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Evaluation of mechanical weed control in legume crops

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ABSTRACT

Two three-year field experiments with soya bean (*Glycine max* (L.) Merr.) and faba bean (V*icia faba* L., var. *minor* Beck.) were carried out in central Italy in order to evaluate the effects of different mechanical methods (spring-tine harrowing, hoeing, hoeing-ridging, split-hoeing, finger-weeding) on weed control and crop yield. Split-hoeing + finger-weeding was the best mechanical weed control option, both in soya bean and faba bean, showing an excellent control of both inter- and intra-row weeds with efficacy values ranging from 73% to 97%. Split-hoeing and hoeing gave a good inter-row weed control, showing an effective action against both broad-leaves and grasses also in relatively advanced developmental stages, although they did not effectively control weeds along the row. Harrowing and finger-weeding gave the worst weed control due to low efficacy against grasses and weeds bigger than 12–14 BBCH-scale. Yield crop showed not significant differences among the untreated control and all the other treatments, confirming the high competitive ability of legume crops. All the treatments gave crops yield values around the overall mean of trials with contained inter-annual variation, showing as the mechanical weed control can be a sustainable method to manage weeds in this legume crops without considerable losses in yield. Furthermore, the adoption of legume crops thanks to their good competitive ability against weeds and other important characteristics, offers the potential of enhancing the productivity and sustainability of the cropping system, especially in the organic farming.

1. Introduction

The increasing interest in organic and low-input farming systems has renewed attention toward alternative methods of weed management, such as the development of innovative mechanical solutions (Avola et al., 2008; Pannacci and Tei, 2014; Melander et al., 2015). Organic and low-input farming systems mainly relied for its crop nutrients on legume crops (De Ponti et al., 2012). In general, increasing legume cultivation could bring benefits for the environment and resource use at a range of scales, from the field to the global; their pre-crop effect, nitrogen provision, and potential to improve nutrient conservation and soil structure add to the sustainability of farm productivity while saving resources and reducing emissions (Covarelli et al., 2010; Reckling et al., 2014). Among the grain legume crops, soya bean and faba bean are considered very important, although due to different reasons.

In fact, soybean (*Glycine max* (L.) Merr.) is one of the most important grain legume and oilseed crops in the world, accounting for more than 50% of the global oilseed production (Datta et al., 2017). Faba bean (*Vicia faba* L.) is grown world-wide as a protein source for food and feed, offering ecosystem services such as renewable inputs of nitrogen (N) into crops and soil via biological N_2 fixation, and a diversification of cropping systems (Jensen et al., 2010).

It is well known that prolonged weed interference not only causes heavy crops yield losses, but increases production costs and reduces the quality of produce, thus requiring early-season weed management to achieve economically acceptable yields (Knezevic et al., 2003; Sardana et al., 2017). In particular, the presence of weeds up to beginning of seed stage of soya bean (R5) may cause 8–55% reduction in yield (Van Acker et al., 1993). Weeds are managed in soya bean primarily by herbicides (Niekamp and Johnson, 2001; Datta et al., 2017), although mechanical and cultural weed control methods showed to be effective (Chauhan and Opeña, 2013; Pannacci and Tei, 2014). Faba bean is known to compete weakly against weeds in the early growth phase (Lee and Lopez-Ridaura, 2002); so the pre-emergence herbicides are commonly used in order to control weeds until the crop is big enough to suppress any additional emerging weeds (Köpke and Nemecek, 2010). However, over the last twenty years, environmental and human health impact of herbicides use, increasing of herbicide resistance, the scarce availability of herbicides for minor crops and the increased of organic farming were the main factors that stimulated the interest to develop alternative methods to chemical weed control, such as mechanical weed control (Melander et al., 2005; Pannacci et al., 2017). Soya bean and faba bean are very often inserted in the organic farming systems, now

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even more than in the past, due to their ecosystem services and increased demand for organic grains as food products (Place et al., 2009; Jensen et al., 2010). In this context, organic soybean and faba bean weed management can rely on mechanical weed control, due to large space between the rows. However, although weeds between the rows (inter-row weeds) can normally be controlled by ordinary inter-row cultivation, such as hoeing, weeds that grow within the line of row crop plants (intra-row weeds) have a great impact on yield and constitute a major problem for selective control, especially for organic farmers (Melander et al., 2012; Pannacci and Tei, 2014). For intra-row weed control, most mechanical methods are based on old principles, but new implements and improved versions have emerged lately, such as finger-weeder, torsion-weeder and intelligent weeders (Van der Weide et al., 2008; Rasmussen et al., 2012; Melander et al., 2015; Pannacci et al., 2017). Over the last fifteen years new mechanical weed control methods such as split-hoeing, finger-weeding and harrowing were introduced in order to give farmers more flexibility and options. However, there is a low availability of data on the performance of mechanical weed control methods obtained from field experiments in legume crops. For these reasons, the aim of this study was to evaluate the effects of mechanical methods on weed control, crop selectivity and crop yield in soya bean and faba bean in central Italy. The mechanical treatments involved in this study were chosen with the aim to compare weed control methods traditionally used (i.e. hoeing and hoeing-ridging) with weed control methods relatively new such as split-hoeing, finger-weeding and harrowing. Several initial studies have supported this choice, showing that these mechanical methods may have application in soya bean and faba bean (Gunsolus, 1990; Avola et al., 2008; Pannacci and Tei, 2014).

2. Materials and methods

From 2005 to 2008, two three-year field experiments with faba bean and soyabean were carried out in central Italy (Tiber valley, Perugia, 42°57′ N - 12°22′ E, 165 m a.s.l.) on a clay-loam soil (24.8% sand, 30.4% clay and 0.9% organic matter). The trials were carried out according to good ordinary practices, as concerns soil tillage and seedbed preparation (Bonciarelli and Bonciarelli, 2001). Experimental design was always a randomized block with four replicates and plot size of 24 and 30 m^2 (3 m width) in soya bean and faba bean, respectively. In each crop, different mechanical weed control methods were compared (Table 1) and untreated and manual weeding plots were added as checks.

Harrowing, a full surface mechanical control, was carried out with a 3 m-wide spring-tine harrow (Type SF-30, Faza, Italy, http://www.fazasrl.com/en/project/spring-tine-weeder-hackstriegel/, equipped with 7 mm-diameter flexible tines) at a cultivation depth of 10–20 mm and a driving speed of 7 km h^{-1}. Harrowing was applied only in soya bean and earlier with respect to the other mechanical treatments because its effectiveness is maximum especially against small weeds (Table 1). Hoeing, an inter-row mechanical control, was carried out with a 3 m-wide powered rotary hoe (Model CERES, Badalini, Italy, http://www.badalini.it/home_en.php?azione=scheda_prodotto_en&id=50) at a cultivation depth of 50–60 mm, a driving speed of 4 km h^{-1} and leaving 120-mm untilled strip in the crop rows. Hoeing-ridging was applied only in faba bean and was carried out with the same rotary hoe as mentioned above, but equipped with ridging implements to bury weeds along the row. Split-hoeing was performed with a 1.5 m-wide Asperg Gartnereibedarf split-hoe (Asperg, Germany, for more details see Tei et al., 2002) at a cultivation depth of 30–40 mm, a driving speed of 3 km h^{-1} and leaving a 100-mm untilled strip in the crop rows. Split-hoe is an inter-row mechanical machine for weed control equipped with shanks provided with sweep tools in front and rotors with steel tine in rear moved by hydraulic power. The sweep tools penetrate and lift the earth, the rotors, turning in the direction of travel between the rows, intercept and crumble the soil and separate (split) earth and weeds. The weeds remain on the soil surface and die quickly. Metal crop shields (100 mm wide) protect crops from moving soil.

Finger-weeding, an intra-row mechanical control, was carried out with a 1.5 m-wide Kress finger-weeder (Kress Umweltschonende Landtechnik GmbH, Germany, http://neu.kress-landtechnik.de/wEnglisch/produkte/gemuesebau/hacktechnik/fingerhacke_start.shtml?navid=12) at a cultivation depth of 10–30 mm and a driving speed of 5 km h^{-1}. Kress finger-weeder equipments were mounted on Kress Argus System (http://neu.kress-landtechnik.de/wEnglisch/produkte/gemuesebau/hacktechnik/argus_start.shtml?navid=19) equipped with special-flat share type "Holland" (340 mm wide, http://neu.kress-landtechnik.de/wEnglisch/produkte/gemuesebau/hacktechnik/hackwerkzeug/hackwerkzeuge_start.shtml?navid=31) that works between the rows. Rubber fingers grip from the side around the plant and there they hoe the weeds. In this way, the area which no other mechanical hoe usually reaches will be weeded as well. Special-flat share cuts the weeds between the rows that remain on the soil surface and die.

Preliminary tests were carried out in order to set the implements with the aim to obtain a level of cultivation intensity able to guarantee the highest efficacy against the weeds with the lowest crops damage.

2.1. Soya bean

Soya bean, cv. Nikko (Asgrow®, maturity group 1-), was sown on 04 May 2006, 09 May 2007 and 2008 in 0.5 m-spaced rows to obtain a final density of 30 plants m^{-2}. Soft winter wheat was always the preceding crop. A low-irrigation regime was adopted, with one irrigation in June and two irrigations in July (30 mm each). All mechanical treatments, except harrowing, were performed with the crop at the growth stage of 12–13 BBCH-scale (Meier, 2001), broadleaved weeds at 12–14 BBCH-scale and grasses at the growth stage of 14–15 BBCH-scale. Harrowing was performed earlier than the other treatments with the crop at the growth stage of 11–12 BBCH-scale, broadleaved weeds at 10–12 BBCH-scale and grasses at the growth stage of 13 BBCH-scale.

Soya bean was harvested on 03 October 2006, 21 September 2007 and 30 September 2008.

2.2. Faba bean

Faba bean, cvs. Vesuvio (2005-06 and 2006-07) and Scuro di Torrelama (2007-08) was sown on 09 November 2005, 07 November 2006 and 06 November 2007 in 0.5 m-spaced rows, at a seeding rate of 56 seeds m^{-2}. Oilseed rape, sunflower and soft winter wheat were the preceding crops, respectively. Mechanical treatments were performed with the crop at the growth stage of 150–200 mm height, broadleaved weeds from 12–14 BBCH-scale to 16–18 BBCH-scale and grasses at the growth stage from 13 BBCH-scale to 21–22 BBCH-scale.

Faba bean was harvested on 28 June 2006, 14 June 2007 and 24 June 2008.

Table 1
Treatments in the field experiments with faba bean and soya bean.

Treatments (codes)	Soya bean			Faba bean		
	2006	2007	2008	2005–06	2006–07	2007–08
Untreated control (UC)	X	X	X	X	X	X
Manual weeding (MW)	X	X	X	X	X	X
Harrowing (HA)	X	X	X	–	–	–
Hoeing (HO)	X	X	X	X	X	X
Hoeing-ridging (HOR)	–	–	–	X	X	X
Split-hoeing (SH)	X	X	X	X	X	X
Finger-weeding (FW)	X	X	X	X	X	X
Split-hoeing + finger-weeding (SH + FW)	X	X	X	X	X	X