Innovative crop and weed management strategies for organic spinach: crop yield and weed suppression

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Abstract

*In organic agriculture, it is important to tackle crop and weed management from a system perspective to make it effective, especially in poorly competitive crops such as vegetables. For that reason, we developed two innovative integrated crop and weed management systems for a field vegetable crop sequence in a commercial organic farm that we have been comparing to a standard farm system from 2006 to 2008. The three systems are applied to a spinach-potato-cabbage-tomato two-year crop sequence and include different levels of technical innovation: Standard Crop Management System (SCMS); Intermediate Crop Management System (ICMS); and Advanced Crop Management System (ACMS). ICMS is based on a sequence of physical weed management treatments, whereas ACMS also includes a subterranean clover (*Trifolium subterraneum*) living mulch. In this paper we analyse the results obtained on spinach (*Spinacia oleracea*) in terms of crop yield and weed suppression. Both innovative systems increased total spinach fresh weight yield compared to SCMS, despite higher weed biomass. In ACMS, total weed biomass decreased linearly with increasing biomass of the subterranean clover living mulch.*

Introduction

In Italy, organic vegetable production has rapidly expanded in recent years. Organic spinach production has risen from 93 ha in 2005 to 347 ha in 2006 (www.sinab.it), but it still is much lower than the area of conventional spinach (ca. 7,000 ha in 2005). Vegetables, including spinach, are generally very sensitive to competition from weeds, so that the weed management component of any organic vegetable cropping system must be given high priority. However, management of short-cycle vegetable crops must necessarily be tackled from a whole system perspective because of the numerous interactions among agroecosystem components that take place under organic production (Bàrberi, 2002). It then is necessary to develop improved crop management systems that take into account two basic features of any successful organic vegetable cropping system: 1) timeliness of interventions, especially with regard to direct physical weed control measures (Peruzzi, 2006); and 2) inclusion of multifunctional elements, such as cover crops, that can suit the needs of soil, crop and weed management,. As to this latter point, use of legumes such as subterranean clover (*Trifolium subterraneum*) has proven to be beneficial in Mediterranean environments and elsewhere (Ilnicki and Enache, 1992; Bath et al., 2006).This study is part of a research project aiming to develop improved crop management systems

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for organic vegetables based on integrated and optimised use of crop rotations, cover crops/green manure, compost, and weed management strategies. Three crop management systems were then developed and compared on a commercial vegetable organic farm with the active involvement of the farm manager. The three systems correspond to increasing levels of innovation: standard (i.e. the usual crop management system practised on farm); innovative; and advanced. All three systems were applied to the same crop sequence (spinach-potato-cabbage-tomato) in the period 2006-08. This paper reports on crop yield and weed suppression results obtained on spinach, the first crop in the sequence.

Materials and Methods

An experiment was carried out in the 2006-07 season at the Colombini vegetable organic farm, located in Crespina (Pisa), central Italy (43°35' N; 10°34' E), on three different fields. The soil is a sandy loam with an organic matter content of 1% and a pH of 6.8. Three different crop management systems were tested: Standard Crop Management System (SCMS); Intermediate Crop Management System (ICMS); and Advanced Crop Management System (ACMS), allocated to the fields according to a randomised complete block (RCB) design with three replicates (each field corresponding to one block). Each plot was 160 x 3 m. Prior to spinach, the fields were disc harrowed at 25 cm depth, chisel ploughed at 70 cm, rotary hoed at 15 cm, and ripped at 50 cm. Subsequently, 1.4 m-wide ridges were created. The SCMS consisted of manual transplanting on biodegradable maize starch mulch (MaterBi®) of 40-60 plants per m^2 in plant units containing 2-3 plants per unit. No direct weed control measures were applied. In the ICMS, false seed bed technique was performed with a rolling harrow (Peruzzi et al., 2007). Spinach was sown on 5 October 2006 by means of a pneumatic drill (5 rows, 55 seeds/m^2). After seeding, a flame weeder and a precision hoe (two passes) were used. (For more information about ICMS strategies and machines see the article by Fontanelli et al. in the Proceedings of this Congress.)

This sequence of physical weed management operations was also used in the ACMS, where in addition a subterranean clover living mulch (cv. Clare) was broadcast interseeded in spinach on 20 November 2006, at a seeding rate of 30 kg ha^{-1}. In each plot, two 1.4 x 2 m control areas received no physical weed control. Spinach yield and weed biomass were sampled twice in four subplots of 1.4 x 2 m, on 28 November and 15 December 2006. Subterranean clover biomass was sampled on 5 March 2007. All data were subjected to ANOVA according to a RCB design with three replicates. Linear regression analysis was used to relate total weed biomass to subterranean clover biomass. Means were compared by LSD tests at $P \leq 0.05$.

Results and Discussion

Table 1 shows the effect of the three management systems on spinach yield. Total yield of spinach was significantly affected by management system: in particular, both ICMS and ACMS increased spinach yield compared to SCMS in terms of both total leaf fresh weight (+34%) and average fresh weight per plant (+46%). Compared to ICMS, inclusion of subterranean clover in ACMS did not result in statistically significant additional yield gain. No difference among systems was observed in the percentage of discarded leaves (on average ca. 20%). The better results of ICMS and ACMS over SCMS are related to higher yields at the second harvest date, when ICMS and ACMS achieved 44% and 43% of total spinach yield respectively vs. 36% for SCMS. This suggests that the innovative systems are likely to cause a more gradual yield accumulation, which should be seen favourably from a farmer's perspective. Yield gains in ICMS and ACMS were likely due to the concomitant effect of lower intra-specific competition in spinach sown with a regular crop spatial arrangement (single-row precision sowing instead of the 2-3 plants per unit transplanting of the SCMS), and to the overall positive effect of weed management strategies.

Tab. 1: Fresh weight yield (g m^{-2}) and unit f.w. (g per plant) of spinach at the first and second harvest dates and in total.

	28 November 2006			15 December 2006		Total harvest		
System[1]	Fresh weight yield		Unit f.w.	Fresh weight yield	Unit f.w.	Fresh weight yield		Unit f.w.
	g m^{-2}	sqrt				g m^{-2}	sqrt	
SCMS	333.22	18.26 ±4.74	20.97 ±6.61	189.11 ±44.41	10.24 ±2.66	522.33	22.97 ±4.09	15.61
ICMS	369.27	19.22 ±4.68	25.95 ±4.57	290.57 ±70.83	18.97 ±5.62	659.84	26.21 ±4.24	22.46
ACMS	421.86	20.54 ±2.42	26.85 ±3.81	318.37 ±42.67	19.30 ±3.84	740.23	27.20 ±2.46	23.08
F (P)	0.75 (.482)		3.07 (.065)	12.04 (.000)	9.66 (.001)	3.53 (.045)		5.91 (.008)
LSD 5%	4.00		5.72	61.55	5.13	3.61		5.33

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

The SCMS had the lowest weed biomass (2.4 and 1.2 g m^{-2} at the first and second harvest dates respectively), thanks to the suppressive effect of biodegradable mulch. Total weed biomass did not differ between ICMS and ACMS, being on average 11.6 and 14.5 g m^{-2} at the first and second dates respectively. Therefore, higher spinach yield in the innovative systems cannot be explained by the weed biomass data. In the case of ACMS, this can partly be due to the lack of appreciable growth of the living mulch at spinach harvest dates because of delayed interseeding. However, in early March 2007 we observed a significant linear negative relationship between subterranean clover biomass and total weed biomass (Figure 1), which might be relevant from a cropping system perspective (e.g. for the subsequent potato crop).

Conclusions

The results show that there were differences among systems in crop yield and weed suppression, and that the two variables were unrelated. In fact, the SCMS showed the lowest weed biomass but also the lowest spinach yield, an effect likely due to the suboptimum crop spatial arrangement on biodegradable plastic mulch, which possibly increased intra-specific competition. No evidence was found that the living mulch-based system, applied as described in this paper, would give better weed control with respect to the system relying only on physical weed management. However, the negative linear relationship between biomass of weeds and of subterranean clover suggests that the latter has a weed suppression potential that was still unexpressed during the spinach growing cycle.

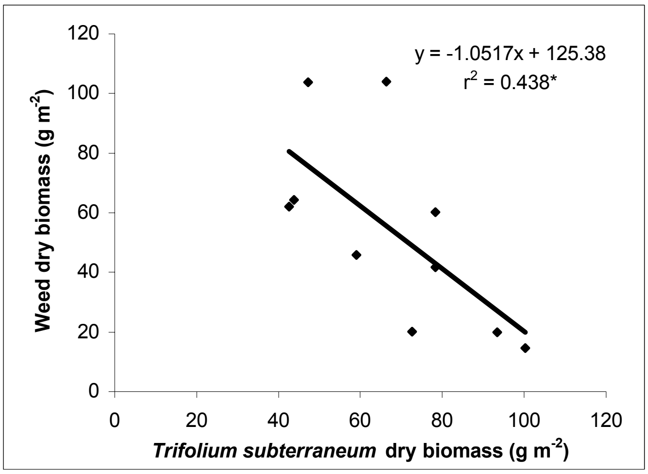

Figure 1: Simple linear regression of weed dry biomass on subterranean clover dry biomass (* significant at P ≤ 0.05)

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