Innovative crop and weed management strategies in organic spinach: machine performances and cultivation costs

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Abstract

*Weed competition is one of the most serious problems in vegetable crops. Physical and cultural methods represent the only adoptable solutions in organic farming systems. A two-year (2006-08) on-farm research is being carried out to test innovative operative machines for physical weed control on a typical vegetable crop sequence in the Arno Valley (Pisa, Italy). In this work we present the first results, obtained on organic fresh market spinach (*Spinacia oleracea*). The new strategy is compared with the standard crop and weed management system, characterised by the use of biodegradable maize starch mulch, and with a system in which the use of improved physical methods is coupled with the use of a subterranean clover (*Trifolium subterraneum*) living mulch. Performances of the operative machines, labour time requirement and cultivation costs of the three crop and weed management systems are reported. The two innovative strategies showed interesting results, determining effective weed control and a significant reduction of costs for working and hand labour (-70%).*

Introduction

Weed management is one of the most serious problems in organic farming systems (Bàrberi, 2002). Crop development and yield can be significantly affected by weed competition, especially in vegetable crops (Fogelberg, 2007), that are often characterized by slow emergence (e.g. carrot), low competitive ability, and limited capacity to cover the soil (Peruzzi et al., 2004 and 2007).
Standard physical weed control machines (e.g. standard duckfoot share equipped hoe) can not successfully carry out effective intra-row crop weed control unlike herbicides. This implies that a high amount of labour time is required for intra-row hand weeding (Fogelberg, 2007). For this reason, the study of innovative strategies and tools for intra-row selective weed control is an important and relevant research area for European agricultural scientists (Dedousis et al., 2007).
Achieving a significant reduction in labour time in organic farming is a target that can effectively be reached by the use of purposely made operative machines and by the choice of a correct, integrated (holistic) weed strategy in which preventive, cultural and direct methods are concurrently used (Bàrberi, 2002).
Different low- and high-tech solutions for physical weed control are presently available on the market or are being studied as prototypes. Precision hand-guided hoes

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equipped with torsion weeders, vibrating tines or finger weeders belong to the first group (Peruzzi et al., 2004 and 2007), while more technologically-advanced hoes equipped with electronic devices for row detection belong to the second group (Dedousis et al., 2007). In this work we report the first results (on fresh market spinach) of a two-year on-farm research project aimed to develop improved crop and weed management systems for organic vegetable crops mainly based on optimised use of innovative operative machines for physical weed control.

Materials and methods

An ongoing field experiment started in October 2006 on a commercial organic farm located in Crespina (43°34' lat. N, 10°33' long. E), near Pisa (central Italy). Innovative machines for physical weed control are being tested on a two-year crop sequence composed of spinach (*Spinacia oleracea* L.), potato (*Solanum tuberosum* L.), cauliflower (*Brassica oleracea* L. var *botrytis* L.) and tomato (*Lycopersicon esculentum* Mill.). In this paper we report the data gathered on spinach, the first crop in the sequence.

Three crop and weed management systems are being compared, characterised by increasing levels of technological innovation: the standard crop management system practices on farm (SCMS), an intermediate crop management system (ICMS) and an advanced crop management system (ACMS). The SCMS is characterised by the use of a black biodegradable maize starch plastic mulch (Mater-Bi®), on which spinach was manually transplanted on 1 m-wide ridges. The ICMS is based on the use of innovative machines for physical weed control and by direct sowing (performed on 5 October 2006) on 1.4 m-wide ridges with a pneumatic 5-row drill. The ACMS has the same features of ICMS plus the inclusion of a subterranean clover (*Trifolium subterraneum* L.) living mulch, interseeded on 20 November 2006 during the last pass of machines for physical weed control (for more informations about agronomical data of the trial look the article Barberi *et al.* in the Proceedings of this Congress).

In ICMS and ACMS we made use of three innovative mounted operative machines: a rolling harrow, a flaming machine and a precision hoe. The rolling harrow is a new patent of the University of Pisa, equipped with spike discs placed in the front and cage rolls in the back (Figure 1). This machine can efficiently be used both for performing the false or stale-seedbed technique (exploiting its whole working width), and for precision hoeing (removing and adjusting the working tools to the inter-row distance). In this trial the rolling harrow was used just for pre-sowing interventions. The flaming machine performs weed control by means of an open flame (Figure 1). The flamer was equipped with three 50 cm-wide rod-burners and three commercial 15 kg LPG tanks. This machine can be used for pre-sowing, pre-emergence or post-emergence treatments (the latter only on tolerant crops), but in this trial it was used just before crop emergence. The precision hoe was equipped with a seat, steering handles and directional wheels. It is characterized by six working units, each one holding one rigid element with a 9 cm wide blade (for inter-row weed control) and two couples of elastic elements for selective intra-row weed control (torsion weeders and vibrating tines) (Figure 1). For spinach, the ICMS and ACMS included one pre-sowing pass with the rolling harrow (5 October 2006), one pre-emergence pass with the flamer (11 October 2006) and one post-emergence pass with the precision hoe (30 October 2006).

Performances of the operative machines, labour time requirement and cultivation costs of the three crop management systems were assessed. Data were not processed to statistical analysis because referred just to the operative aspects of the research.

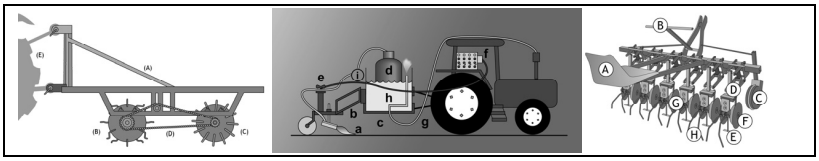

Figure 1: Innovative operative machines used for physical weed control: rolling harrow (left), flaming machine (middle) and precision hoe (right).

Results and discussion

The performances of the innovative operative machines utilised in ICMS and ACMS are shown in Table 1. The working width was the same for all the machines tested and was set at 1.4 m, corresponding to the ridge width. The highest working speed and work capacity was reached by pre-sowing treatments with the rolling harrow (ca. 8 km h^{-1}). Flaming was performed at 5 km h^{-1} while precision hoeing was the most expensive operation., since it was characterised by low speed (2 km h^{-1}) and the need of a back seated operator. All the operative machines require a low engine power (37 kW are almost exceeding); for flaming, LPG consumption was ca. 30 kg ha^{-1}.

Tab. 1: Performances of operative machines adopted for mechanical and physical weed control on spinach

Parameter	Unit of measure	Rolling harrow	Flamer	Precision hoe
Working width	m	1.4	1.4	1.4
Working depth	cm	3.1	-	2.5
Driving speed	km h^{-1}	7.9	5.0	2.0
Work capacity	ha h^{-1}	1.0	0.6	0.3
Working time	h ha^{-1}	1.0	1.7	3.3
Number of workers	-	1.0	1.0	2.0
Tractor power	kW	37.0	37.0	37.0
Engine load	-	0.2	0.2	0.2
Fuel consumption	kg ha^{-1}	2.0	3.4	6.6
LPG pressure	MPa	-	0.3	-
LPG consumption	kg ha^{-1}	-	33.3	

Total labour time requirement and total cultivation costs were considerably higher for the SCMS with respect to the two innovative systems (+225% for both parameters), mainly due to spinach planting operations (Table 2). Costs of the crop nursery phase plus manual transplanting were 11-fold that of mechanical precision planting. Sensible differences in the cost of weed management were also registered: the cost of SCMS (mainly due to biodegradable plastic mulch) was nearly double that of ACMS and triple that of ICMS (Table 2).

Tab. 2: Labour time and cost estimations (including cost of the technical means used but excluding cost of machines) of the three crop and weed management systems tested on spinach

System[1]	Soil tillage		Manual harvest		Planting		Weed management		Total	
	h ha^{-1}	€ ha^{-1}	h ha^{-1}	€ ha^{-1}	h ha^{-1}	€ ha^{-1}	h ha^{-1}	€ ha^{-1}	h ha^{-1}	€ ha^{-1}
SCMS	8	450	340	3,000	815	11,487	8	1,004	1,171	15,951
ICMS	8	450	340	3,000	5	1,042	6	317	359	4,809
ACMS	8	450	340	3,000	5	1,042	8	524	361	5,017

[1]SCMS = Standard Crop Management System, ICMS = Intermediate Crop Management System, ACMS = Advanced Crop Management System. See text for details.

Consequently, the estimated total cost per unit yield was appreciably higher for SCMS (3.24 € kg^{-1}) than for the innovative systems (on average 0.72 € kg^{-1}).

Conclusions

The comparison between the standard and the innovative systems gave very interesting and encouraging results. ICMS and ACMS showed considerable lower costs and hand labour requirements (on average -70%) with respect to the standard system practised on farm. The operative machines used in the innovative systems are cheap, versatile and well adapted to the farm context. Furthermore, soil incorporation of interseeded subterranean clover seeds did not interfere with physical weed control interventions. No appreciable cost differences were observed between the two innovative systems. Further experiments are ongoing to evaluate the feasibility of use of the innovative systems on other organic vegetable crops typical of the Arno Valley.

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