AGRÁRIA
Revista Brasileira de Ciências Agrárias
ISSN (on line): 1981-0997
v.6, n.2, p.197-202, abr.-jun., 2011
Recife, PE, UFRPE. www.agraria.ufrpe.br
Protocolo 814 – 04/02/2010 *Aprovado em 21/02/2011
DOI:10.5039/agraria.v6i2a814

José C. Barros[1]
Gottlieb Basch[1]
José G. Calado[1]
Mario Carvalho[1]

Reduced doses of herbicides to control weeds in barley crops under temperate climate conditions

ABSTRACT

Yield losses in cereal crops under temperate climate conditions due to weed-crop competition, namely *Lolium rigidum* G., can reach up to 80%, depending on the season and infestation level. Nevertheless, the costs of chemical weed control and the environmental impact caused by herbicides recommend the search for strategies to reduce their input. Therefore, the aim of this work was to study the possibility of reducing the input of different post-emergence herbicides (diclofop-methyl + fenoxaprop–*p*-ethyl and amidosulfuron + iodosulfuron-methyl-sodium) to control *Lolium rigidum* G. and broad-leaf weeds in barley under no-till, and to monitor the effect on weed population levels and crop yields. A field experiment was carried out in 2007-2008 and 2008-2009, in an experimental farm in the south of Portugal, combining different herbicide doses applied at different weed development stages. Results show that, for all herbicide doses, the earlier application provides higher weed control efficacy and higher grain yields, indicating that the reduction of doses is possible while maintaining satisfactory crop grain yields.

Key words: *Lolium rigidum*, broad-leaf weeds, no-till farming, crop yields

Redução de doses de herbicidas no controle de plantas daninhas em cultivo de cevada sob condições climáticas temperadas

RESUMO

As quebras de produção em cereais sob condições climáticas temperadas devido à competição das infestantes, nomeadamente *Lolium rigidum* G., podem atingir mais de 80%, dependendo da época e do nível de infestação. Contudo, os custos do controle químico das infestantes e o impacto ambiental causado pelos herbicidas recomendam a procura de estratégias de modo a reduzir a sua aplicação. Assim, o objetivo do presente trabalho foi estudar a possibilidade da redução da aplicação de diferentes herbicidas de pós-emergência (diclofope-metilo + fenoxaprope-*p*-etilo e amidosulfuron + iodosulfuron) no controle de *Lolium rigidum* G. e infestantes dicotiledôneas em cevada sob plantio direto, e monitorar o efeito nos níveis de populações de infestantes e na produção de grão. O experimento foi conduzido em 2007-2008 e 2008-2009, numa fazenda experimental no Sul de Portugal, combinando diferentes doses de herbicidas aplicados em diferentes estádios de desenvolvimento das infestantes. Os resultados mostram que, para todas as doses de herbicidas, a aplicação mais cedo conduz a uma maior eficácia no controle das infestantes e maiores produções de grão, indicando que a redução das doses é possível, mantendo uma produção de grão na cultura satisfatória.

Palavras-chave: Dicotiledôneas, *Lolium rigidum*, plantio direto, produções

[1] Universidade de Évora, Departamento de Fitotecnia, Apartado 94, 7002-554, Évora, Portugal. Fone: +351 266760877. Fax: +351 266711163. E-mail: jfcb@uevora.pt; gb@uevora.pt; jcalado@uevora.pt; mjc@uevora.pt

Introduction

Barley (*Hordeum vulgare* L.) is an important cereal crop in Portugal, grown for malt production. In recent years, barley has become more popular, due to its competitive price, relative to other cereal crops such as wheat and oats. Moreover, barley is an interesting crop to be included in crop rotations to control grass and broad-leaf weeds under Mediterranean climate, due to its late sowing timing (December-January) which allows pre-sowing control of already emerged weeds, by applying a total, systemic and non-residual herbicide (Carvalho et al., 1990). Nevertheless, in this cereal crop, a post-emergence weed control is usually necessary, regardless of the tillage system used, in order to guarantee the required grain quality.

Weeds are the most important factor in wheat grain yield reduction (Baghestani et al., 2007). However, an acceptable weed control can often be obtained by applying herbicides at lower doses than recommended (Fernandez-Quintanilla et al., 2000; Navarrete et al., 2000; Zhang et al., 2000; O'Donovan et al., 2001; Boström & Fogelfors, 2002) while maintaining satisfactory crop yields (Fernandez-Quintanilla et al., 2000; Navarrete et al., 2000; Barros et al., 2005, 2007, 2008).

Using data from different studies of several crops and under different environmental conditions, Zhang et al. (2000) found substantial variations in weed control efficacy using different herbicide doses. In a few studies, using recommended doses, they obtained a weed control efficacy of only 20-40%, whereas a weed control efficacy of 70% or higher was achieved in 50% of the studies with herbicide doses as low as 20% of the label recommendation. The same authors found that weed control efficacy tended to be lower and varied more at reduced doses than at the recommended ones, but remained within the 60-100% range in over 90% of the cases. For cereals, weed control was over 70% in more than 90% of the cases at doses between 30% and 60% of the label recommendation.

Several studies based on the application of tralkoxydim showed that a 50% dose controlled more than 85% of wild oat (*Avena fatua* L.) in barley (*Hordeum vulgare* L.) (Belles et al., 2000), and that below-labelled doses often provide good control of wild oat (O'Donovan et al., 2001).

Studying the effect of different herbicides (fluroxypyr); diflufenican plus MCPA and Clopyralid plus 2, 4 – D and different herbicide doses to control broad-leaf weeds in winter wheat in Iran, Zand et al. (2007) reported that the control of *Galium tricornutum* is over 85% for the highest herbicide dose, but it drops below 50% at the lowest dose, and that these three herbicides applied at the highest dose also control *Lamium amplexicaule* and *D. Sophia* in over 82%. However, when the herbicide doses were decreased, the control of these annual broad-leaf weeds was significantly reduced. According to the same authors, the control of *S. arvensis* and *Beta maritime* populations with all herbicide treatments ranges from 91% to 100%, while significant differences are obtained for *Malva neglecta* and *Silybum marianum*.

Annual ryegrass (*Lolium rigidum* Gaud.) is an annual grass that has become one of the most troublesome cereal weeds in Mediterranean climates (Gonzalez-Andujar & Saavedra, 2003). Yield losses in cereal crops due to competition from ryegrass can reach up to 80%, depending on the season and infestation level (Izquierdo et al., 2003). Studies performed by Navarrete et al. (2000) in Spain have shown that the level of ryegrass control achieved with commercial herbicides applied at standard doses ranged from 57% to 99%, with an average value of 90%. These studies have also shown that reducing herbicide doses below the standard usually has a low impact on weed control level.

It has also been demonstrated that it is possible to reduce post-emergence herbicide doses in wheat (*Triticum aestivum* L.) under Mediterranean conditions and no-till farming, while achieving satisfactory control efficacy of grass and broad-leaf weeds and maintaining potential crop yields (Barros et al., 2005, 2007, 2008). According to the same authors, to achieve such results, it is necessary to apply the herbicides at an early weed development stage, when weeds are more sensitive. This can only be guaranteed using no-till farming for crop establishment, as the necessary soil-bearing capacity in the frequently wet winter months is only assured in the absence of soil disturbance.

The practice of no-till farming in cereal production has been increasing in Portugal in order to reduce costs and soil erosion. No-till farming represents a major change in production practices and it is likely to produce new weed management challenges (Young & Thorne, 2004; Calado et al., 2010). This tillage system may strongly affect the environment for seed germination by changing the temperature and humidity of the topsoil and the amount of crop residues on the soil surface (Froud-Williams, 1988). Weed seeds under no-till farming are no longer distributed throughout the upper soil profile, they tend to accumulate in the very topsoil layer. Therefore, densities of weed populations may increase because most weed seeds are under favorable conditions (Streit et al., 2002). Thus, a high initial weed emergence can be expected after the first rainfalls, as most of the weed seeds remain on or near the soil surface. Reduced late emergence of annual weeds can be observed when decreasing soil tillage intensity, especially on uncultivated land (Gill & Arshad, 1995). Consequently, spraying the herbicide before sowing eliminates an important proportion of potential weeds and reduces the subsequent weed pressure in the established crop (Calado et al., 2010). Both the reduced weed pressure and the advantage of a much better soil-bearing capacity allow an improved application timing and thus sufficient weed control at reduced herbicide doses.

Earlier application timings will not reach only weeds at a more sensitive stage but may also allow the use of lower application volumes that ensure sufficient crop penetration for the necessary contact with the weed leaves. Furthermore, as demonstrated by O'Donovan et al. (1985), removing weeds earlier is important to avoid crop yield losses.

Material and Methods

Experiments were performed to study the effects of three doses of two different post-emergence herbicides on the control of *L. rigidum* and broad-leaf weeds in barley (*Hordeum vulgare* L.) at two weed development stages. The experiments were conducted in the years 2007-2008 and 2008-2009, in an experimental farm which belongs to the University of Évora in the south of Portugal (Beja). One of the two herbicides used (H1) was a commercial mixture of 250 g L^{-1} of diclofop-methyl + 20 g L^{-1} of fenoxaprop-*p*-ethyl + 40 g L^{-1} of mefenpyr-diethyl (safener). It acts both as contact and as systemic herbicide and is absorbed by the leaves of the weeds and translocated to the growth zones. This herbicide is used in post-emergence to control grass weeds, mainly *Lolium rigidum* Gaud., *Phalaris minor* Retz and *Avena sterilis* L. The other herbicide used (H2) was a commercial mixture of 100 g L^{-1} of amidosulfuron + 25 g L^{-1} of iodosulfuron–methyl–sodium + 250 g L^{-1} of mefenpyr-diethyl (safener). This herbicide is indicated to control broad-leaf weeds in wheat and barley at post-emergence. Nevertheless, only iodosulfuron-methyl-sodium is registered for *L. rigidum* control. The two herbicides studied were homologated for barley in Portugal in the present year (2009-2010).

To control *Bipolaris sorokiniana* a fungicide was applied at the mid boot stage, corresponding to stage 43 of Zadoks' scale for barley (Zadoks et al., 1974). This fungicide is a commercial mixture of tebuconazole (125 g L^{-1}) + prothioconazole (125 g L^{-1}). It is a preventive and curative fungicide and it was applied at a concentration of 1 L ha^{-1} with 300 L ha^{-1} of water.

The experimental design was a randomized complete block design with four replications. The treatments and their respective levels are summarized in Table 1.

The experiment was carried out for 2 years in different fields of the experimental farm, but both sites had identical soil characteristics (Vertisol), with a silty clay texture in the A and B horizons and silt loam in the C-horizon. 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 2%.

The study sites were located in a typical Mediterranean climatic region with rainfall concentration during the winter months, which correspond to the early growing season of barley. Barley was sown under no-till farming in the middle of December. Weeds emerging before sowing were sprayed with glyphosate at a dose of 450 g L^{-1} per hectare.

The herbicide treatments were carried out with a plot sprayer equipped with flat-fan nozzles (110º – 10) when about 90% of the *L. rigidum* was at the beginning of tillering (first application timing) or when it had reached complete tillering (second application timing). When *L. rigidum* was at the beginning of tillering, the broad-leaf weeds had around 3 to 4 pairs of leaves and when the *L. rigidum* had reached complete tillering, broad-leaf weeds had around 6 to 7 pairs of leaves. These two application timings correspond to stages 22-25 and 31–32 of Zadoks' scale for barley (Zadoks et al., 1974), respectively. The plot size was 10 m x 3 m and the harvest area was 15 m^2.

The main broad-leaf weeds present in the experiment were, in decreasing order of frequency: *Lactuca serriola* L.; *Papaver rhoeas* L.; *Galium aparine* L.; *Anchusa italica* Retz; *Centaurea melitensis* L. *Chrysanthemum segetum* L.; *Polygonum aviculare* L.; *Medicago nigra* L.; *Fumaria agraria* Lag.; *Andryala integrifolia* L.; *Chamaemelum mixtum* L.; *Lavatera cretica* L.; *Picris echioides* L.; *Senecio vulgaris* L.; *Silene gallica* L.; *Sonchus asper* L. and *Reseda luteola* L.

The weeds were identified and counted twice each year, but not removed. The first counting took place immediately before the herbicide application and the second one about 2 months later. For the counting, quadrates with a side length of 50 cm were used in all plots inside the 15 m^2 area used for yield determination, in the central part of the plots. For the second counting, the quadrates were placed at the same position as in the first counting. The results are presented as number of weeds per square meter.

Weed control efficacy of the different treatments is expressed as the percentage of weed control obtained, calculated by the following expression (Barros et al., 2005):

$$Ef = 100 – [(C2 – d)/C1].100,$$

in which *Ef* is the efficacy of the treatment (%), C1 is the number of weeds per square meter counted before the treatment, C2 the number of weeds per square meter counted approximately 2 months after the treatment and *d* is the difference in the number of weeds per square meter between the first and second counting in the untreated (control) plots (reinfestation). The *d* value (average of the 2 years) determined for the first weed development stage was 3 plants m^{-2} for *L. rigidum* and 10 plants m^{-2} for broad-leaf weeds. For the second weed development stage, the *d* value was 1 plant m^{-2} for *L. rigidum* and 3 plants m^{-2} for broad-leaf weeds.

Table 1. Application doses and timings used for *Lolium rigidum* G. and broad-leaf weeds control in barley

Tabela 1. Datas e doses de aplicação usadas para o controle de Lolium rigidum G. e plantas daninhas dicotiledóneas em cevada

Dose (L ha^{-1})		Herbicide application timing	
H1	H2	*Lolium* development stage	Broad-leaf weed development stage
1.5	0.100	Beginning of tillering (WDS1)	3 - 4 pairs of leaves (WDS1)
2.0	0.125	Complete tillering (WDS2)	6 – 7 pairs of leaves (WDS2)
2.5	0.150		

The average number of weeds per square meter of all plots and before the application of the herbicides was 48 for *L. rigidum* and 101 for broad-leaf weeds.

A short duration barley cultivar (Pewter) was sown at 180 kg ha^{-1} and the N-P-K fertilization was applied according to yearly soil analyses and the respective recommendations, to maintain fertility levels and a potential crop yield between 2500 and 3000 kg ha^{-1}.

The harvest of the centre of the plots (10 x 1, 5 m) was performed using a plot combine harvester. Grain yields per area were determined based on dry weight. The analysis of variance (ANOVA) was performed to determine significant differences. Duncan's multiple range test was used for the separation of the means when the F-test revealed an error probability of less than or equal to 5% ($P \leq 5\%$). All statistical analyses were performed using the MSTATC program (version 1.42) (Michigan State University).

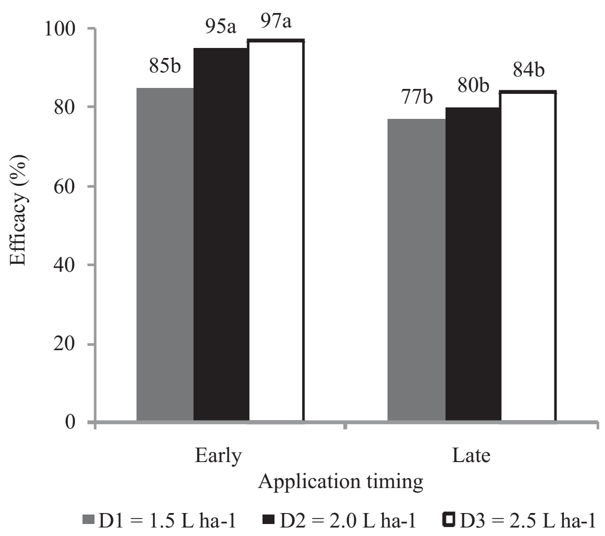
Results and Discussion

Weed control efficacy

Control of *L. rigidum* was mainly due to the effect of the diclofop-methyl + fenoxaprope-*p*-ethyl herbicide (H1). *L. rigidum* control efficacy decreased for all herbicide doses when the application timing was delayed (complete tillering) and for this timing, the maximum efficacy was achieved with the highest herbicide dose, though the differences were not significant between doses (Figure 1). For the first application timing (beginning of tillering), the higher efficacy was obtained with the maximum dose, but the difference was not significant when compared to the intermediate herbicide dose. The lowest herbicide dose had a significantly lower *L. rigidum* control efficacy.

The control of broad-leaf weeds was due to the action of the amidosulfuron + iodosulfuron – methyl herbicide (H2). As with the H1 herbicide, the broad-leaf weeds' control efficacy decreased for all herbicide doses when the application timing was delayed (6-7 pairs of leaves) (Figure 2). For the first application timing (3-4 pairs of leaves) the maximum control efficacy was achieved with the highest herbicide dose, but the difference between the highest and intermediate doses was not significant.

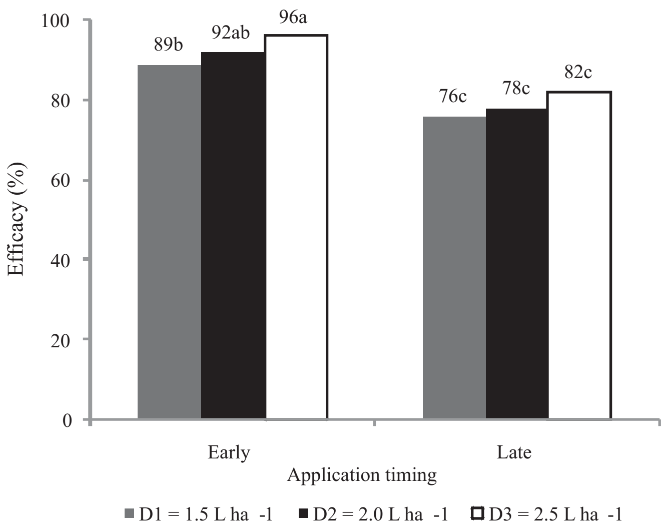
The results of the experiments confirm that a satisfactory control of *L. rigidum* and broad-leaf weeds can be achieved with below-labelled herbicide doses, as it has been reported by Belles et al. (2000), Fernandez-Quintanilla et al. (2000), Navarrete et al. (2000), Zhang et al. (2000), O'Donovan et al. (2001), Boström & Fogelfors (2002) and Barros et al. (2005, 2007, 2008). The results achieved in these experiments also show that the success of reduced herbicide doses depends on an early application timing, when the weeds are more sensitive to herbicides, which is in accordance with O´Donovan et al. (1985) and Barros et al. (2005, 2007, 2008). The H2 herbicide (amidosulfuron + Iodosulfuron – methyl) showed some difficulties in controlling *Lavatera cretica* L.,



Values followed by the same letter or letters are not significantly different at a 5% level (Duncan´s multiple range test)

Figure 1. Efficacy of the diclofop-methyl + fenoxaprop-*p*-ethyl herbicide applied at three doses (D1-1.5; D2-2.0; D3-2.5 L ha^{-1}), on the control of *Lolium rigidum* Gaud

Figura 1. *Eficácia do herbicida methyl-2-(4-(2, 4-dichlorophenoxy) phenoxy) propionate + D-(+)-2-4-(6-chloro-1, 3-benzoxazol-2pyloxy) phenoxypropionacid, aplicado em três doses (D1-1,5; D2-2,0; D3-2,5 L. ha^{-1}) no controle do Lolium rigidum Gaud*



Values followed by the same letter or letters are not significantly different at a 5% level (Duncan´s multiple range test)

Figure 2. Efficacy of the amidosulfuron + iodosulfuron-methyl herbicide, applied at three doses (d1-0.1; d2-0.125; d3-0.15 L ha^{-1}) on the control of broad-leaf weeds

Figura 2. *Eficácia do herbicida 3-(4,6-dimethoxypyrimidin-2-yl)-1-(N-methyl-N-methylsulfonyl-aminosulfonyl)-urea + 4-iodo-2-(3-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)ureidosulfonyl)benzoate, sodium salt, aplicado em três doses (d1-0,1; d2-0,125; d3-0,15 L ha^{-1}) no controle de plantas daninhas dicotiledóneas*

Anchusa italica Retz, *Centaurea melitensis* L. and *Fumaria agraria* Lag., even at the early application timing and using the recommended dose.

The use of no-till farming for crop establishment seems to contribute in two different ways to the possibility of reducing herbicide doses, while ensuring satisfactory weed control in autumn-sown cereal crops under Mediterranean conditions. The first one, also reported by Streit et al. (2002), is due to the improved bearing capacity of the undisturbed soil during the rainfall period, which allows herbicide application at the weed development stage when these are more sensitive to the herbicide. The second aspect, which is related to the use of no-till farming, refers to weed emergence as influenced by soil disturbance. The reinfestation rate found after both application timings and for the monitored weed species (*L. rigidum* and broad-leaf weeds) can be considered as quite low and it seems to be a consequence of the absence of soil disturbance. These results are in accordance with the findings of many authors, who have reported low late emergence of annual weeds while decreasing soil tillage intensity (Gill & Arshad, 1995; Streit et al., 2002; Barros et al., 2005, 2007, 2008).

Grain yield

The grain yields of the plants at the control plots for comparison with the plots for the first and second application timings were 91 g m^{-2} and 89 g m^{-2}, respectively. Table 2 shows that, for all the treatments, the grain yields decreased when the application timing was delayed (complete tillering for *L. rigidum* and 6-7 pairs of leaves for broad-leaf weeds). For both application timings, there was a tendency for the grain yield to increase when the amidosulfuron + iodosulfuron – methyl herbicide (H2) dose increased, and the highest dose of this herbicide even provided significantly higher yields when compared to the lowest one. On the contrary, at both application timings, the diclofop-methyl + fenoxaprop-*p*-ethyl herbicide (H1) did not show significant differences in grain yield when applied at different doses. However, the lowest dose tended to provide slightly lower grain yields.

The lower *L. rigidum* and broad-leaf weeds control efficacy and a consequently longer period of competition between crop and weeds must be considered responsible for the decrease in grain yield for the second application timing when compared with the first one. As also reported by some researchers, earlier application timings provide higher grain yields (O´Donovan et al., 1985; Fernandez-Quintanilla et al., 2000 and Barros et al., 2005, 2007, 2008). Even though the highest grain yields tended to be achieved with the highest doses for both herbicides at the first application timing, herbicide doses lower than the recommended (intermediate doses) were sufficient at both application timings to avoid significant yield losses, which is in accordance with Fernandez-Quintanilla et al. (2000), Navarrete et al. (2000) and Barros et al. (2005, 2007, 2008).

Table 2. Effect of herbicides in three doses (D1, D2, D3 for H1 and d1, d2, d3 for H2) and of the application timings on grain yield (g m^{-2}) (2 years' average)

Tabela 2. *Efeito de herbicidas em três doses (D1, D2, D3, para H1 e d1, d2, d3 para H2) e das datas de aplicação na produção de grão (g m^{-2}) (média de 2 anos)*

Application timings	Doses (H1)	doses (H2)			
		d1	d2	d3	Mean
Early	D1	181 cg	213 ad	217 ac	204 A
	D2	189 cf	208 ae	229 ab	209 A
	D3	215 ad	213 ad	234 a	220 A
	Mean	195 BC	211 AB	227 A	211 a
Late	D1	149 g	173 eg	173 eg	165 B
	D2	162 fg	170 eg	199 af	177 B
	D3	148 g	178 dg	194 bf	173 B
	Mean	153 E	174 D	189 CD	172 b

Values followed by the same letter or letters are not significantly different at a 5% level (Duncan´s multiple range test). The comparison of different means is indicated by the different format of the letters used

CONCLUSIONS

The results of this experiment reveal that it is possible to reduce both the dose of 2,5 L ha^{-1} (recommended by the manufacturer) of the diclofop-methyl + fenoxaprop – *p*-ethyl herbicide and the recommended dose (0,150 L ha^{-1}) of the amidosulfuron + iodosulfuron-methyl herbicide to achieve sufficient control of *L. rigidum* and some broad-leaf weeds and, consequently, to obtain satisfactory crop grain yields.

The herbicide used to control broad-leaf weeds (amidosulfuron + iodosulfuron – methyl - sodium) showed some difficulties in controlling some of these weeds, such as *Lavatera cretica* L., *Anchusa italica* Retz, *Centaurea melitensis* L. and *Fumaria Agraria* Lag, even at the early application timing and with the recommended dose. Therefore, when these weeds are present, the addition of a hormonal herbicide to improve their control is recommended.

There were no visible injury symptoms, even at the first and more sensitive application timing (stage 22-25 of Zadoks' scale (Zadoks et al., 1974)) and for the two highest herbicide doses. This means that crop tolerance is sufficient and, consequently, that these two herbicides are effective means for growers to control *L. rigidum* and many broad-leaf weeds in post-emergence in barley crops under Mediterranean conditions.

Acknowledgements

The authors would like to thank the University of Évora and Bayer Crop Science Agribusiness (Portugal), which supported the experiments.

Literature Cited

Baghestani, M.A.; Zand, E.; Soufizadeh, S.; Bagherin, N.; Deihimfard, R. Weed control and wheat (*Triticum aestivum* L.) yield under application of 2,4 – D plus carfentrazone-ethyl and florasulam plus flumetsulam: evaluation of the efficacy. Crop Protection, v.26, n.12, p.1759-1764, 2007. Crossref

Barros, J.F.C.; Basch, G.; Carvalho, M. Effect of reduced doses of a post-emergence graminicide mixture to control *Lolium rigidum* G. in winter wheat under direct drilling in Mediterranean environment. Crop Protection, v.24, n.10, p.880-887, 2005. Crossref

Barros, J.F.C.; Basch, G.; Carvalho, M. Effect of reduced doses of a post-emergence herbicide to control grass and broad-leaf weeds in no-till wheat under Mediterranean conditions. Crop Protection, v.26, n.10, p.1538-1545, 2007. Crossref

Barros, J.F.C.; Basch, G.; Carvalho, M. Effect of reduced doses of a post-emergence graminicide to control *Avena sterilis* L. and *Lolium rigidum* G. in no-till wheat under Mediterranean environment. Crop Protection, v.27, n.6, p.1031-1037, 2008. Crossref

Belles, D.S.; Thill, D.C.; Shafi, B. PP-604 rate and *Avena fatua* density effects on seed production and viability in *Hordeum vulgare*. Weed Science, v.48, n.3, p.378-384, 2000. Crossref

Boström, U.; Fogelfors, H. Response of weeds and crop yield to herbicide dose decision-support guidelines. Weed Science, v.50, n.2, p.186-185, 2002. Crossref

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

Carvalho, M.J.G.R.; Basch, G.; Azevedo, A.L.; Barros, J.C.; Alpendre, P.F. Avaliação de herbicidas de pré-sementeira (Glifosato e Paraquato) e de pré-emergência (Metabenztiazurão e Clortolurão) no controlo de infestantes na sementeira directa de trigo. Revista da Sociedade Portuguesa de Pastagens e Forragens, v.11, n.1, p.159-170, 1990.

Fernandez-Quintanilla, C.; Barroso, J.; Recasens, J.; Sans, X.; Torner, C.; Sánchez Del Arco, M.J. Demography of *Lolium rigidum* in winter barley crops: analysis of recruitment, survival and reproduction. Weed Research, v.40, n.3, p.281-291, 2000. Crossref

Froud-Williams, R.J. Changes in weed flora with different tillage and agronomic management systems. In: Altieri, M. A.; Liebman, M. (Eds.). Weed management in agroecosytems: ecological approaches. Boca Raton, FL: CRC Press, 1988. p.213-236.

Gill, K.S.; Arshad, M.A. Weed flora in the early growth period of spring crops under conventional, reduced and zero tillage systems on a clay soil in northern Alberta, Canada. Soil Tillage Research, v.33, n.1, p.65-79, 1995. Crossref

Gonzalez-Andujar, J.L. Saavedra, M. Spatial distribution of annual grass weed populations in winter cereals. Crop Protection, v.22, n.4, p.629-633, 2003. Crossref

Izquierdo, J.; Recasens, J.; Fernandez-Quintanilla, C.; Gill, G. The effects of crop and weed densities on the interactions between barley and *Lolium rigidum* in several Mediterranean locations. Agronomie, v.23, n.4, p.529-536, 2003. Crossref

Navarrete, L.; Sánchez del Arco, M.J.; González Ponce, R.; Taberner, A.; Tievas, M.A. Curvas de dosis respuesta para avena loca Y vallico en cultivos de cebada de invierno. In: Reunión Anual del Grupo de Trabajo Malas Hierbas y Herbicidas, 19., 2000, Oviedo. Actas. Oviedo: Consejería de Agricultura y Pesca del Principado de Asturias, 2000. p.50-53.

O' Donovan, J.T.; St. Remy, A.; O. Sullivan, P.A.; Dew, D.A.; Sharma, K.A. 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, v.33, n.4, p.498-503, 1985.

O'Donovan, J.T.; Harker, K.N.; Clayton, G.W.; Newman, J.C.; Robinson, D.; Hall, L.M. Barley seeding rate influences the effects of variable herbicide rates on wild oat. Weed Science, v.49, n.6, p.746-754, 2001. Crossref

Streit, B.; Rieger, S.B.; Stamp, P.; Richner, W. The effect of tillage intensity and time of herbicide application on weed communities and populations in maize in central Europe. Agriculture Ecosystems & Environment, v.92, n.2-3, p.211-224, 2002. Crossref

Young, F.L.; Thorne, M. E. Weed - species dynamics and management in no-till and reduced-till fallow cropping systems for the semiarid agricultural region of the Pacific Northwest, USA. Crop Protection, v.23, n.11, p.1097-1110, 2004. Crossref

Zadoks, J.C.; Chang, T.T.; Konzak, C.F. A decimal code for the growth stages of cereals. Weed Research, v.14, n.6, p.415-421, 1974. Crossref

Zand, E.; Mohammad, A.B.; Saeid, S.; Reza, P.A.; Mozhgan, V.; Naser, B.; Alireza, B.; Mohammad, M.K.; Nooshin, N. Broadleaved weed control in winter wheat (*Triticum aestivum* L.) with post-emergence herbicides in Iran. Crop Protection, v.26, n.5, p.746-752, 2007. Crossref

Zhang, J.; Weaver, S.E.; Hamill, A.S. Risks and reliability of using herbicides at below- labeled doses. Weed Technology, v.14, n.1, p.106-115, 2000. Crossref