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Evaluation of post-emergence herbicides for the control of wild oat (*Avena fatua* L.) in wheat and barley in Argentina

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ABSTRACT

Wild oat (*Avena fatua* L.) is the most troublesome weed in cereal crops in Argentina. With the aim of studying the effects of different herbicides, doses, and wild oat growth stage at application on weed control and crop yield, field experiments were conducted in wheat and barley crops during three growing seasons in the south of Buenos Aires Province, Argentina. Treatments were post-emergence applications of new herbicide, pinoxaden + cloquintocet mexyl (5%–1.25%), at doses that ranged from 20 g to 60 g a.i. pinoxaden ha^{-1}, applied at two to three leaves and the beginning of tillering of wild oat. In addition, standard treatments were included and applied at the same wild oat growth stages. Diclofop methyl at 511 g a.i. ha^{-1} and fenoxaprop-p-ethyl at 55 g a.i. ha^{-1} were applied in barley. In wheat, diclofop methyl was replaced by clodinafop-propargyl + cloquintocet mexyl (24%–6%) at 36 g a.i. clodinafop-propargyl + 9 g cloquintocet mexyl ha^{-1} and in 2008/09 wheat experiments, iodosulfuron plus metsulfuron methyl (5%–60%) at 3.75 g a.i. ha^{-1} + 3 g a.i. ha^{-1} also was included. In both crops, pinoxaden at 30 g a.i. ha^{-1} and at higher rates, fenoxaprop-p-ethyl and clodinafop-propargyl gave the best control of wild oat. In 2006/07 wheat crops, treatments applied at tiller initiation provided better control than the early timing averaged across herbicides. However, wheat yield generally was greater with early application. In barley, wild oat control and crop yield were similar regarding time of application. Variations in crop yield were correlated with grain number m^{-2} both in wheat and barley, but relationships between both grain number and spikes m^{-2} and with grains per spike were identified only in wheat.

1. Introduction

Wild oat (*Avena fatua* L.) is an annual grass considered to be one of the most wide-spread and harmful weeds of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) crops worldwide (Holm et al., 1977; Simpson, 1990). In Argentina, 5.85 M ha and 0.43 M ha are currently cropped with wheat and barley, respectively. Thirty percent of the area under wheat and 50% percent of the area under barley are located in the south of the Buenos Aires Province (SAGPyA, 2008), between 36° and 39° S, and 58° and 62° W. In surveys undertaken in this region almost 30 years ago, Catullo et al. (1983a) detected wild oat in 40% of wheat crop fields and a recent survey (Scursoni et al., 2007) detected an increase in this figure to 60%, indicative of a steady increase in wild oat abundance. In addition, Scursoni (1995) registered *A. fatua* in 77% of barley crops.

Yield losses related to wild oat interference have been registered in a wide range of agronomic conditions. Morishita and Thill (1988) reported 40% grain yield reductions in barley crops grown at 160 plants m^{-2} and infested with 170 plants m^{-2} of *A. fatua*. Stougaard and Xue (2004) measured 54% yield loss as wild oat density increased to 500 plants m^{-2} in Montana. However, the use of higher crop seeding rates and seed size improved crop yield by 12% in wheat and 18% in barley. In Argentina, Scursoni and Benech-Arnold (1998) determined yield losses of 30 and 22% in barley and wheat, respectively, when wild oat density was 60 plants m^{-2} and crop density was 250 plants m^{-2}. In a subsequent experiment, Scursoni and Satorre (2005) reported 25% yield loss in barley grown at stand densities between 160 and 220 plants m^{-2} with a wild oat density of 70 plants m^{-2}. Interestingly, they found that yield losses decreased when crop seeding rate was increased to 280 plants m^{-2}. In addition, lack of wild oat control reduced both harvest efficiency and grain quality of crops (King, 2007). This is a particularly important aspect in barley production, because the trading

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Table 1
Herbicide treatments in barley and wheat experiments in 2006/2007, applied at wild oat Zadoks stages 12–13 and 15–22.

Treatment	Dose (g a.i. ha^{-1})	Trade name in Argentina
Pinoxaden (5%)	20	AXIAL
Pinoxaden (5%)	30	AXIAL
Pinoxaden (5%)	40	AXIAL
Pinoxaden (5%)	50	AXIAL
Pinoxaden (5%)	60	AXIAL
Clodinafop-propargyl (24%)	36	TOPIK
Fenoxaprop-p-ethyl (6.9%)	55	PUMA/PUMA EXTRA
Diclofop-methyl (28.4%)	511	ILOXAN

standard set by industry may prescribe substantial penalties in final price received by farmers.

Wild oat control as for many grass weed species in cereals is strongly dependent on herbicide application. In the mid 1970s, the development of products in the aryloxyphenoxypropionates (‘fops’) and cyclohexanediones (‘dims’) chemical families made possible the selective control of a broad spectrum of annual and perennial grasses in a range of crops (Cobb and Kirkwood, 2000). These herbicides inhibit the activity of acetyl-CoA carboxylase and lipid synthesis (Kudsk and Streibig, 2003). In Argentina, diclofop methyl, fenoxaprop-p-ethyl and clodinafop-propargyl are recommended for wild oat control in wheat, and diclofop methyl and fenoxaprop-p-ethyl can be used in barley. Pinoxaden is a newly registered grass weed herbicide, which belongs to the phenolpyrazolines chemical group and also inhibits the activity of acetyl-CoA carboxylase and lipid synthesis (Zand et al., 2007). It is recommended for wild oat and ryegrass (*Lolium multiflorum*) control in both wheat and barley crops.

All in all, grass weed control represents a significant percentage (15%) of total production costs of wheat and barley for the area under study. This fact highlights the importance of increasing herbicide effectiveness, which includes not only product choice but also the selection of precise dose and timing of application. Control of grass weeds in winter cereal, therefore, demands accurate crop management strategies for improving herbicide performance. The development of these strategies requires improving our understanding of weeds and crops responses to management practices recommended by chemical companies, which usually do not include physiological responses at the crop level (e.g., biomass production, number of kernels m^{-2}). For this purpose, nine experiments were performed across three growing seasons (2006/07, 2007/08 and 2008/09) aimed to study the effect of different herbicides (pinoxaden, fenoxaprop-p-ethyl, diclofop methyl, clodinafop-propargyl, and iodosulfuron plus metsulfuron methyl) recommended for wild oat control in Argentina, on growth and fecundity of wild oat and grain yield of wheat and barley. Treatments included a range of herbicide doses and two weed growth stages at time of application.

2. Materials and methods

2.1. Study site, experimental design and treatments

Three and six field experiments were conducted in barley and wheat crops, respectively. They were carried out in commercial fields in the south of Buenos Aires Province, at Coronel Dorrego (38° 42′ S, 61° 17′ W) and Otamendi (38° S, 57° 33′ W). The experiments were conducted in a randomized complete block design with split-plot arrangement and three replications for each treatment (herbicide × time of application). Application time was the main plot and herbicide treatment the sub-plot. Experimental sub-plots were 3 m × 10 m and in all experiments, a weedy check without herbicide treatment was included. Different herbicide treatments in wheat and barley experiments of 2006/07 crops are shown on Table 1. Treatments in 2007/08 experiments consisted of two pinoxaden doses (25 g a.i. ha^{-1} and 35 g a.i. ha^{-1}) applied at the same weed growth stages as in 2006/07. In 2008/09, pinoxaden doses were increased to 30 g ha^{-1} and 40 g ha^{-1} and another treatment with iodosulfuron plus metsulfuron methyl (3.75 g ha^{-1} + 3 g ha^{-1}) was included.

Wheat and barley were sown between June 20 and July 10 each year in rows 15 cm apart, with seed placement 3 cm below the soil surface in no-till system. The entire experimental area was fertilized at sowing with 70 kg N ha^{-1} and 55 kg P ha^{-1}, broadcast and band-placed, respectively.

Herbicide treatments were applied at 13–15 and 21–23 Zadoks crop growth stages (Zadoks et al., 1974) when wild oat was at 12–13 and 15–22 Zadoks growth stage, respectively. Herbicide application was carried out with a CO_2-pressurized backpack sprayer delivering 130 l ha^{-1} spray solution at 2.8 kg cm^{-2} pressure at 17 °C air temperature.

2.2. Wild oat control

Native wild oat density was 280(±30), 223(±25) and 180 (±20) plants m^{-2}, in 2006, 2007 and 2008, respectively. Visual percentage control based on 0–100 linear scale of wild oat control was estimated twenty-five days after application and at pre-harvest of the crop. In addition, to assess wild oat fecundity and biomass, three quadrats of 0.5 m^2 were delimited within each plot. At pre-harvest, the number of wild oat tillers and wild oat panicles were counted. Individual plants were removed by hand and the number of panicles, spikelets and seeds per spikelet were counted. Total seed production of *A. fatua* (seeds m^{-2}) for each treatment was calculated based on individual fecundity and weed density (1). Individual biomass was determined after drying at 70 °C for 48 h.

$$\text{Wild oat seed production m}^{-2} = \text{Wild oat plants m}^{-2} \times \text{Individual fecundity} \quad (1)$$

The effect of herbicides was calculated as the measured decrease of wild oat density in each herbicide treatment compared with the control treatment (2). The same calculation was applied to calculate efficacy in terms of biomass reduction.

$$\text{Effect of herbicide}(\%) = (1 - \text{wild oat shoot density at herbicide treatment/wild oat shoot density on control plot}) \times 100 \quad (2)$$

2.3. Crop yield composition

At pre-harvest of wheat and barley, spikes were counted in a quadrat of 1 m^2 in each plot. Plants were then removed by hand and grain number by spike was assessed. In addition, thirty percent of the whole spikes per quadrat were sampled, threshed and one thousand grains were weighed after drying for 48 h at 60 °C. Weights were adjusted to 11.5% moisture. From the experimental sub-plots 18 m^{-2} were harvested with an experimental combine to assess grain yield adjusted to 11.5% moisture.

2.4. Statistical analysis

Data for all variables studied were analyzed by ANOVA each year, and when the F Test indicated significant effects, means were compared using LSD Fisher ($P < 0.05$) test. Regression analyses

Table 2
Visual % control of wild oat estimated at 25 days after application of herbicides in barley and wheat in 2006/07.

Barley experiments (%)		Wheat experiments (%)	
Pinoxaden (20 g a.i. ha^{-1})	58 a	Pinoxaden (20 g ha^{-1})	60 a
Diclofop methyl (511 g ha^{-1})	62 ab	Fenoxaprop-p-ethyl (55 g ha^{-1})	82 b
Pinoxaden (30 g ha^{-1})	73 abc	Pinoxaden (30 g ha^{-1})	83 b
Fenoxaprop-p-ethyl (55 g ha^{-1})	77 bcd	Clodinafop-propargyl (36 g ha^{-1})	85 bc
Pinoxaden (40 g ha^{-1})	80 cde	Pinoxaden (40 g ha^{-1})	91 cd
Pinoxaden (50 g ha^{-1})	91 de	Pinoxaden (50 g ha^{-1})	92 d
Pinoxaden (60 g ha^{-1})	94 e	Pinoxaden (60 g ha^{-1})	94 d
SE	5.4	SE	2.0
LSD ($p < 0.05$)	16.6	LSD ($p < 0.05$)	6.2

Means followed by the same letter are not significantly different (LSD $p < 0.05$).

were applied to determine the relationships among the different wheat components and between wild oat biomass and seed m^{-2} and between wild oat biomass and wheat yield.

3. Results

3.1. *Efficacy*

3.1.1. *Visual % control*

Experimental site did not affect results ($P > 0.05$), and experimental design was different each year, consequently, results are presented on the average of each crop growing season. In 2006/07 experiments, in both wheat and barley crops, wild oat control assessed 25 days after the first time of herbicide application was lower with pinoxaden applied at the lowest dose (20 g ha^{-1}) than all other treatments (Table 2). However, in barley experiments there were no differences ($P > 0.05$) among pinoxaden at 20 g ha^{-1}, 30 g ha^{-1} and diclofop methyl treatments. On the other hand, highest efficacy was achieved with pinoxaden at 40 g ha^{-1} or higher doses. At barley maturity, pinoxaden at the lowest dose (20 g ha^{-1}) applied early during the crop cycle and diclofop methyl at both application times gave the least control (Table 3). In wheat crops, there were significant differences ($P < 0.05$) among treatments. Pinoxaden and clodinafop-propargyl applied at the later growth stage provided a similar level of control and the highest efficacy. Fenoxaprop-p-ethyl and pinoxaden at 55 and 50 g ha^{-1}, respectively, provided similar control at both times of application.

For 2007/08 experiments, there were no differences among treatments. Visible control 25 days after the first application averaged over doses of pinoxaden (25 and 35 g a.i. ha^{-1}) was 92% and at crop maturity these figures were at least 96% across treatments. In 2008/09 experiments there was a significant interaction ($P < 0.05$) for herbicide × time of application. With iodosulfuron plus metsulfuron methyl, control decreased significantly when it was applied later during the crop cycle. Pinoxaden used at both doses and times of application achieved similar levels of control (Table 4).

Table 3
Visual % control of wild oat at barley and wheat maturity in 2006/07.

Barley experiment (%)		Wheat experiment (%)	
Diclofop methyl (511 g ha^{-1})[b]	77 a	Pinoxaden (20 g ha^{-1})[a]	94 a
Diclofop methyl (511 g ha^{-1})[a]	82 a	Pinoxaden (30 g ha^{-1})[a]	96 ab
Pinoxaden (20 g ha^{-1})[a]	82 a	Pinoxaden (40 g ha^{-1})[a]	96 bc
Pinoxaden (30 g ha^{-1})[a]	96 b	Clodinafop-propargyl (36 g ha^{-1})[a]	96 bc
Fenoxaprop-p-ethyl (55 g ha^{-1})[a]	97 b	Fenoxaprop-p-ethyl (55 g ha^{-1})[a]	96 bcd
Pinoxaden (40 g ha^{-1})[a]	97 b	Fenoxaprop-p-ethyl (55 g ha^{-1})[a]	96 bcd
Fenoxaprop-p-ethyl (55 g ha^{-1})[b]	97 b	Pinoxaden (60 g ha^{-1})[a]	98 cde
Pinoxaden (50 g ha^{-1})[a]	97 b	Pinoxaden (50 g ha^{-1})[a]	98 cde
Pinoxaden (60 g ha^{-1})[a]	97 b	Pinoxaden (30 g ha^{-1})[b]	98 def
Pinoxaden (20 g ha^{-1})[b]	98 b	Pinoxaden (20 g ha^{-1})[b]	98 def
Pinoxaden (30 g ha^{-1})[b]	99 b	Clodinafop-propargyl (36 g ha^{-1})[b]	99 ef
Pinoxaden (40 g ha^{-1})[b]	99 b	Pinoxaden (40 g ha^{-1})[b]	99 ef
Pinoxaden (50 g ha^{-1})[b]	99 b	Pinoxaden (50 g ha^{-1})[b]	99 ef
Pinoxaden (60 g ha^{-1})[b]	100 b	Pinoxaden (60 g ha^{-1})[b]	100 f
SE	2.5	SE	0.6
LSD ($p < 0.05$)	7.3	LSD ($p < 0.05$)	1.9

Means followed by the same letter are not significantly different (LSD $P < 0.05$).
[a] Application at Zadoks 12–13 wild oat stage.
[b] application at Zadoks 15–22 wild oat stage.

Table 4
Visual % control of wild oat at wheat maturity in 2008/09 following herbicide application at two wild oat growth stages.

	Wild Oat (Z 12–13)	Wild Oat (Z 15–22)
Pinoxaden (30 g ha^{-1})	100 a	92 bc
Pinoxaden (40 g ha^{-1})	100 a	96 ab
Iodosulfuron (3.75 g ha^{-1}) + Metsulfuron methyl (3 g ha^{-1})	90 c	46 d
SE	1.6	
LSD ($p < 0.05$)	5.1	

Means followed by the same letter are not significantly different (LSD $P < 0.05$).

3.1.2. *Wild oat density, biomass and fecundity at crop maturity*

Regarding the number of wild oat plants at crop maturity in 2006/07 experiments, there was a similar trend to the one identified for visible control. In barley crops, diclofop methyl showed lower performance than the other herbicides regardless of the time of application, and the efficacy of pinoxaden at the lowest dose was lower when it was applied early compared to later applications during the crop cycle (Table 5). In wheat crops, herbicide efficacy, on average of all treatments, was higher for the second time of application. There were 13(±3.3) and 4(±2.8) wild oat plants m^{-2}

Table 5
Wild oat density at barley and wheat crop maturity in 2006 and 2007.

Barley experiment (plants m^{-2})		Wheat experiment (plants m^{-2})	
Weedy plot	173	Weedy plot	118
Diclofop methyl (511 g ha^{-1})[b]	49 b	Pinoxaden (20 g ha^{-1})[a]	18 f
Diclofop methyl (511 g ha^{-1})[a]	39 b	Pinoxaden (40 g ha^{-1})[a]	16 ef
Pinoxaden (20 g ha^{-1})[a]	40 b	Pinoxaden (50 g ha^{-1})[a]	14 def
Pinoxaden (30 g ha^{-1})[a]	16 a	Clodinafop propargyl (36 g ha^{-1})[a]	14 def
Fenoxaprop-p-ethyl (55 g ha^{-1})[a]	14 a	Pinoxaden (30 g ha^{-1})[a]	12 bc
Pinoxaden (40 g ha^{-1})[a]	16 a	Fenoxaprop-p-ethyl (55 g ha^{-1})[a]	11 bcdef
Fenoxaprop-p-ethyl (55 g ha^{-1})[b]	8 a	Fenoxaprop-p-ethyl (55 g ha^{-1})[b]	9 abcde
Pinoxaden (50 g ha^{-1})[a]	13 a	Pinoxaden (60 g ha^{-1})[a]	8 abcde
Pinoxaden (60 g ha^{-1})[a]	14 a	Pinoxaden (30 g ha^{-1})[b]	5 abcd
Pinoxaden (20 g ha^{-1})[b]	4 a	Pinoxaden (20 g ha^{-1})[b]	4 abc
Pinoxaden (30 g ha^{-1})[b]	4 a	Clodinafop-propargyl (36 g ha^{-1})[b]	3 ab
Pinoxaden (40 g ha^{-1})[b]	3 a	Pinoxaden (40 g ha^{-1})[b]	2 ab
Pinoxaden (50 g ha^{-1})[b]	6 a	Pinoxaden (50 g ha^{-1})[b]	3 ab
Pinoxaden (60 g ha^{-1})[b]	2 a	Pinoxaden (60 g ha^{-1})[b]	0 a
SE	6.2	SE	2.9
LSD ($p < 0.05$)	18.5	LSD ($p < 0.05$)	8.6

Means followed by the same letter are not significantly different (LSD $P < 0.05$).
[a] Application at Zadoks 12–13 wild oat stage.
[b] Application at Zadoks 15–22 wild oat stage.

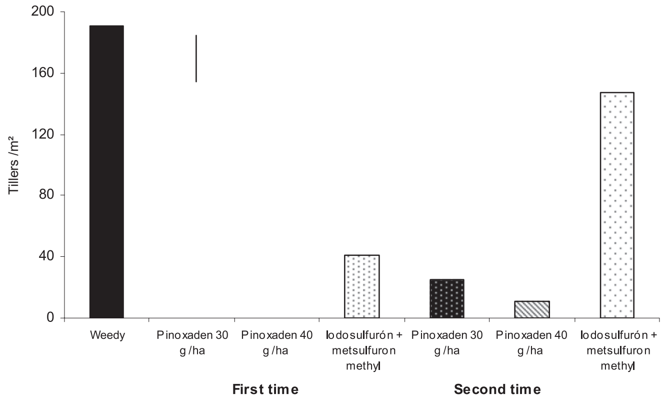

Fig. 1. Wild oat tillers m^{-2} for herbicide treatments in 2008/09 wheat experiments. Bar in the figure represents LSD ($P < 0.05$).

for the first and second time of application, averaged across herbicide treatments, respectively.

In 2007/08 experiments, there was no effect ($P > 0.05$), either in dose or time of application, on wild oat tillering. In weedy plots, 443 (±92) wild oat tillers m^{-2} were counted while on the average of pinoxaden doses and time of application 9(±2.4) wild oat tillers m^{-2} were counted. Regarding biomass, there were 210(±20) g m^{-2} in weedy plots and 1.5 g m^{-2} (±0.3) on the average of herbicides treatments. In 2008/09 experiments there was a significant effect of time of application ($P < 0.05$) for iodosulfuron plus metsulfuron methyl. In this treatment, wild oat density was 10(±1.5) plants m^{-2} and higher than 60(±7.2) plants m^{-2} at the first and second time of application, respectively. Similar differences were registered in terms of wild oat tillers and biomass (Figs. 1 and 2).

Wild oat fecundity was highly correlated with plant biomass (Fig. 3, $r^2 = 0.86$). On average, about 40 seeds were produced per g of wild oat. Interestingly, there were seven fold more seeds when iodosulfuron plus metsulfuron methyl were applied at Z 15–22 than at Z 12–13 wild oat growth stage.

3.2. Crop yield and components

In barley in 2006/07, mean grain yield was 3780(±412) kg ha^{-1} across herbicide treatments. With diclofop methyl on the average of time of application it was 3250(±386) kg ha^{-1} and was significantly ($P < 0.05$) lower than the yield obtained with the other treatments except for the lowest dose of pinoxaden at the first time of application (3410 ± 362 kg ha^{-1}). On the average of all the treatments, barley yield was 3820(±395) kg ha^{-1} and 3740 (±412) kg ha^{-1} ($P > 0.05$) for the first and second time of application, respectively. On the contrary, in wheat crops, yield was significantly different ($P < 0.05$) for different times of application. Mean yields were 1975(±175) kg ha^{-1} and 1798(±168) kg ha^{-1} for the first and second time of application, respectively, taken across herbicides treatments. In addition, there was a trend ($P < 0.10$) to lower crop yield with pinoxaden at a low dose (20 g ha^{-1}) (data not shown). In 2007/08 there were significant differences between experimental sites in crop yield. Comparing time of herbicide application for pinoxaden at 25 g ha^{-1}, crop yield was greater when it was applied early during the crop cycle. In 2008/09 there was also significant effect of time of application ($P < 0.05$) (Table 6).

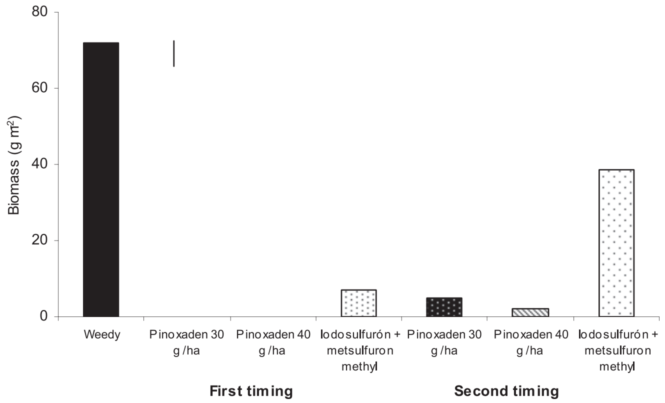

Fig. 2. Wild Oat biomass (g m^{-2}) for herbicide treatments in 2008/09 wheat experiments. Bar in the figure represents LSD ($P < 0.05$).

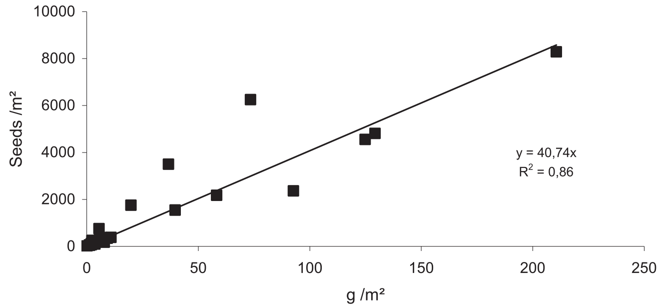

Fig. 3. Wild oat seeds m^{-2} as a function of dry weight m^{-2} averaged across experiments.

As was expected, crop yield was significantly related to grain number both in wheat (Fig. 4) and barley crops ($y = 0.48\,x$; r^2: 0.92) and there was no significant ($P > 0.05$) relationship between yield and grain weight ($r^2 = 0.13$). In barley crops, grain number was significantly related with spikes per square meter ($y = 18.1\,x$) ($r^2 = 0.91$) but in wheat crops grain number was significantly related both with spikes by square meter and also by grain by spike (Fig. 5). In addition, there was a significant inverse relationship between crop yield and wild oat biomass (Fig. 6).

4. Discussion

Time of application is a critical decision when using post-emergence non-residual herbicides (Knezevic et al., 2002). Knowledge of emergence dynamics of weed populations and competition is key to achieving both effective weed control and high crop yields. Although applying herbicides at early compared

Table 6
Wheat yields under different herbicide treatments in 2007/08 and 2008/09 following herbicide application at two wild oat growth stages.

	"Location"			
	Otamendi		Cnel. Dorrego	
2007/08				
"Growth stage"	Z 12–13 (kg ha^{-1})	Z 15–22 (kg ha^{-1})	Z 12–13 (kg ha^{-1})	Z 15–22 (kg ha^{-1})
Pinoxaden (25 g ha^{-1})	6727 a	6073 b	4044 a	3241 b
Pinoxaden (35 g ha^{-1})	6462	6547	4194 a	3404 b
SE	261		285	
LSD ($p < 0.05$)	664		712	
2008/09				
Pinoxaden (30 g ha^{-1})	3758	3341	1638 a	665 b
Pinoxaden (40 g ha^{-1})	4026 a	3412 b	1204	1023
Iodosulfuron (3.75 g ha^{-1}) + Metsulfuron methyl (3 g ha^{-1})	3812 a	2841 b	1345 a	574 b
SE	241		285	
LSD ($p < 0.05$)	632		754	

Means followed by the same letter are not significantly different (LSD $P < 0.05$).

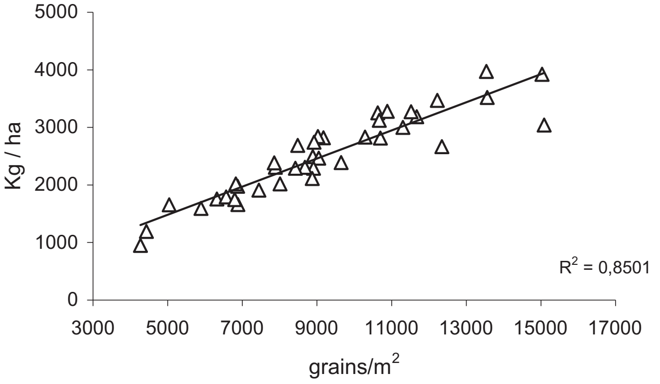

Fig. 4. Wheat grain yield (kg ha^{-1}) as a function of grain m^{-2} for different treatments in all the experiments.

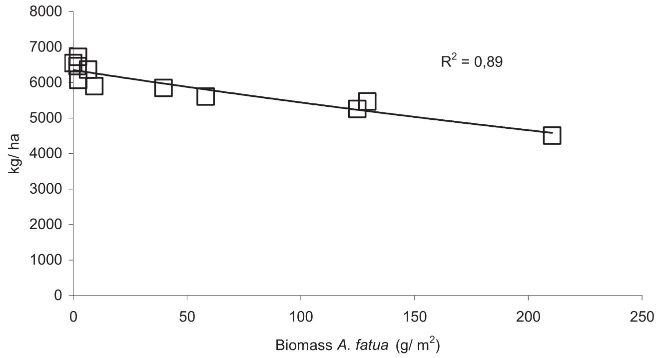

Fig. 6. Wheat grain yield (kg ha^{-1}) related to wild oat biomass (g m^{-2}) in 2007/08 experiments.

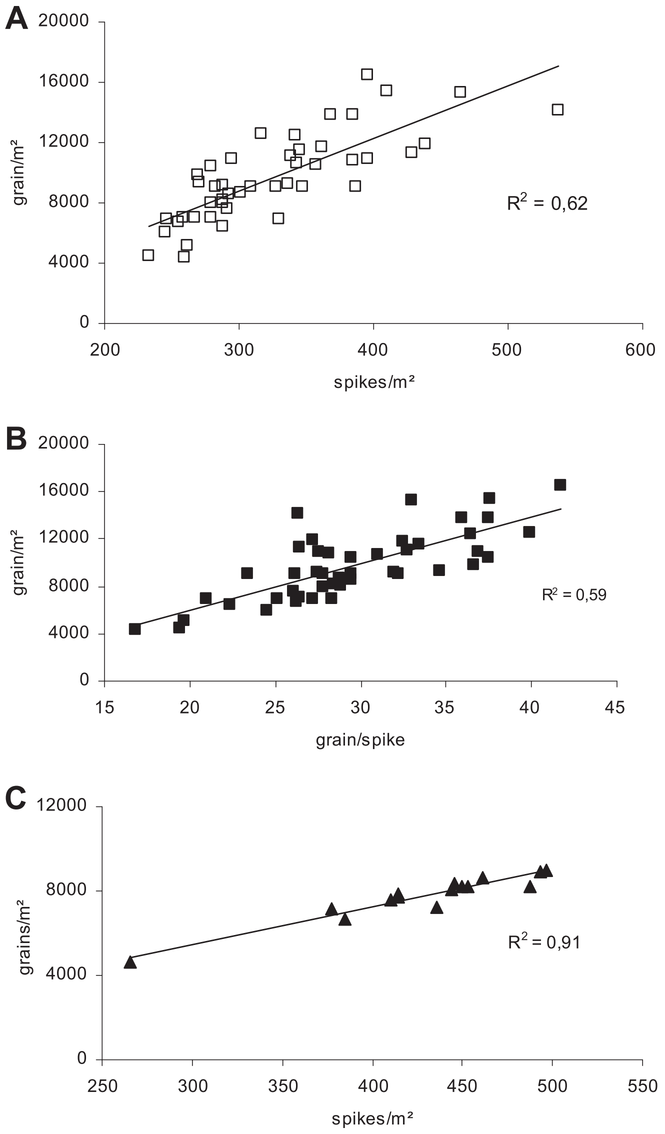

Fig. 5. Wheat grain number m^{-2} as a function of spikes m^{-2} (A); Wheat grain number as a function of grains/spike (B) and Barley grain number as a function of spikes m^{-2} (C).

with later stages of wild oat is imperative for avoiding early weed interference, late weed cohorts could escape herbicide treatment. Consequently, knowledge of optimal combinations of dose and stage of application could improve the effectiveness and net benefit of commonly used graminicides (Holm et al., 2000). In wheat experiments of 2006/07 growing season, there was higher performance when herbicides were applied later during the crop cycle. Herbicides applied early may provide inadequate weed control in areas where environmental conditions favor wild oat germination for an extended period of time. Thus, a second application may be needed to control late-emerging wild oat. Moreover, split application of reduced rates of herbicides for wild oat control provided equal performance that one application at label rates (Lockhart and Howatt, 2004). Consequently, better performance for late application in wheat crops is explained because it controls late emergence cohorts that avoid the early treatment. In this sense, Scursoni et al. (1999) registered almost 20% of wild oat population emerged after diclofop-methyl application in wheat and barley crops. Holm et al. (2000) found that applying clodinafop-propargyl, fenoxaprop-p-ethyl, and tralkoxydim early during the crop cycle resulted in similar to higher levels of wild oat fresh weight compared with delayed applications and there was no effect on crop yield. On the other hand experiments carried out by Spandl et al. (1997) with different graminicides showed that the effect of time of application was less consistent than dose; however, late compared with early application of imazethabenz and fenoxaprop-p-ethyl caused poorer wild oat control, crop yield and economic return. In our experiments there was a significant advantage in terms of wheat yield to herbicide applied early during the crop cycle. This suggests that initial competition is critical in terms of yield reduction in wheat crops. These results are in agreement with other authors (Peters and Wilson, 1983; O'Donovan et al., 1985). In addition, Catullo et al. (1983b) recorded significant wheat yield losses in Argentina when *Polygonum aviculare* L. was controlled after thirty days from crop emergence, at pre-tillering of the crop.

In barley crops, pinoxaden applied at 30 g ha^{-1} and at higher doses and fenoxaprop-p-ethyl showed the best performance regardless of time of application. Differences in competitive ability between crops may explain this result. Fernández and Martínez (1994) showed a difference in competitive ability between barley and wheat crops, registering higher weed biomass at the beginning of tillering in wheat than in barley crops. Scursoni et al. (1999) observed higher wild oat individual fecundity in wheat than in barley crops. However, differences in competitive ability between crops may be strongly influenced by cultivars, seeding rates and date of sowing.

Besides the effect on crop yield, individual escapes are critical in demographic processes as seed dispersion pre-harvest increases the soil seed bank. Therefore, there should be a recommended strategy to anticipate or not to delay crop harvest. Scursoni et al. (1999), comparing wild oat demography in barley and wheat crops, found that 33 and 44% of seeds had been dispersed before crop harvest, respectively. Barley harvest is carried out ten days before wheat harvest so this explains the difference in seed rain between crops.

As was expected, on the average of experiments, crop yield was significantly related to grain number. In addition, spikes per square meter in barley crops were significantly related to grain number, and in wheat crops, both spikes m^{-2} and grains $spikes^{-1}$ were significantly related to grain number. There was no relationship between yield and grain weight either in wheat or in barley crops. Several studies showed that grain number is the dominant component of yield accounting for much of the variation in yield (Aguilar and Fisher, 1975; Slafer and Andrade, 1989). Grain number is determined in the period preceding anthesis (Magrin et al., 1993) making it critical period for grain establishment. In order to get the maximum spike growth rate and, therefore, grain number, wheat and barley crops should be free of weeds during the initial growth stages to reach the maximum radiation interception during the critical period. Moreover, it also is convenient to apply herbicides when weeds are at young growth stages because they are more sensitive to the herbicide application.

It is known that as wild oat density increases, yield losses also increase according to a hyperbolic model (Cousens et al., 1984). From the results obtained in these studies, 100 g of wild oat per square meter caused yield losses of approximately 20%. From experiments carried out by Scursoni et al. (1999), 1 g is an average of wild oat individual biomass found in fields in the cropping area of Argentina.

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