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Effect of different doses of post-emergence-applied iodosulfuron on weed control and grain yield of malt barley (*Hordeum distichum* L.), under Mediterranean conditions

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Abstract: A study was carried out over a two year period (2009/2010 and 2012/2013) on an experimental farm in the Alentejo region (Beja), in southern Portugal where rainfed malt barley (*Hordeum distichum* L.) is sown at the end of autumn or beginning of winter (November–December). The aim of this experiment was to study the efficiency of the herbicide iodosulfuron-methyl-sodium to control post-emergence broadleaved weeds in this cereal crop. The malt barley crop was established using no-till farming. This technology provides the necessary machine bearing capacity of the soil to assure the post-emergence application of herbicides at two different weed development stages. The herbicide iodosulfuron-methyl-sodium was applied at three doses (5.0, 7.5, and 10.0 g a. i. · ha^{-1}) and at two different broadleaved weed development stages (3 to 4 and 6 to 7 pairs of leaves), that also corresponded to two different crop development stages (beginning of tillering and complete tillering). The results indicated that early herbicide application timing provided a significantly higher efficiency for all the applied herbicide doses, but this better weed control was not reflected in a higher crop grain yield. The lack of a higher crop grain yield was probably due to a crop phytotoxicity of the herbicide, when used at an early application timing.

Key words: broadleaved weeds, herbicide doses, iodosulfuron-methyl-sodium, malt barley

Introduction

Numerous studies in many countries have evaluated the reduction of herbicide doses below label recommendations with the objective to reduce the costs and/or environmental effects of weed management. A satisfactory control of weeds can often be obtained when herbicides are used at lower doses than normally recommended (Férnandez-Quintanilla *et al*. 1998; Boström and Fogelfors 2002). According to Kaczmarek *et al*. (2013), the reduced herbicide dose proved to be effective in weed control and ensured a significant increase in the grain yield of spring cereals.

The parameters to be considered while optimising herbicide doses are: weed flora and growth stage, crop competitiveness, climatic conditions, application technique, formulation/adjuvant and combination with other pesticides (Kudsk 2008), and tillage systems used (Young and Thorne 2004). The efficiency of foliar-applied herbicides under various climate and soil conditions is closely related to environmentally-induced differences in herbicide uptake, translocation, and metabolism in weeds. The relationship between the final effect of an individual herbicide and the environmental conditions also depends on the herbicide's mechanism of action and on the controlled weed species (Kieloch and Kucharski 2012).

More and more frequently, the main goal of weed management is to keep weed infestation at an acceptable level (Kaczmarek and Matysiak 2015). According to Domaradzki (2003), under optimal weather and soil conditions, weed control may be achieved as a result of an application of a lower than recommended herbicide dose. But Medd *et al*. (2001) stated, that under less favourable conditions, a higher dose than the recommend one will be required, and under unfavourable conditions even the highest doses of herbicide may still give unsatisfactory results.

Using data from various studies on several crops and under different environmental conditions, Zhang *et al*. (2000) found substantial variations in weed control efficiency using different herbicide doses. In a few studies, the application of the recommended dose provided a weed control efficiency of only 20–40%. 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. For cereals, more than 70% weed control was still maintained in over 90% of the cases at doses between 30% and 60% of the label recommendation. Férnandez-Quintanilla *et al*. (1998) also reported that weeds may often be satisfactorily controlled when herbicides are used at lower doses than those normally recommended. The effectiveness of the use of reduced herbicide doses was also confirmed in studies made by other authors (Domaradzki 2003; Malecka and Bremanis 2006). According to Kudsk (2002), a highly sensitive weed species may

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be controlled with doses two to four times lower in comparison with species considered as less sensitive.

However, studies conducted worldwide normally report herbicide resistances of some weeds with lower application doses than the recommended doses. Manalil *et al*. (2011) showed that the evolution of diclofop-methyl *Lolium rigidum* Gaudin resistance was faster at low herbicide doses than at higher doses. This faster resistance was due to the rapid selection of minor gene herbicide resistance traits at low doses and their subsequent recombination by cross-pollination. Many weed species throughout the world, have been found to be resistant to acetolactate synthase (ALS) inhibitors (Heap 2014). According to Zand *et al*. (2010), sulfonylureas are good alternatives for the current grass weed herbicides. A rotational application of these herbicides with other modes of action could reduce the risk of resistance-development in the target weed species.

In conventional tillage systems, as a consequence of the inversion of soil layers, weed seeds are buried, mixed, and returned to soil layers. They then emerge and establish in the following crop. Under no-till, weed seeds are no longer distributed over the soil profile but tend to accumulate in the top soil layer. Thus no-till not only changes the weed seed distribution in the surface soil layers but also the timing of weed emergence (Rahman *et al*. 2000; Calado *et al*. 2008). Densities of weed populations may then increase because most weed seeds are under favourable conditions (Streit *et al*. 2002). Under Mediterranean conditions, a high initial weed emergence can be expected after the first rainfalls in autumn, as most of the weed seeds remain at or near the soil surface (Calado 2010). Consequently, spraying before sowing eliminates an important proportion of potential weeds and reduces the subsequent pressure in the established crop. Both, the reduced weed pressure and the advantage of a much better machine-bearing capacity of the soil, allow an improved application timing (earlier application) and thus sufficient weed control at reduced herbicide doses. Chauhan *et al*. (2012) noted that if weeds can be controlled, earlier seeding of winter wheat and other cereal crops can also be advantageous for yield potential. It was demonstrated by ODonovan *et al*. (1985), and Vargas and Roman (2005), that early removal of weeds is important to avoid crop yield reductions. When the control is performed at an earlier weed development stage, herbicide doses lower than those recommended by the manufacture are sufficient to achieve good weed control and to obtain the crop yield potential. This can be interpreted as the result of the higher weed control efficiency and a shorter period of competition between crop and weeds for the early application timings. It is important to note, that in earlier herbicide applications both weeds and crop are more sensitive to the herbicide. This means that the higher weed control efficiency of these application timings may not result in a higher crop grain yield, due to a phytotoxicity caused by the herbicide. Barros *et al*. (2007, 2009) applied the herbicide mesosulfuron-methyl + iodosulfuron-methyl-sodium in wheat and did not find any phytotoxicity in the crop at earlier application timings even with the higher herbicide doses. However, Barros (2010) (data not published) found that in malt barley (*Hordeum distichum* L.), there was a significant grain yield reduction in this crop when the herbicide iodosulfuron-methyl-sodium was applied at an early crop and weed development stage. Also, Vargas and Roman (2005) reported that barley shows a greater sensitivity to iodosulfuron-methyl-sodium than wheat (*Triticum aestivum* L.), rye (*Secale cereale*), and triticale (× *Triticosecale* Witt.). Applying this herbicide when these cereal crops had around 3–5 leaves and evaluating visually its selectivity, 7, 14, 25 and 40 days after the application, these authors found that barley was the only one of them that showed symptoms of phytotoxicity (leaf chlorosis) 40 days after herbicide application, indicating that the application of iodosulfuron-methyl-sodium in barley must be thoughtful. Jin *et al*. (2010) noted that crop species and crop cultivars are different in their sensitivity and responses to the same or different herbicides, hence they differ in morphology, physiology, and phenology.

The iodosulfuron-methyl-sodium ({[5-iodo-2-(methoxycarbonyl) phenyl] sulfonyl} carbamoyl) (4-methoxy-6-methyl-1,3,5-triazin-2-yl) azanide] is a post-emergence herbicide with a WG formulation (water dispersible granules), belonging to the sulfonylurea group of herbicides, and it is applied to control post-emergence broadleaved and grass weeds in cereal crops. Its mode of action is to inhibit the activity of ALS.

The present study aimed at determining the effect of different doses of iodosulfuron-methyl-sodium (at the recommended and below the recommended doses) on weed control and malt barley grain yield at two different weed development stages, under no-till.

Materials and Methods

Experimental location and treatments

Field experiments were carried out in the 2009/2010 and 2012/2013 seasons, at an experimental farm which belongs to the University of Évora in southern Portugal (Beja). The experiments were located on a Vertisol, with a silty clay texture in the A and B horizons, and silt loam in the C horizon. The soil pH in water was around 7.3 in the top layers, reaching up to 7.7 in the subsoil. The organic matter in the topsoil was around 1.2%. N-P-K fertilisation was applied according to the recommendations of the yearly soil test, to maintain fertility levels and a potential crop grain yield of 3,000 kg · ha^{-1}. The experimental plots had a surface area of 30 m^2 (10 × 3 m) and the harvest area was 13.5 m^2. The inter-row spacing was 15 cm.

The experiments were performed to study the effects of three doses of the herbicide iodosulfuron-methyl-sodium (5%) + mefenpyr-diethyl (15%) as a safener, on the control of broadleaved weeds in malt barley (*H. distichum*) at two of the weeds' development stages (3–4 pairs of leaves and 6–7 pairs of leaves). The herbicide doses used in the present study were: those recommended (7.5 and 10.0 g a.i. · ha^{-1}) and a lower dose than recommended (5.0 g a.i. ·ha^{-1}). The effects of the herbicide doses were compared to the control treatment (0 g a.i. · ha^{-1}).

Malt barley was sown at a rate of 190 kg $\cdot$ha^{-1}, under no-till, in the middle of December. Weeds which emerged before sowing were sprayed off with glyphosate at a dose of 450 g a.i. $\cdot$ l^{-1} $\cdot$ ha^{-1} and a water application with a water volume of 100 l $\cdot$ha^{-1}. The herbicide treatments were carried out with a plot sprayer equipped with flat-fan nozzles which had an opening angle jet of 110° and an orifice diameter of 1 mm, when about 90% of the broadleaved weeds present had around 3–4 pairs of leaves (first application timing) and when the same weeds had around 6–7 pairs of leaves (second application timing), corresponding to stages 20–21 and 28–29 of Zadoks scale for barley, respectively (Zadoks *et al*. 1974). The volume of the water application was 200 l $\cdot$ ha^{-1} with a pressure sprayer and working speed of 2 bars and 2.75 km $\cdot$ h^{-1}, respectively.

Weed control efficiency

To determine the weed control efficiency, the weeds were counted twice for each application timing, but not removed. The first counting took place immediately before the herbicide application and the second one about two months later. For this purpose, two quadrates with a side length of 50 cm were used and placed in the centre area of each plot in places where the density of weeds appeared to be greater. The quadrates were placed at the same position for both the first and second counting. The number of weeds determined is expressed as the number of plants per square metre.

Weed control efficiency of the different treatments is expressed as the percentage of weed control obtained and calculated using the following expression:

$$Ef = 100 - [(C2 - d)/C1] \times 100,$$

where: Ef – the efficiency of the treatment (%), $C1$ – the number of weeds per square metre counted before the treatment, $C2$ – number of weeds per square metre counted approximately two months after the treatment, and d – the difference in the number of weeds per square metre between the first and the second counting in the untreated (the control) plots (reinfestation). The d value (the 2-year average) for the first weed development stage was 6 plants $\cdot$ m^{-2} and for the second weed development stage was 1 plant $\cdot$ m^{-2}. The average infestation level in the two experimental years was 106 plants per square meter.

Grain yield and yield components

To obtain the crop grain yield per square metre the harvest of the centre of the plots (10 × 1.35 m) was performed using a plot combine harvester. This parameter was determined based on dry weight and is expressed in grams per square metre. From each plot, 100 spikes were collected before combining, to determine the number of spikes per square metre and the number of grains per spike, based on the grain weight and grain weight per square metre of the 100 spikes. A determination was made of the 1,000 grain weight based on the dry weight. The number of grains per square metre was calculated on the basis of grain yield per area and 1,000 grain weight.

Statistical analysis

The experimental layout was a randomised complete block design with four replications. An analysis of variance (ANOVA) was performed to determine the significant differences. Duncanȁs multiple range test was performed for the separation of means when the F-test revealed an error probability less than or equal to 5% ($p \leq 5\%$). Simple linear regression equations were fitted to describe the relationship between the herbicide doses and the number of spikes per square metre.

Since the interaction years' × treatments were not significant (i.e. in both years of experimentation the results were similar), the statistical analysis could be done as the average of the two experimental years.

Statistical analyses were performed using the MSTA-TC program (version 1.42) (Michigan State University).

Results

The weeds in the experiment and the respective frequency in the two experimental years are shown in table 1. All the weeds are indicated by Bayer CropScience as being sensitive to iodosulfuron-methyl-sodium for the recommend herbicide doses (7.5 and 10.0 g a.i.).

Table 2 shows that the control efficiency of the broadleaved weeds, by iodosulfuron-methyl-sodium, decreased significantly when the application timing was delayed for all herbicide application doses. At the early application, there were no significant differences between the intermediate and higher dose, 7.5 and 10.0 g a.i. $\cdot$ ha^{-1}, respectively. For the late application timing it was necessary to apply the higher herbicide dose to achieve the significantly higher efficiency. For both application timings, the lower herbicide dose (5.0 g a.i. $\cdot$ ha^{-1}) achieved a lower efficiency than the recommend ones (7. 5 and 10.0 g a.i. $\cdot$ ha^{-1}).

Table 1. Frequency of the weeds present on the experiment (a two years average)

Weeds	Frequency [%]
Lactuca serriola L.	9.1
Calendula arvensis L.	9.0
Galium aparine L.	8.9
Rumex conglomeratus L.	8.5
Papaver rhoeas L.	8.1
Sonchus asper L.	7.5
Chamaemelum mixtum L.	7.1
Picris echioides L.	6.5
Centaurea melitensis L.	6.3
Chrysanthemum segetum L.	6.1
Anagallis arvensis L.	5.2
Silene gallica L.	5.0
Chenopodium album L.	4.1
Polygunum aviculare L.	4.1
Chichorium intybus L.	3.2
Others	1.3

Table 2. Efficiency of the herbicide dose and application timing (a two years average)

Application timing	Doses [g a.i. · ha^{-1}]			The mean efficiency [%]
	5.0	7.5	10.0	
Early	93.7 b	97.2 a	97.8 a	96.2 A
Late	80.2 d	87.0 c	91.2 b	86.1 B
The mean	86.9 B	92.1 A	94.5 A	–
Factors	Degrees of freedom	F value	The mean square	K value (Prob.)
Factor A (timing)	1	134.940	610.042	0.0000
Factor B (dose)	2	25.084	120.508	0.0001
A × B	2	4.994	23.990	0.0264
Error	12	–	4.804	–
CV (coefficient of variation): 2.40%				

Values followed by the same letter or letters are not significantly different at a 5% level (Duncanś multiple range test)
Capital letters refer to differences between main factors (doses, application timing), small letters refer to differences between the interaction of factors (doses × application timing)

Table 3. Effect of the herbicide dose and application timing on the grain yield (a two years average)

Application timing	Doses [g a.i. · ha^{-1}]				The mean grain yield [g · m^{-2}]
	0	5.0	7.5	10.0	
Early	205.0 bc	213.9 bc	160.3 c	188.0 bc	191.8 B
Late	203.7 bc	325.4 a	265.5 ab	302.2 a	274.2 A
The mean	204.4 B	269.6 A	212.9 B	245.1 AB	–
Factors	Degrees of freedom	F value	The mean square	K value (Prob.)	
Factor A (timing)	1	12.469	32,480.82	0.0123	
Factor B (dose)	3	3.542	2,412.20	0.0356	
A × B	3	3.251	2,214.52	0.0460	
Error	18	–	681.036	–	
CV (coefficient of variation): 8.86%					

Values followed by the same letter or letters are not significantly different at a 5% level (Duncanś multiple range test)
Capital letters refer to differences between main factors (doses, application timing), small letters refer to differences between the interaction of factors (doses × application timing)

Table 4. Yield components for the different treatments (a two years average)

Application timing	Doses [g a.i. · ha^{-1}]	No. of grains per m^2	The mean grain weight [mg]	No. of spikes per m^2	No. of grains per spike
Early	0.0	7,777 b	34.6 bc	505	16
	5.0	8,203 b	33.2 cd	472	18
	7.5	7,644 b	31.1 e	448	17
	10.0	8,305 ab	32.0 de	447	20
The mean		7,982	32.7 B	468	18
Late	0.0	8,022 b	35.1 b	454	18
	5.0	9,566 a	37.2 a	538	18
	7.5	8,568 ab	38.2 a	498	18
	10.0	8,946 ab	38.9 a	484	18
The mean		8,775	37.3 A	493	18

Values followed by the same letter or letters are not significantly different at a 5% level (Duncanś multiple range test)
Capital letters refer to differences between main factors (doses, application timing), small letters refer to differences between the interaction of factors (doses × application timing)

Late application timing to control broadleaved weeds, significantly increased crop grain yield for all herbicide doses. At the early application timing, no significant differences between the three herbicide doses and the control treatment were observed (Table 3). For the different treatments, table 4 shows a significant difference in the number of grains per square metre and in the mean grain weight. The three herbicide doses resulted in a significantly higher mean grain weight when applied at the second application timing.

Discussion

The results obtained in the present study showed that the success to control post-emergence broadleaved weeds in the malt barley crop was higher when the herbicide application was performed at an early weed development stage (3–4 pairs of leaves) as a result of a greater sensitivity of weeds to the herbicide (Table 2). At this application timing, despite the significantly lower efficiency of the lowest herbicide dose (5.0 g a.i. · ha^{-1}) relatively to the recommend ones, its efficiency was very satisfactory, which is in accordance with Férnandez-Quintanilla *et al*. (1998), Zhang *et al*. (2000), Boström and Fogelfors (2002), Domaradzki (2003), Nordblom *et al*. (2003), and Malecka and Bremanis (2006).

In contrast to the results obtained by Barros *et al*. (2007, 2009) in wheat, the anticipation of the herbicide application to an early weed and crop development stage led to a significant reduction in grain yield for all applied doses (Table 3), despite a significantly higher weed control efficiency (Table 2). Even at this early development stage, the crop grain yield between the control treatment and the other treatments was not significant. These results are also not in accordance with those of ODonovan *et al*. (1985), Vargas and Roman (2005), Chauhan *et al*. (2012), and Kaczmarek *et al*. (2013).

The present study showed that a higher efficiency in the weed control and a lower competition period between crop and weeds did not lead to an increase in grain yield, but instead, to its significant decrease for all herbicide doses used. The reason for these results is most probably the phytotoxicity caused by the herbicide when the crop was more sensitive (beginning of tillering). This hypothesis is consistent with the reduction in the number of spikes per square metre when the herbicide application dose was increased. This reduction was more evident at the earlier application timing (Fig. 1). These results are in accordance with Barros (2010) (data not published) and Vargas and Roman (2005) who reported the great sensitivity of barley to iodosulfuron-methyl-sodium. Therefore the application of iodosulfuron-methyl-sodium in barley must be seriously thought about first.

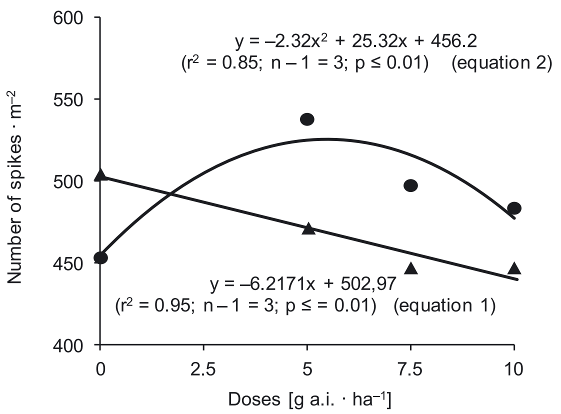

Fig. 1. Relationship between herbicide doses and number of spikes m^{-2} for the first application timing (equation 1) and second application timing (equation 2)

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References

Barros J.F.C., Basch G., Carvalho M. 2007. Effect of reduced doses of a post-emergence herbicide to control grass and broad-leaved weeds in no-till wheat under Mediterranean conditions. Crop Protection 26 (10): 1538–1545.

Barros J.F.C., Basch G., Freixial R., Carvalho M. 2009. Effect of reduced doses of mesosulfuron + iodosulfuron to control weeds in no-till wheat under Mediterranean conditions. Spanish Journal of Agricultural Research 7 (4): 905–912.

Boström U., Fogelfors H. 2002. Response of weeds and crop yield to herbicide dose decision-support guidelines. Weed Science 50 (2): 186–195.

Calado J.M.G., Basch G., Carvalho M. 2008. Aparecimento de plantas espontâneas com e sem perturbação do solo em condições Mediterrânicas. [Appearance of spontaneous plants from disturbed and undisturbed soil under Mediterranean conditions]. Revista de Ciências Agrárias 31 (2): 68–78. (in Portuguese)

Calado J.M.G., Basch G., Carvalho M. 2010. Weed management in no-till winter wheat (*Triticum aestivum* L.). Crop Protection 29 (1): 1–6.

Chauhan B.S., Singh R.G., Gulshan M. 2012. Ecology and management of weeds under conservation agriculture: A review. Crop Protection 38: 57–65.

Domaradzki K. 2003. Weed control in spring cereals by lower doses of herbicides. Journal of Plant Protection Research 43 (3): 247–254.

Férnandez-Quintanilla C., Barroso J., Recasens J., Sans X., Torner C., Sánchez Del Arco M.J. 1998. Demography of *Lolium rigidum* in winter barley crops: analysis of recruitment, survival and reproduction. Weed Research 40: 281–291.

Heap I. 2014. Herbicide resistant weeds. p. 281–301. In: "Integrated Pest Management" (P. David, P. Rajinder, eds.). Springer Netherlands, Corvallis OR, USA, 470 pp.

Jin Z.L., Zhang F., Ahmed Z.I., Rasheed M., Naeem M.S., Ye Q.F., Zhou W.J. 2010. Differential morphological and physiological responses of two oilseed *Brassica* species to a new herbicide ZJ0273 used in rapeseed fields. Pesticide Biochemistry and Physiology 98 (1): 1–8.

Kaczmarek S., Matysiak K., Adamczewski K. 2013. Cereal mixtures – an effective weed management tool. Journal Plant Protection Research 53 (4): 364–374.

Kaczmarek S., Matysiak K. 2015. Application of reduced doses of chlorsulfuron in semi-dwarf and full-height cultivars of winter triticale. Journal Plant Protection Research 55 (1): 8–15.

Kieloch R., Kucharsky M. 2012. Weed species response to two formulations of iodosulfuron methyl sodium and amidosulfuron mixture applied at various environmental conditions. Polish Journal of Agronomy 8: 15–19.

Kudsk P. 2002. Optimising herbicide performance. p. 323–344. In: "Weed Management Handbook" (R.E.L. Naylor, ed.). 9th ed. Blackwell Publishing, Oxford, UK, 423 pp.

Kudsk P. 2008. Optimizing herbicide dose: a straightforward approach to reduce the risk of side effects of herbicides. The Environmentalist 28 (1): 49–55.

Malecka S., Bremanis G. 2006. Effectivity of reduced doses of herbicides to weed constitution of spring barley. Agronomy Research 4 (Special issue): 287–292.

Manalil S., Busi R., Renton M., Powles S.B. 2011. Rapid evolution of herbicide resistance by low herbicide dosages. Weed Science 59 (2): 210–217.

Medd R.W., Van de Ven R., Pickering D.I., Nordblom T.L. 2001. Determination of environment-specific dose response relationships for clodinafop-propargyl on *Avena* spp. Weed Research 41 (4): 351–368.

ODonovan J.T., de St. Remy A., OSullivan P.A., Dew D.A., Sharma K.A. 1985. Influence of the relative time of emergence of wild oat (*Avena fatua*) on yield loss of barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*). Weed Science 33 (4): 498–503.

Rahman A., James T.K., Mellsop J., Grbavac N. 2000. Effect of cultivation methods on seed distribution and seedling emergence. New Zealand Plant Protection 53: 28–33.

Streit B., Rieger S.B., Stamp P., Richner W. 2002. The effect of tillage intensity and time of herbicide application on weed communities and populations in maize in central Europe. Agriculture Ecosystems and Environment 92 (2–3): 211–224.

Vargas L., Roman E.S. 2005. Seletividade e eficiência de herbicidas em cereais de Inverno. [Selectivity and efficiency of herbicides in winter cereals]. Revista Brasileira de Herbicidas 3: 1–10. (in Portuguese)

Young F.L., Thorne M.E. 2004. Weed-species dynamics and management in no-till and reduced-till fallow cropping systems for the semi-arid agricultural region of the Pacific Northwest, USA. Crop Protection 23 (11): 1097–1110.

Zadoks J.C., Chang T.T., Konzak C.F. 1974. A decimal code for the growth stages of cereals. Weed Research 14 (6): 415–421.

Zand E., Baghestani M.A., AghaAlikhani M., Soufizadeh S., Khayami M.M., PourAzar R., Sabeti P., Jamali M., Bagherani N., Forouzesh S. 2010. Chemical control of weeds in wheat (*Triticum aestivum* L.) in Iran. Crop Protection 29 (11): 1223–1231.

Zhang J., Weaver S.E., Hamill A.S. 2000. Risks and reliability of using herbicides at below-labeled doses. Weed Technology 14 (1): 106–115.