increasing Chevalier rate from 20.25 to 71.25 g a.i./ha increased control from 36.5 to 52%, but increment was not significant (Table 2). At Expressing weed control measurement on the basis of biomass reduction showed high efficiency of Chevalier in controlling *H. spontaneum* at Karaj, regardless of application rates (Table 2). At Karaj, 98% biomass reduction observed at 40.5 g a.i./ha is contrasted to minor reduction in *H. spontaneum* density. This discrepancy illustrates that losses to *H. spontaneum* population is more likely due to the retardant effect of Chevalier rather than being as a result of directly death of individuals. At Eslamshahr, 61.8% biomass reduction achieved at recommended rate did not improve with increased application rates (Table 2). However, beyond 40.5 g a.i./ha there were no significant differences among Chevalier rates in terms of weed density reduction. Biomass did not decrease at labeled rate and maximum reduction achieved was not more than 54% at higher rates (Table 3). Contrary to POST treatments, density was more a sensitive trait than biomass when Chevalier applied PPI. It seems that *H. spontaneum* seedling emergence is directly inhibited by soil applied Chevalier. Comparing the efficiency of PPI applied Chevalier with that of a POST application suggests an overall superiority of PPI over the POST treatments under karaj climate conditions (Table 2 and 3).

Table 2. Effect of Chevalier rate applied POST[a] on *H. spontaneum* density and biomass 4WAT in 2006-2007 growing seasons[b].

Chevalier rate (g a.i./ha)	Density reduction (%)		Biomass reduction (%)	
	Eslamshahr[c]	Karaj	Eslamshahr	Karaj
0	0.0b	0.0b	0.0b	0.0c
20.25	36.5a	22.7a	61.8a	84.5a
30.75	39.0a	30.1a	62.2a	87.1a
40.50	42.4a	20.2a	48.3a	98.7a
51.00	48.9a	20.9a	66.1a	93.0a
60.75	48.8a	15.7a	44.3a	82.9a
71.25	52.5a	28.1a	48.6a	74.3a

[a] Abbreviations: WAT, weeks after treatment; POST, postemergence., [b] In 2004-2005 experiments were conducted at Eslamshahr, Karaj and ; in 2005-2006 experiment was conducted at Kermanshah., [c] Means within each column (location) followed by the same letter are not significantly different according to Fisher's protected LSD test at $P< 0.05$.

Table 3. Effect of Chevalier rate applied POST[a] on *Hordeum spontaneum* density and biomass 4WAT in 2006-2007 growing seasons[b].

Chevalier rate (g a.i./ha)	Density reduction (%)		Biomass reduction (%)	
	Karaj	Slamshahr	Karaj	Slamshahr
0	0.0b	0.0d	0.0b	0.0e
20.25	22.7a	57.5c	70.2a	25.4d
30.75	30.1a	78.4b	95.4a	31.4cd
40.50	20.2a	83.0ab	95.0a	42.0c
51.00	20.9a	86.8ab	92.7a	60.1b
60.75	15.7a	90.4ab	95.2a	43.4c
71.25	28.1a	90.8a	87.3a	80.2a

[a] Abbreviations: WAT, weeks after treatment; POST, postemergence., [b] In 2004-2005 experiments were conducted at Karaj and ; in 2005-2006 experiments were conducted at Slamshahr., [c] Means within each column (location) followed by the same letter are not significantly different according to Fisher's protected LSD test at $P< 0.05$.

Hordeum murinum experiment

Chevalier control of *H. murinum* was examined at karaj by both POST and PPI applications. No reduction in *H. murinum* density occurred at first sampling date (wheat mid-tillering) when Chevalier applied POST. Control improved over time (i.e. at second sampling date) and density decreased 47.4% at 71.25 g a.i./ha (Table 4). Degree of control expressed in terms of biomass reduction showed a similar trend to *H. murinum* density data, again confirming a poor control of *H. murinum* with Chevalier POST application. Despite failing to control *H. murinum* when applied POST, Chevalier PPI application resulted in complete control, however, not at recommended rate (20.25 g a.i./ha) (Table 4Density reduction was about 100% at rates over 20.25 g a.i./ha. According to the results, almost a complete control of *H. murinum* could be expected by 30.75 g a.i./ha PPI applied Chevalier. Better performance of PPI treatments over POST applications is consistent with our pervious results and those reported by others (Blackshaw and Hamman, 1998; Geier *et al*., 1998; Ball and Walenta, 1997; Koscelny *et al*., 1997).

Wheat yield

Hordeum spontaneum experiment

Applying Chevalier either POST or PPI increased wheat yield significantly at all test sites (Table 5). At Eslamshahr, applying 30.75 g a.i./ha increased wheat yield 51% but further increase in application rate had no positive effects on wheat yield. At Karaj, 56.5% increased yield acquired at 51 g a.i./ha declined as Chevalier rate increased (Table 5). Wheat yield doubled at 30.75 g a.i./ha and further increased with Chevalier PPI application rates reaching to 186.6% at 71.25 g a.i./ha (Table 5). As shown in Table 5 for all Chevalier rates, wheat yield increases obtained form PPI treatments were markedly greater than those of POST treatments. This finding coincide better control achieved by PPI applied Chevalier.

Hordeum murinum experiment

No changes in wheat yield were observed with Chevalier POST application rates (data not shown). It seems to be as a result of poor *H. murinum* control obtained with POST treatments (Table 4). However, with PPI application wheat yield increased 46% at labeled rate (20.25 g a.i./ha). No rather increase in wheat yield was observed with higher Chevalier application rates.

Table 5. Wheat yield increase percent in *H. spontaneum* experiment in 2006-2007 growing seasons[a].

Chevalier rate (g a.i./ha)	Eslamshahr[b]	Karaj
0	100.0c	100.0d
20.25	122.9bc	121.2c
30.75	151.1a	124.3c
40.50	164.1a	127.5bc
51.00	151.8a	156.5a
60.75	139.3ab	146.7ab
71.25	151.2a	132.5bc

[a] In 2004-2005 Chevalier applied POST at Eslamshahr and Karaj; in 2006-2007 Chevalier applied., [b] Abbreviations: POST, postemergence; PPI, preplant incorporated, [c] Means within each column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P < 0.05$.

Based on the results of this study it could be concluded that an acceptable control of weed barleys could not be expected by applying Chevalier at recommended rate (20.25 g a.i./ha). The maximum control levels obtained at this rate were 84% and 70% for *H. spontaneum* respectively, where exceptionally achieved at Karaj. In most cases, a minimal application rate of 40.5 g a.i./ha was required for a satisfactory control of weedy barleys as well as high wheat yield gain. The superiority of PPI applied Chevalier over its POST application in terms of both weedy barleys control and wheat yield gain was apparent. For example, despite POST treatments rarely resulted in control levels greater than 50%, complete control of *H. murinum* was obtainable with PPI application. Similar results reported by Blackshaw and Hamman, (1998); Geier *et al*. (1998); Ball and Walenta, (1997); and Koscelny *et al.* (1997). Chevalier control of barley species increased with application rate and no crop injury was observed over the range Chevalier rates examined in this study as reported elsewhere (Parrish *et al*., 1995). Wheat yield progressively increased with increasing rates of Chevalier, however at higher rates it tended to plateau. Similarly, in the study of Blackshaw and Hamman, (1998) wheat yield leveled off or, in few instances, declined at Chevalier rates higher than 40 g/ha.

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Table 4. Effect of Chevalier rate applied POST and/or PPI[a] on and *Hordeum murinum* density and biomass in 2006-2007 growing seasons.

Chevalier rate (g a.i./ha)			*H. murinum*[c]					
	Density reduction[d] (%)	Biomass Reduction (%)	Mid-tillering		Early jointing			
			Density reduction (%)		Density reduction (%)		Biomass reduction (%)	
			PRE	POST	PRE	POST	PRE	POST
0	0.0b	0.0d	0.0b	-[e]	0.0b	0.0d	0.0d	0.0c
20.25	56.8a	40.1bc	13.3b	-	0.0a	8.3c	32.1c	0.0c
30.75	46.1a	31.6c	100a	-	100a	7.3c	96.6a	14.6b
40.50	60.5a	52.6abc	100a	-	100a	27.4b	94.6a	11.3b
51.00	64.3a	69.7ab	92.1a	-	100a	41.5a	94.2a	17.8b
60.75	57.7a	57.4ab	100a	-	100a	38.7a	94.1a	36.6a
71.25	49.7a	81.6a	85.0a	-	96.6a	47.4a	92.5a	40.8a

[a] Abbreviations: POST, postemergence; PPI, preplant incorporated; WAT, weeks after treatment.
[b] Chevalier applied POST at Eslamshahr in 2004-2005 growing season (data measured at 4 WAT are represented).
[d] Means within each column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P < 0.05$.