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Research article

Weed control strategies for grain legumes

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Abstract – There has been increasing interest in sustainable weed management in low-input farming systems. In an integrated approach, the development of cropping systems such as appropriate spatial arrangement and efficient tillage will help crops themselves to compete with weeds. With this aim, we investigated the strategic use of plant lodging combined with mechanical weed treatment to improve crop competitiveness and reduce the use of herbicides. We studied weed infestation and grain yield of three grain legumes, field bean, chickpea and field pea, grown according to different plant lodgings (narrow, wide and twin rows) and weed suppression methods: untreated, chemical and mechanical control. In the two years of the trial, two different weed infestation levels were observed due to different meteorological conditions. Our results show that the different crops showed different competitive behaviours, especially in weedy conditions. Indeed, in the bean plots, weed infestation was decreased from 70% in wide rows to 30% in narrow rows. Mechanical treatment produced weed levels similar to those in narrow rows (27%). Mechanical treatment gave grain yields of 2.3 t ha^{-1}, that are comparable with chemically treated plots (2.7 t ha^{-1}). For chickpea, mechanical treatment combined with wide rows proved effective in fighting weeds at a similar level to chemical treatment. Moreover, the yield using mechanical treatment, of 1.6 t ha^{-1}, was only slightly lower than the yield using chemical treatment (2.3 t ha^{-1}). For field peas, mechanical and cropping weed control can limit herbicides, but they are unable to control weed infestation on their own.

***Vicia faba* L. / *Cicer arietinum* L. / *Pisum sativum* L. / weed control / plant lodging / integrated weed management**

1. INTRODUCTION

The increasing interest in low-input farming systems has renewed attention toward alternative methods of weed management, such as the development of innovative mechanical solutions and improved agronomic practices. With this in mind, emphasis should be placed on developing non-chemical methods to increase the competitive ability of grain legume crops. While mechanical weed control is based on the development of new tools for physical and thermal control, innovative agronomic management is mainly addressed to the development of cropping systems in which crops themselves are able to compete against weeds. Nevertheless, physical and agronomic weed control are usually less effective compared with chemical control, but from an integrated point of view the application of several management practices may represent a practicable way to reduce herbicides rates (Johnson and Hoverstad, 2002; Anderson, 2007). In order to control weeds, cultural strategies can largely be put into practice by choosing competitive species and manipulating plant density and plant spacing. Combination of weeding methods has been widely studied in cereal crops (Johnson et al., 1998; Weiner et al., 2001; Lemerle et al., 2001). On grain legumes, studies have mostly focused on plant density as an important factor affecting weed competition, and consequently grain yield (Lawson and Topham, 1985; McEwen et al., 1988; Townley-Smith and Wright, 1994; Lemerle et al., 1995), while less information is available on plant lodging.

Spatial arrangement in grain legumes may reduce weed emergence and increase crop competitive ability; indeed, narrow rows generally increase plant height, which is positively correlated with a powerful weed suppression capability (Mohler, 1996). These effects cannot be generalised, since they are dependent upon crop species and location. Plant competition in grain legumes suggests that the ability of crops to suppress weeds at high crop density is often inversely correlated with grain productivity (Benvenuti and Macchia, 2000), because of intra-crop competition. Moreover, current mechanical weed management does not generally control weeds efficiently in the narrow inter-row area, because of technical constraints. The effectiveness of mechanical weed control in field

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bean varied over years and tillage methods, because it is influenced by soil moisture conditions; the advantages of no-tillage for the yield were clear in drought years and when a chemical control was adopted (Giambalvo et al., 1999). However, serious concerns arise over the effectiveness on a wide range of weeds and on crop tolerance of many chemical active compounds. A moderate crop injury, in fact, in faba bean seedling, occurring to a greater extent in pea, chickpea and lentil, was observed when pre-emergence treatment with imazethapyr or pendimentalin was applied (Wall, 1996; Abbate et al., 2001; Avola et al., 2004). Manipulation of the crop-weed relationship to favour the crop at the expense of the weeds is the basis of integrated weed management (Walker and Buchanan, 1982). It is addressed to reduce the need for herbicides through both mechanical and cultural weed control methods (Regehr, 1993).

Several studies have investigated in grain legumes the effect of row spacing (Whish et al., 2002; Laureti et al., 1995), and chemical and mechanical control (Mohamed et al., 1997; Amador-Ramirez et al., 2001; Giambalvo et al., 1999; Hanson and Thill, 2001) on weed suppression. Other research was addressed to integrated weed control (Solh and Pala, 1990; Gunsolus, 1990; Kluchinski and Singer, 2005). This last topic, however, is generally presented with few references to its impact on crop competitiveness and weed management practices in a Mediterranean environment. On this basis, an investigation was focused on the strategic use of plant lodging and its combination with mechanical weed control to improve crop competitiveness and thus limit the herbicide use. In a two-year field experiment, we explored weed infestation and grain yield in three grain legumes (field bean, chickpea and field pea) grown under different spatial plant arrangements (narrow, wide and twin rows) and weed suppression methods (no control, and chemical and mechanical control).

2. MATERIALS AND METHODS

Field experiments were carried out in rainfed conditions during the 2000 and 2001 growing seasons in a hilly inner environment of Sicily (Italy 450 m a.s.l., lat. 37°27' N and long. 14°14' E) on a light clay soil, well-endowed in potassium and rather poor in nitrogen and phosphorous, with grain as the previous crop.

2.1. Treatments

The following factors were studied: (i) weed control techniques: (chemical – CC, mechanical – MC and untreated – UC), (ii) plant lodging (narrow – NR, wide – WR and twin rows – TR) on three grain legume species: field bean (*Vicia faba* L. var *minor*, cv Sikelia), chickpea (*Cicer arietinum* L. cv Sultano) and field pea (*Pisum sativum* L. cv Corallo).

Chemical control was performed with a pre-emergence treatment of a mixture of imazethapyr and pendimentalin (15/1 v:v), and sprayed with a backpack sprayer at the dose of 2 litres a.i./400 litres ha^{-1} of water. Mechanical control was performed by one pass in each direction of a cultivator (80 cm apart within rows) at the 5th leaf appearance.

For field bean and chickpea, three plant lodgings were adopted: NR (inter-row distance of 0.36 cm), WR (1.0 m) and TR (0.18 centred at 0.90 cm). In field pea, two plant lodgings were adopted: NR (0.18 cm) and TR (0.18 cm centred at 0.90 cm). In field pea, WR was not performed, because it is not usually adopted in management techniques of this species, due to its decumbent growth habit. Weed mechanical control was not adopted in NR, because it was not compatible with this inter-row distance.

A split-plot design with three replications was used, with weed control treatment as the main factor and plant lodging as the sub-factor; the experimental design was unbalanced due to the limitation imposed by management techniques. The elementary plot has variable area in relation to plant lodging: 18 m^2 (3.6×5 m) in NR, 20 m^2 (4×5 m) in WR and 21.6 m^2 (4.3×5 m) in TR. In all treatments, a density of 40 plants per m^{-2} in field bean, 50 plant per m^{-2} in chickpea and 70 plants per m^{-2} in pea was maintained by modifying the intra-row plant distance.

Seeds were planted on December 18 of 2000, and on December 13 of 2001. Each year 100 kg ha^{-1} P_2O_5 was applied.

2.2. Data collected

Crop and weed biomass were collected and counted during pod set in a quadrate area (2×2 m). The weed infestation in percentage was estimated as the ratio between weed biomass and total biomass (crop plus weed biomass); the most abundant weed species were also identified.

In order to assess crop injury, at the seedling stage, the number of seedlings emerged was counted. At flowering, the number of plants per area unit was counted. At full ripening plant height, first pod insertion height, pod number, seed number per pod, 1000-seed weight and yield were determined on a number of rows included between 2 and 5, in relation to row distance, by sampling 4 m^2 for each elementary plot. In both years, the harvest was carried out by hand during June in field bean and field pea and in early July in chickpea.

2.3. Data analysis

Data of each species were analysed by means of a combined ANOVA for split plots across years (Steel and Torrie, 1980). Since the interactions 'year × weed control techniques' and 'year × plant lodging', were significant due to the different meteorological course of the two years, ANOVA was therefore performed separately for each year. In agreement with the experimental design, and in order to compare all the treatments tested, the following combinations were arranged (Fig. 1):

"3 weed control techniques × 2 plant lodging (WR and TR)" – $Anova_1$ – and "2 weed control techniques (UC and CC) × 3 plant lodging" – $Anova_2$ – for faba bean and chickpea;

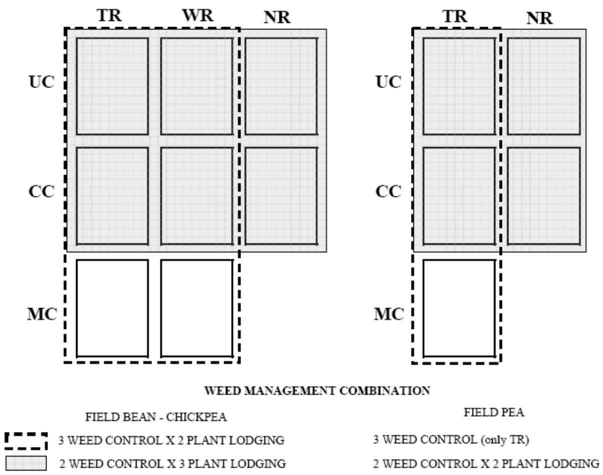

Figure 1. Schematic representation of the experimental arrangement. Each species was assigned to a whole plot; each plot was subdivided into subplots, which included weed control techniques as main factor (CC = chemical control, MC = mechanical control and UC = untreated) and plant lodging (NR = narrow rows, WR = wide rows and TR = twin rows) as sub-factor. The ANOVA was performed on the following factors: "3 weed control techniques × 2 plant lodging (WR and TR)" (dotted line – $ANOVA_1$) and "2 weed control techniques (UC and CC) × 3 plant lodging" (solid line – $ANOVA_2$) for field bean and chickpea. "3 weed control techniques (only in TR)" (dotted line – $ANOVA_1$) and "2 weed control techniques (UC and CC) × 2 plant lodging (NR and TR)" (solid line – $ANOVA_2$) for field pea.

"3 weed control techniques (only in TR)" – Anova $_1$ – and "2 weed control techniques (UC and CC) × 2 plant lodging (NR and TR)" – Anova $_2$ – for field pea.

Weed infestation percentages were analysed after arcsine transformation; in the tables and figures non-transformed data are reported.

When ANOVA results were statistically significant ($P \leqslant 0.05$), the Student-Newman-Keuls range test was performed to allow adequate multiple comparisons among groups. The analysis was carried out using SigmaStat 3.1 software (Systat Inc.). When the interaction was not significant, the main effects (from $Anova_1$ for weed control techniques and from $Anova_2$ for plant lodging) are reported.

3. RESULTS AND DISCUSSION

3.1. Climatic data and growing conditions

Compared with the ten-year meteorological data, the December-June period 1999/00 was unusually rainy with an abundant (612 mm) and well-distributed rainfall (50% in winter and 50% in spring). The following year (2000/01) can be described as representative of the Mediterranean climate with scarce rainfall (415 mm) heavily concentrated in the winter season (70%). In both years, the thermal course was mild with minimum values always above 0 °C and maximum never over 30 °C.

3.2. Field bean

In the first year, the Anova results showed a significant effect of the studied treatments, while no effect emerged from interactions. Weed infestation never exceeded 13%; chemical and mechanical controls determined an almost complete weed suppression (1.6% on average); otherwise, the sowing pattern did not show any effect on weed biomass (Fig. 2). Weed composition showed a clear prevalence of grasses (*Avena* spp.) with values over 90%, followed by *Papaver rhoeas* in the untreated plots (Tab. I). In mechanical control plots, the weed community was composed of *Avena* spp. and *Gladiolus segetum* in the same amount. Crop height and first pod insertion did not vary in relation to either weed control technique or the different plant arrangements (Tab. II). Narrow rows showed the best productive performances compared with the other sowing pattern. The number of pods per plant showed a progressive increase with the decreasing of the intra-row plant distance (from wide to narrow rows). These increases were balanced by the parallel reduction of 1000 seed weight (from 735 g of wide rows to 674 g of narrow rows).

In the second year, a significant interaction was observed for the weed infestation (Fig. 3). Plant lodging did not influence the weed suppression effect of mechanical control (weed incidence 27%); narrow rows and twin rows enhanced the effect of chemical control, reducing weed incidence from 32% (wide rows) to 16% on average; narrow rows reduced the infestation to 33% when the weed control was entrusted exclusively to plant lodging. The weed community was dominated by grasses (*Avena* and *Phalaris* spp.) with values over 90% in untreated and chemical control plots, without any difference in relation to plant arrangements (Tab. III). Minor incidences were represented by *Papaver* e *Brassica* spp., whose percentage reached around 26% each, in mechanical control plus twin rows. Mechanical control reduced grass infestation to less than 50% in twin rows compared with wide rows. Both mechanical and chemical weed controls increased plant height by 16% in comparison with untreated plots (Tab. II); mechanical control enhanced the first pod insertion height by 10 cm compared with untreated plots. Wide rows determined an increase in plant height and first pod insertion height, compared with the other arrangements. Differently from the first year, grain yield was significantly influenced by weed control techniques and not by plant lodging. This different behaviour may be ascribed to the different meteorological course, weedy infestation and consequently different competitiveness conditions for water. In fact, with the favourable rain distribution of the first year, narrow rows positively affected yield. Both mechanical and chemical controls increased the grain yield by 47%, on average, compared with untreated plots, mainly due to a greater seed weight (580 g, on average). This behaviour was different from that observed in the first year, where both the number of pods per plant and seed weight were the main yield components. Water stress conditions, in fact, determined firstly a depressive effect on pod number per plant.

In field bean, the results indicate that chemical control can be avoided by adopting a mechanical control, where a slight yield penalty occurs only in weedy conditions. In such

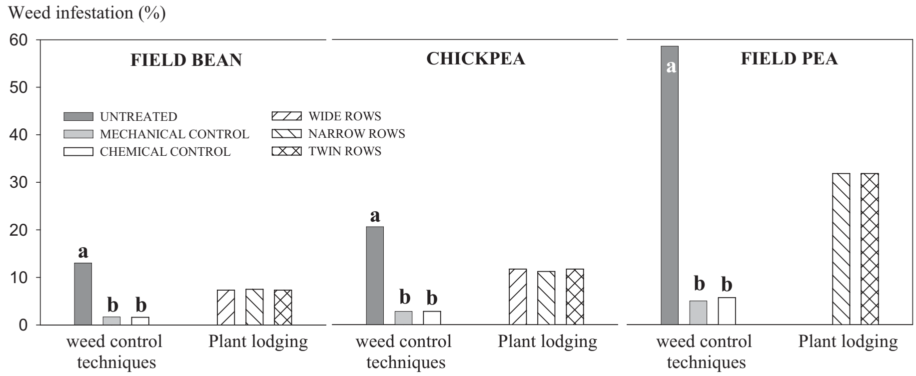

Figure 2. Weed infestation in 1999–2000. For each treatment, values followed by different letters are significantly different ($P < 0.05$) based on an ANOVA SNK test.

Table I. Weed composition (%) in 1999–2000.

	UNTREATED				CHEMICAL				MECHANICAL			
	Av	An	Pa	Gl	Av	An	Pa	Gl	Av	An	Pa	Gl
Field bean	92	–	8	–	–	–	–	–	50	–	–	50
Chickpea	72	20	8	–	–	–	–	–	100	–	–	–
Field pea	89	2	9	–	–	–	–	–	88	–	12	–

Av: *Avena* spp.; An: *Anethum graveolens* L.; Pa: *Papaver rhoeas* L.; Br: *Brassica* spp.; Gl: *Gladiolus segetum* Ker-Gawl.

a situation, the sowing pattern influenced the weed incidence: 'narrow rows' or 'twin rows' were able to increase crop competitiveness ability and enhance the weed suppression effect of chemical control. Moreover, narrow rows improved yield components in both low-weed and weedy conditions, and crop yield in low-weed conditions, as observed by Bonari and Macchia (1975) in field bean, and Felton (1976) and Silim et al. (1990) in other grain legumes.

3.3. Chickpea

In the first year, the Anova results showed no interaction among the studied treatments. Weed infestation did not exceed 21% in the untreated plots (Fig. 2). Chemical and mechanical controls were able to reduce weeds to about 3% of total biomass, without differences between these treatments. Plant lodging did not affect weed infestation. The weed community was composed of 72 and 100% grasses (*Avena* spp.) in untreated and controlled plots, respectively (Tab. I). Other species, in lower amounts, were *Anethum* spp. and *Papaver rhoeas,* in untreated plots. Plant height and first pod insertion were not affected by the studied factors (Tab. IV). Chemical control determined a significant depressive effect on grain yield (25% less than mechanical and untreated plots), mainly influenced by the lower number of germinated seeds that determined a plant density lower than the planned one (40.5 versus 50.5 p m^{-2} of the other treatments).

In the second year, a significant interaction was recorded on weed incidence. In the absence of control, none of the three sowing patterns was able to reduce the weed infestation ratio (44% on average) (Fig. 3). A satisfying weed control

Table II. Plant and first pod insertion height, yield and its components of field bean.

Treatments	Plant m^{-2} n	Plant height cm	1st pod insertion cm	Yield T ha^{-1}	Pod $plant^{-1}$ n	1000 seed weight g
			1999–2000			
Weed control techniques						
Untreated	43.5	71.9	23.5	3.5	4.4	683
Chemical	42.5	66.6	20.0	3.9	4.4	723
Mechanical	43.5	75.8	23.3	3.8	4.4	693
Plant lodging						
Wide rows	44.8	67.3	22.1	3.6b	3.8c	735a
Narrow rows	40.5	71.4	18.4	4.3a	6.1a	674c
Twin rows	41.2	71.2	21.5	3.8b	5.0b	701b
			2000–2001			
Weed control techniques						
Untreated	47.3	32.2b	76.5b	1.7b	2.6	495b
Chemical	48.3	35.3ab	88.3a	2.7a	3.0	572a
Mechanical	45.7	42.8a	89.2a	2.3a	3.0	587a
Plant lodging						
Wide rows	51.5	37.0a	86.2a	2.2	2.6b	533
Narrow rows	44.5	33.0b	83.7b	2.1	3.4a	522
Twin rows	46.0	30.5b	78.7b	2.1	2.9b	534

The main effects (from $ANOVA_1$ for weed control techniques and from $ANOVA_2$ for plant lodging) are reported. For each treatment, values in the same column followed by different letters are significantly different ($P < 0.05$) based on an ANOVA SNK test.

was obtained when wide rows were combined with mechanical and twin rows with chemical control; in the first case, weed infestation was reduced from 25% (twin rows) to 14% (wide rows), and in the second case from 33% (wide rows) to 16% (twin rows). However, the best weed control was observed in chemical control plus narrow rows (4%). Similar to field bean, weed infestation was mainly composed of grasses (*Phalaris* spp. and *Avena* spp.) with values higher than 90% in untreated and chemical control, while mechanical treatment was able to reduce weed presence to 57 and 77% in wide and twin rows, respectively (Tab. III). *Papaver* and *Brassica* spp. were also detected. Plant height was positively influenced by chemical compared with the other treatments (+9 cm) and first pod insertion varied in relation to weed control modalities and

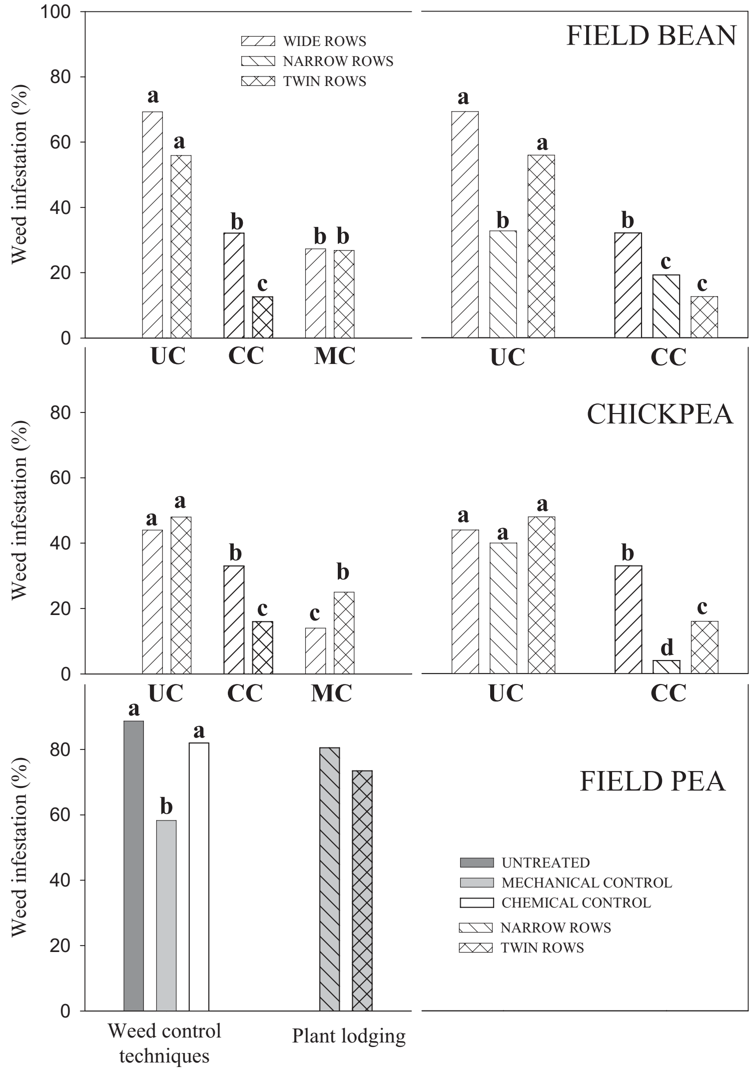

Figure 3. Weed infestation in 2000–2001. UC = untreated control, CC = chemical control and MC = mechanical control For each treatment, values followed by different letters are significantly different ($P < 0.05$) based on an ANOVA SNK test.

Table III. Weed composition (%) in 2000–2001.

		UNTREATED				CHEMICAL				MECHANICAL			
		Av	Ph	Pa	Br	Av	Ph	Pa	Br	Av	Ph	Pa	Br
Field bean	WR	–	100	–	–	–	95	5	–	–	88	12	–
	NR	–	90	10	–	–	100	–	–	–	–	–	–
	TR	–	95	5	–	–	100	–	–	–	47	25	28
Chickpea	WR	–	90	3	7	–	98	–	2	27	29	43	–
	NR	–	97	–	3	–	100	–	–	–	–	–	–
	TR	–	96	–	4	–	91	–	9	33	44	7	16
Field pea	NR	–	100	–	–	–	100	–	–	–	–	–	–
	TR	–	94	–	6	–	100	–	–	–	72	24	4

Av: *Avena* spp; Ph*: Phalaris* spp; Pa: *Papaver rhoeas*; Br: *Brassica* spp.
NR = narrow rows. WR = wide rows and TR = twin rows.

sowing patterns (Tab. IV). Grain yield was notably affected by weed control modalities. Both chemical and mechanical controls determined a yield increment of 77% when compared with untreated plots (0.93 t ha^{-1}), due to a general increase in all the yield components.

Chickpea generally develops slowly and has an open and short canopy architecture that reduces its competitive ability against weeds (Knights, 1991). However, under low weed pressure, as occurred in our experiment, the plasticity of chickpea allowed a better growth, and consequently an early canopy closure of the inter-row space, decreasing weed infestation even when no control was adopted, contrasting with Whish et al. (2002). In weedy conditions, chickpea was not able to compete with weeds and only weed control enabled an acceptable yield. The mechanical control in wide rows proved the best tool in contrasting weeds because it showed similar efficacy, but without the depressive effect on yield of the chemical control. Plant lodging alone did not show any effect on yield, in agreement with the observation of Whish et al. (2002) on chickpea, but in contrast with Felton (1976), Silim et al. (1990)

Table IV. Plant and first pod insertion height, yield and its components of chickpea.

Treatments	Plant m^{-2} n	Plant height cm	1st pod insertion cm	Yield T ha^{-1}	Pod $plant^{-1}$ n	1000 seed weight g
			1999–2000			
Weed control techniques						
Untreated	49.3a	74.6	49.0	2.5a	19.0	288
Chemical	40.1b	76.1	50.3	2.0b	18.7	295
Mechanical	50.5a	76.4	51.3	2.8a	19.2	293
Plant lodging						
Wide rows	48.6	74.8	49.7	2.3	19.9	288
Narrow rows	45.7	72.1	46.6	2.2	21.7	281
Twin rows	48.8	75.9	49.7	2.2	18.8	295
			2000–2001			
Weed control techniques						
Untreated	58.0	77.5b	62.3b	0.9b	6.8b	257b
Chemical	61.5	86.0a	68.3a	1.7a	12.9a	292a
Mechanical	60.5	77.0b	61.8b	1.6a	9.9b	271ab
Plant lodging						
Wide rows	63.2	–	68.3a	1.4	9.5	269
Narrow rows	62.5	–	62.5b	1.4	9.8	288
Twin rows	58.1	–	62.3b	1.2	10.1	272

The main effects (from $ANOVA_1$ for weed control techniques and from $ANOVA_2$ for plant lodging) are reported. For each treatment, values in the same column followed by different letters are significantly different ($P < 0.05$) based on an ANOVA SNK test.

and Malik et al. (1993) in other grain legumes. In these researches, narrow row spacing was able to improve crop yield in both weed-free and weedy situations.

3.4. Field pea

In the first year, the weed infestation rate reached 58.6%, exceeding the values recorded in the other species (Fig. 1). Similar to the other studied grain legumes, infestation was reduced by about 91% by direct weed management methods, while weed infestation was not influenced by the studied sowing patterns.

Weed composition included mostly *Avena* spp., in all the plots; in untreated plots, *Papaver rhoeas* and *Anethum* spp. were also present, but in low percentages (Tab. I). The studied treatments did not affect plant height or first pod insertion (Tab. V). Chemical control reduced plant density by 15%, seed weight by 13% and grain yield by 12%. Among the studied sowing patterns, narrow rows increased the number of crop plants, the seed weight and the grain yield of field pea, in comparison with twin rows.

In the second year, weed infestation reached 85% on average for mechanical and untreated plots, and chemical control was able to significantly suppress weeds by up to 58% (Fig. 3). None of the sowing patterns influenced weed development. The weed community was almost exclusively composed of *Phalaris* spp. and, to a lesser extent, of *Papaver* (prevalently in mechanical plus twin rows) and *Brassica* spp. (Tab. III). The high competition rate exerted by weeds negatively influenced

Table V. Plant and first pod insertion height, yield and its components of field pea.

Treatments	Plant m^{-2} n	Plant height cm	1st pod insertion cm	Yield T ha^{-1}	Pod $plant^{-1}$ n	1000 seed weight g
			1999–2000			
Weed control techniques						
Untreated	85.3a	61.2	35.9	2.8a	4.9	137a
Chemical	71.3b	62.9	43.0	2.5b	4.5	121b
Mechanical	82.4a	57.5	36.5	2.9a	5.2	140a
Plant lodging						
Narrow rows	82.0a	59.8	34.9	3.7a	5.9	150a
Twin rows	68.0b	62.1	39.4	2.7b	4.7	130b
			2000–2001			
Weed control techniques						
Untreated	73.9	48.0b	40.3ab	0.4b	6.5b	117b
Chemical	75.1	62.0a	32.7b	1.2a	12.9a	134a
Mechanical	75.2	64.0a	50.3a	0.6b	8.2b	121b
Plant lodging						
Narrow rows	70.0	54.0	38.5	0.8	8.5	122
Twin rows	74.5	55.0	36.5	0.8	9.7	125

The main effects (from $ANOVA_1$ for weed control techniques and from $ANOVA_2$ for plant lodging) are reported. For each treatment, values in the same column followed by different letters are significantly different ($P < 0.05$) based on an ANOVA SNK test.

productivity, which was very low. Where the weed pressure was lower, yield and its components showed a marked increment (Tab. V).

Field pea showed lower competitiveness against weeds compared with the other crops, as ascertained by Lemerle et al. (1995) and Lutman et al. (1994). This is partly due to the characteristics of this species and partly to its management techniques (McDonald, 2003). Certainly, chemical control emerged as the most efficacious method in tackling weeds in this crop, though in low weed infestation mechanical control is applicable as well. As observed in chickpea, no measurable advantage was ascertainable in relation to plant lodging.

In the two-year study period, in which different weed infestation conditions were encountered, some interesting considerations on weed-crop interaction in both low-weed and weedy conditions can be summarised. Generally, the low weed pressure determined an initial size advantage of the studied crops, impeding a wide weed establishment. In the presence of weeds, a different competition behaviour emerged in relation to the crops. Notable suppression of weeds was observed in field bean and in chickpea; field pea showed a much lower competitive ability.

The different row arrangements considered in this study aimed to test the hypothesis that wider row spacing, compared with the narrow traditional one, might allow easier mechanical control and hence better weed control. The use of wide rows had no negative effect on the competitive ability of the studied crops and so may enable a greater diversity of management practices to be employed, such as in-row cultivation.

The use of mechanical and chemical control affected the floristic composition of weeds: imazethapyr plus pendimethalin was able to control *Anethum* and *Papaver*, but generally failed against *Avena* and *Phalaris*. These last weeds were not controlled in twin rows by mechanical control in chickpea, due to its late in-row canopy closure, while better competition was shown by field bean in the same treatment. Winter cereal crops, in fact, show faster initial growth compared with other crops (Cousens et al., 1991) and become dominant when not controlled. In chickpea and field pea, a lower plant density than the programmed one was recorded due to chemical injury on seedlings. The same results were observed by Avola et al. (2004).

4. CONCLUSION

In field bean, regardless of the weed infestation level, weed control can be executed without chemicals, using mechanical control combined with plant arrangement without significant yield loss; in chickpea, cultural weed control can be applied when low weed densities are present; finally, in field pea, much more so than chickpea, crop control can be useful in limiting herbicides but it is not able to control weed infestation on its own.

The search for complete weed suppression is, as we have seen, improbable, or more likely impossible. Although there is no ideal sowing pattern to tackle weeds, it is possible to hypothesise a synergic integrated weed management in order to minimise weed competition. This combination is not unique, but is strictly linked to species and infestation degree.

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