The effect of barley and *Lolium rigidum* plant densities on the biomass and spike density of the weed

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Summary The influence of both barley and *Lolium rigidum* Gaudin densities on the growth and reproduction of *L. rigidum* was examined in four field experiments carried out in Western Australia and the Mediterranean drylands of north-east Spain. *L. rigidum* biomass and spike production increased following a hyperbolic model as weed density increased, reaching a plateau which was dependent on the crop sowing rates. In spite of the varied climatic and agronomic conditions of the trials, a consistent trend was observed in all of them: an increase in crop sowing rates resulted in a lowering of the biomass and spike density of *L. rigidum*. According to the fitted model, reductions of between five and 61% in weed biomass and between 24 and 85% in spike density were expected in the trials at the highest weed densities. These results support the view that high crop densities increase the competitiveness of barley and should be taken into account when considering a *L. rigidum* control strategy in Mediterranean cropping systems.
Keywords Competition, *Lolium rigidum*, barley, crop sowing rate, weed biomass, spike density, Mediterranean region.

INTRODUCTION

Lolium rigidum Gaudin (annual ryegrass) is one of the most widespread weeds in the Mediterranean drylands. Several studies indicate that *L. rigidum* can be extremely competitive in cereal crops due to its biological and ecological characteristics (Recasens *et al*. 1998). Current control measures are based on herbicides, but climatic variability of the Mediterranean regions cause their efficacy to be erratic. Furthermore, the spread of herbicide resistance in *L. rigidum* (Heap and Knight 1982, Bravin *et al*. 2001) is a new threat to the sustainability of the cereal cropping systems in these regions. The adoption of other strategies leading to an increase in the crop's competitive ability and a reduction of *L. rigidum* seed banks are needed. Several field trials were undertaken at different Mediterranean dryland locations in order to evaluate the effect of the crop and weed density on biomass and spike density of *L. rigidum*.

MATERIALS AND METHODS

Site description Trials were conducted in commercial fields at Alguaire (Catalonia, Spain), Arganda (Central Spain) and Wongan Hills (Western Australia) between 1993 and 1996. Soils were loamy at Alguaire and Arganda and sandy loam at Wongan Hills, with pH ranging from 7.5 to 8.5. For more details of the trials, refer to Table 1.

Experimental design Winter barley varieties and sowing rates were selected by site managers according to their local conditions. Barley was sown with a plot seeding machine and *L. rigidum* was hand-broadcast the same day in 1.5 × 8.5 m^2 plots in Spain and 1.5 × 25 m^2 plots in Australia. Weed seeds came from natural populations in Spain and from a commercial supplier in Australia. Actual weed densities were determined at crop maturity. A split-plot with four replicates was used in Spain and a randomised block design with three replicates was used in Australia. Fertiliser was hand-broadcast according to local management. Broad-leaved weeds were controlled at the beginning of the spring and grass weeds were pulled out by hand when present.

Measurements Plot sampling was carried out at crop maturity in two quadrats of 50 × 50 cm^2. Weed and crop plants were removed, counted and stored in separate bags. The dry biomass of weeds was estimated (80°C for 36 h.) as was the number of spikes in ALG94 and WH96.

Statistics Data was fitted to the rectangular hyperbolic equation proposed by Cousens (1985):

$$y= id/(1+id/a)$$

where y is the biomass in g m^{-2} or spikes m^{-2} of *L. rigidum*, d is the weed density in plants m^{-2}, i is the weed biomass or the number of spikes per unit weed density as d approaches zero, and a is the maximum weed biomass or number of spikes at infinite weed density. Fitting was done using SAS (1999). Parallel curve analysis between curves in each experiment was done using the MLP software (1986).

Table 1. Details of the experiments.

Experiment[A]	Season	Cultivar	Rainfall[B] (mm)	Barley sowing rate[C] (kg ha^{-1})	*L. rigidum* density[D] (pl m^{-2})	Sowing date	Harvest date
ALG94	93/94	Dobla	99	L: 75 M: 150 H: 300	0–620 0–622 0–502	12 Nov	27 May
ALG95	94/95	Dobla	87	L: 75 M: 150	0–1011 0–968	3 Nov	30 May
ARG95	94/95	Dobla	175	L: 60 M: 120	0–2485 0–2187	16 Nov	6 June
WH96	96	Yagan	231	L: 25 M: 50 H: 200	0–572 0–396 0–309	16 June	29 Nov

[A] ALG: Alguaire, ARG: Arganda, WH: Wongan Hills.
[B] Rainfall during the growing season.
[C] L,M,H: Low, medium and high sowing rate for the experiment.
[D] Range of densities at crop maturity.

RESULTS AND DISCUSSION

Weed biomass was related to crop and weed density following a hyperbolic relationship as showed in Figure 1. Weed biomass became greater as weed density increased, until it reached a plateau. This plateau, given by parameter *a* of the model (Table 2), varied significantly ($P<0.01$) according to the crop sowing rates in all the experiments except in ARG95. The lowest values of weed biomass were observed at the highest crop sowing rates. The highest reductions due to the crop sowing rate on the maximum weed biomass predicted by the model were achieved in WH96, where *a* declined from 369 to 143 g m^{-2} (61% reduction) and ALG94, where *a* declined from 277 to 142 g m^{-2} (49% reduction). The shapes of the crop sowing rate curves in each experiment, given by the parameter *i* in the model, were not significantly different.

The low weed biomass achieved in ALG94 can be related to the low rainfall recorded at that site (99 mm), where most of the rainfall was recorded early in the season and plants showed strong water stress symptoms by the end of the season. Conversely, the scarce rainfall recorded at ARG95 (87 mm) occurred almost entirely at the end of the growing season, resulting in a late growth of the crop. No significant differences were observed between the two barley sowing curves in ARG95, probably because plant densities were not statistically different in the two treatments (196 pl m^{-2} on average for low density and 262 pl m^{-2} for medium density).

The density of weed spikes followed a similar hyperbolic trend, reaching a plateau that was dependent on the crop sowing rate. According to parameter *a* in the model, maximum spike density declined from 2114 to 1235 m^{-2} (42% reduction) in ALG94, and from 859 to 129 m^{-2} (85% reduction) in WH96 when crop sowing rate was increased. In WH96, the highest crop sowing rate made weed spike density reach the plateau at a very low weed density (129 spikes m^{-2}). No significant differences between the shapes of the crop sowing rate curves in each experiment were observed.

Biomass and density of spikes achieved by the weed varied between sites and years due to the different climatic and agronomical conditions of the experiments. Mediterranean environments have high year-to-year and seasonal variability of rainfall that seriously affects the growth and development of plants. In spite of that, a consistent trend of a lower weed biomass and number of spikes at the higher crop sowing rates was observed. Experiments done by Medd *et al*. (1985) and Lemerle *et al*. (1996) likewise found that increases in the wheat density resulted in significant biomass suppression of the weeds and a lowering of the weed seed production. Furthermore, although *i* parameters of the biomass and spikes models were not significantly different for the crop sowing rates, the lowest weed values were found at the highest crop densities.

These studies support the view that high barley stands, which can be achieved by increasing the crop seeding rate and by having a good emergence of the crop, will minimise windows for the weed to develop and, as a consequence, will increase the competitiveness of the crop against *L. rigidum*. In fact, seeding rates used in Spain (by 200 kg ha^{-1}) are higher than in Australia (by 80 kg ha^{-1}) and this may contribute to maintain crop yield even at moderate weed infestations

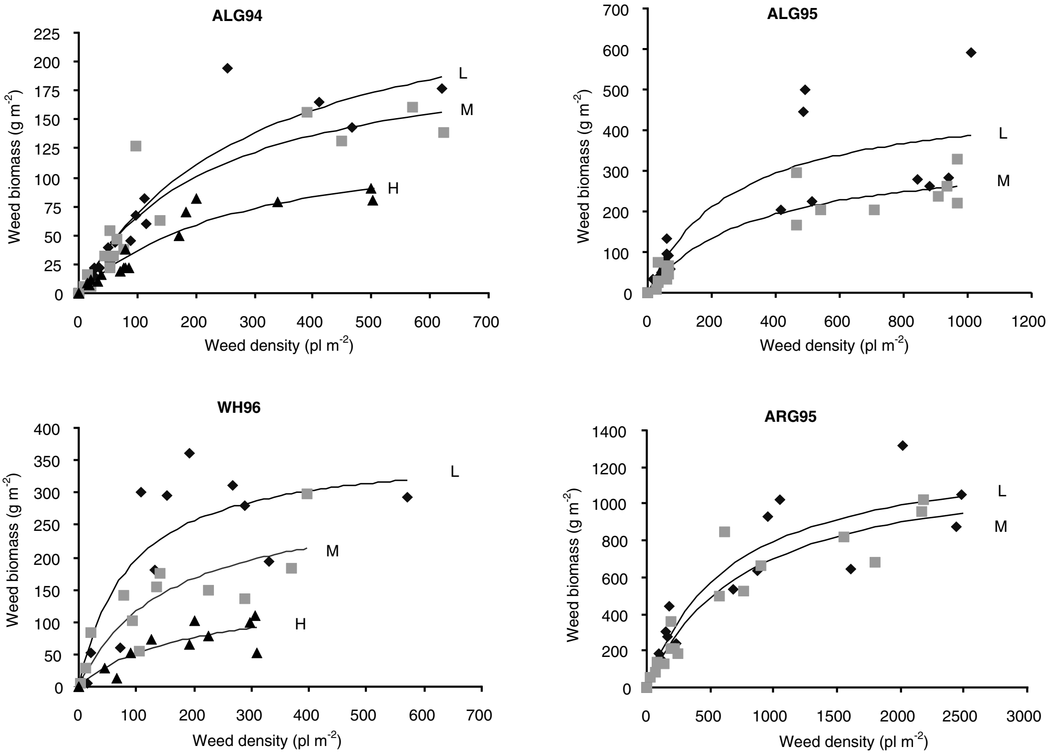

Figure 1. Relationships between the biomass (g m^{-2}) and the density (plants m^{-2}) of *L. rigidum* at the different barley densities.
ALG: Alguaire, ARG: Arganda, WH: Wongan Hills.
L, M and H: L,M,H: Low, medium and high sowing rate for the experiment.

Table 2. Parameter estimates of the hyperbolic model $y= id/(1+id/a)$ for (a) *L. rigidum* biomass (g m^{-2}) and (b) *L. rigidum* spikes m^{-2}. Standard errors of estimates in brackets. ALG: Alguaire, ARG: Arganda, WH: Wongan Hills. L, M and H: see Table 1. Loss: reduction of the maximum weed biomass and spike density (given by the *a* parameter) for the barley sowing rates in relation to the lowest rate (L).

	a				b			
Trial	*i*	*a*	Adj. R^2	Loss	*i*	*a*	Adj. R^2	Loss
ALG94L	0.92 (0.14)	277 (42)	0.92	–	5.55 (0.39)	2114 (161)	0.98	–
M	0.96 (0.19)	211 (29)	0.89	24%	6.01 (0.46)	1618 (.95)	0.98	24%
H	0.50 (0.07)	142 (21)	0.93	49%	4.28 (0.62)	1235 (183)	0.93	42%
ALG95L	1.85 (0.85)	489 (107)	0.76	–				
M	1.10 (0.31)	346 (48)	0.92	29%				
ARG95L	2.04 (0.48)	1317 (173)	0.88	–				
M	1.61 (0.29)	1248 (151)	0.92	5%				
WH96L	4.22 (2.22)	369 (85)	0.72	–	3.20 (0.89)	859 (222)	0.87	–
M	1.91 (0.83)	298 (93)	0.68	19%	2.70 (0.48)	539 (83)	0.93	37%
H	0.82 (0.37)	143 (52)	0.78	61%	4.09 (2.43)	129 (18)	0.82	85%

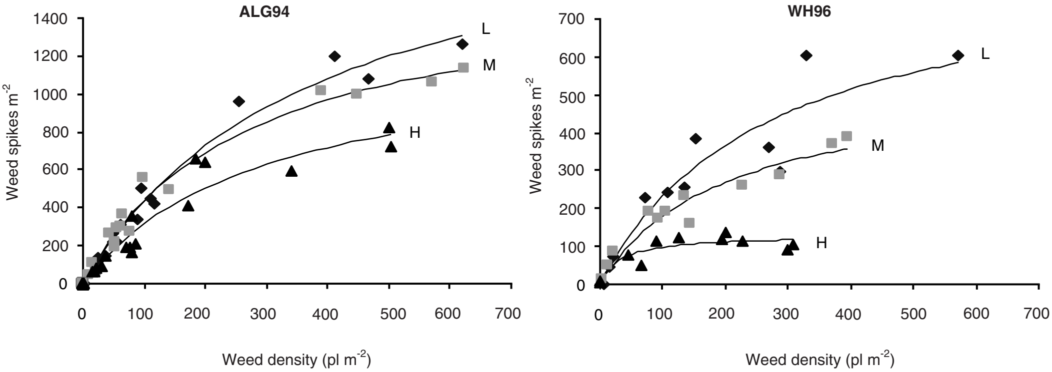

Figure 2. Relationships between the number of spikes m^{-2}) and the density (plants m^{-2}) of *L. rigidum* at the different barley densities.
ALG: Alguaire, ARG: Arganda, WH: Wongan Hills.
L, M and H: L,M,H: Low, medium and high sowing rate for the experiment.

without spraying (these are personal observations). The crop seeding rate should be considered in the development of integrated weed management programs against *L. rigidum* in cereals. It is anticipated that holistic weed management systems that integrate crop density with other control strategies would have a reduced dependence on selective herbicides, which are being rendered useless by the widespread development of resistance in *L. rigidum*.

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