Living mulch and vegetable production: effect on crop/weed competition

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Abstract

Two field experiments were carried out in order to test the effect on weed management of living mulch introduction in organically managed cauliflower (Brassica oleracea L.) in Central Italy and leek (Allium porrum L.) in Denmark. Burr medic (Medicago polymorpha L.) and Dyers Woad (Isatis tinctoria L.) were sown as living mulch in Central Italy and Denmark, respectively. Different living mulch managements and cultivars were tested in strip plot designs. The main objective of the research was the evaluation of their effects on both crop growth and weed suppression. Biomass of crops, living mulches and weeds were measured and competitive indices were used to assess their competitive relationships. The burr medic showed the lower weed biomass when sowed later than crop, avoiding competitiveness on crop. Furthermore, dyers woad showed the highest tolerance to competition when late sowed.

Introduction

Cover crop introduction into rotation can contribute to create an unfavourable ecological environment for weeds, ensuring the biodiversity and soil protection. The weed suppressive potential of the cover crop may depend on plant species, place in crop rotation and management. Thus, interseeded cover crops (living mulch) can be introduced to improve the competitive ability of vegetable crops, which are commonly weak competitors against weeds (Baumann et al., 2000), matching their sowing with the cash crop transplanting. The selection of proper living mulch species and cultivars can uncouple weed and crop suppression, then filling the ecological niches otherwise used by weeds, without smothering the crop. Also the interseeding timing and the living mulch spatial distribution (i.e. on the entire field or stripped) can contribute to achieve this result (Masiunas, 1998). In order to study the benefits and shortcomings of living mulch introduction on crop competitiveness, the InterVeg research project is evaluating the use of living mulches in vegetable cropping systems in different European environments. This paper presents the preliminary results of living mulch introduction (sowing dates and spatial distributions) on weed and crop competitive relationships in organic cauliflower and leek cultivars in the IT and DK experiments.

Material and methods

The Experiment 1 was carried out at the Vegetable Research Unit of the Consiglio per la Ricerca e la sperimentazione in Agricoltura (CRA-ORA) in Monsampolo del Tronto (AP), (42°53'N, 13°48'E), along the coastal area of the Marche Region, Central Italy. In a strip plot experimental design with two factors and three replicates, cauliflower (*Brassica oleracea* L. var. *botrytis*) was grown within August 2011 and January 2012 with Burr medic (*Medicago polimorpha* L. var. *anglona*) as living mulch. The first factor was Burr medic management and the following treatments were compared: (i) control (no living mulch – No lm), (ii) living mulch early sowing (at cauliflower transplanting – Early) and (iii) living mulch late sowing (three weeks delayed after cauliflower transplanting – Late). The No lm treatment was managed and weeded in accordance to the standard agronomic practices, commonly used by organic farmers in the area. The Early and Late treatments were weeded until the living mulch sowing. The second factor was the cauliflower genotype and three different cultivars were compared (Emeraude –Em– , a hybrid cultivar, and – VCO1 and VCO2 – two open-pollinated, locally adapted cultivars). The Experiment 2 was carried out at the Research Centre at Aarslev (55°18'N,10°27'E) in Denmark. In a strip plot experimental design with two factors and three replicates, leek (*Allium porrum* L.) was grown within May and October 2012 alternating with Dyers Woad (*Isatis tinctoria* L.) living mulch strips. The first factor was Dyers Woad management and the following treatments were compared: (i) control (no living mulch – No lm), (ii) living mulch early sowing (sown 4 weeks

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delayed after leek transplanting – Early) and (iii) living mulch late sowing (sown 7 weeks delayed after leek transplanting – Late). In order to meet the specific needs of this study, in contrast with the standard agronomic practices for leek production in Denmark, the No lm treatment was unweeded. The living mulch Early and Late was weeded until the living mulch sowing. The second factor was the leek genotype and two different cultivars were compared (Hannibal –Ha– an open-pollinated cultivar, and Runner –Ru– a hybrid one). In order to allow the competition assessment among crop, weeds and living mulch, besides the plots with the three components simultaneously present (hereafter reported as "mixed plots"), additional stands were included in triplicate in both the experiment 1 and 2 layouts. Stands with only one component ("pure crop", "pure weed" and "pure living mulch" for crop, weeds and living mulch, respectively) and two components ("living mulch - crop mix" –weeded–, and "living mulch - weed mix" – no crop) were realized. At the end of the crop harvest, aboveground total crop, living mulch and weed biomasses were determined in each plot/stand and for each treatment. Competitive indices (Weigelt and Jolliffe, 2003; Paolini et al., 2006) were calculated by using the measured biomass (Table 1). The RB was calculated for each component (RBc, RBlm, RBw for crop, living mulch and weeds, respectively). The C_b was calculated for either the crop against weeds - living mulch mix (C_bc) and the crop - living mulch mix against weeds (C_bclm).

Table1. Competitive indices used for competitive evaluation

Index	Calculation	Evaluation
Agronomic Tolerance to Competition (ATC%)	$(Y_{mix}/Y_{pure}) * 100$	The highest is the value the lowest is the competitive effect on crop yield
Relative Biomass (RB)	B_{AB}/B_A	The highest is the RB value the lowest is the tolerance of the component to competition
Competitive balance index (C_b)	$Ln[(B_{AB}/B_{BA})/(B_A/B_B)]$	If C_b is greater than, less than or equal to 0, the component is more, less, or equally competitive.

Notes:
Y_{mix}, Y_{pure} : the crop yield in presence of competitors and the crop yield in absence of competitor ("pure crop").
B_{AB}, B_{BA}, B_A, B_A: the aboveground biomass of the A component in mixture with B, of B in mixture with the A, of A in pure stand and of the B in pure stand respectively.
A: component for which the index is calculated to (i.e. crop; weeds; living mulch - lm)
B: component or components in mixture with A (i.e. crop; weeds; lm; crop – weeds; crop – lm; lm – weeds)

Results

Experiment 1: ANOVA results and average values regarding the biomass parameters and competitive indices are reported in Table 2. No significant difference for living mulch biomass was recorded between Early and Late treatments, whereas the Early one showed the highest weed biomass and the lowest crop biomass. Furthermore, the Early treatment showed the lowest RBc, highlighting a stronger decrease in cauliflower biomass compared to pure condition (absence of competition) than Late and No lm treatments. On the contrary, the RBw was higher in Early than Late and No lm treatments. Also the ATC% and C_bc showed the lowest value in Early treatments putting respectively in evidence the cauliflower's low tolerance to competition and competitive ability, when the living mulch was interseeded at crop transplanting. On the other hand the No lm and Late treatments did not differ for most of the evaluated parameters except for C_bc, which showed the highest value in the weeded No lm treatment. However, the C_bc index showed a positive value (and then, competitive ability) in the Late treatment too. Also the highest value of C_bclm in the Late treatment underlines the high weed suppressive potential of living mulch-crop mix when the living mulch interseeding is delayed with respect to cauliflower transplanting. Then, the results showed the Late treatment as a possible alternative to the standard agronomic practices of the area, ensuring similar weed control and avoiding the cauliflower suppression. As far as genotype factor is concerned, Em cultivar showed the highest biomass, whereas the VCO2 was characterized by the highest living mulch production. The Em and VCO2 cultivar showed the highest and the lowest values for all the competitive indices except for RBw (no significant difference among cultivars), respectively. However, the positive C_bc value highlighted an high competitive ability for all the cultivars. Moreover, the C_bclm showed the competitiveness of the living mulch - cauliflower mix against weeds for all the cultivars, where Em showed the highest value and the VCO2 the lowest one. These results put in evidence the high competitiveness of Em hybrid but also a good suitability of the VCO1 cultivar to living mulch interseeding.If you use tables, please make it as following example (Table 1):

Table 2. Experiment 1. Italian cauliflower. Biomass and competitive indices.

	C	**LM**	**W**	**RBc**	**RBw**	**ATC%**	**C_bc**	**$C_b$clm**
LM management (M)								
No lm	8.41 a	-	0.14 b	0.86 a	0.03 b	54.2 a	+3.93 a	-
Early	2.28 b	0.42	2.01 a	0.25 b	0.40 a	25.1 b	-0.14 c	+0.81 b
Late	7.44 a	0.64	0.77 b	0.80 a	0.15 b	66.8 a	+1.28 b	+1.63 a
Level of significance	***	n.s.	**	***	**	***	***	**
Cultivar (Cv)								
Em	8.02 a	0.23 b	0.48	0.90 a	0.10	59.6 a	+2.72 a	+1.99 a
VCO1	4.59 b	0.40 b	1.22	0.46 b	0.24	49.9 ab	+0.92 b	+1.32 ab
VCO2	5.52 b	0.96 a	1.22	0.56 b	0.24	36.5 b	+1.43 b	+0.55 b
Level of significance	***	**	n.s.	***	n.s.	*	**	**
Mean	6.04	0.53	0.97	0.64	0.19	48.7	+1.69	+1.19
M x CV	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.

Notes: Early = early living mulch sowing treatment: Late = late living mulch sowing treatment; No lm = control treatment. Em = Emeraude hybrid; VCO1 = open - pollinated cultivar 1; VCO2 = open - pollinated cultivar 2; C (Crop); LM (living mulch); W (weed): above ground dry biomass (t ha^{-1}). The mean values in each column followed by a different letter are significantly different according to DMRT at the $P \leq 0.05$ probability level. n.s., *, **, *** non-significant or significant at $P \leq 0.05$, 0.01, 0.001

Experiment 2: The high weed pressure characterizing the experiment 2 did not allow to separate the living mulch and weed biomasses, thus the RBw and $C_b$clm were not determined. ANOVA results and average values regarding the biomass parameters and competitive indices are reported in Table 3. The three LM management treatments did not significantly differ for all the considered parameters except the ATC%, showing the highest value in the Late treatment. Moreover, a low competitive ability of the leek in all the systems ($C_b<0$) was highlighted. This could be related to the particularly high weed pressure during the experiment and due to the lack of weeding. Concerning the genotype factor (CV), the Ha cultivar showed the highest crop biomass, ATC%, RBc and C_bc, resulting more competitive than Ru. The T x CV interaction was found significant for leek biomass, RBc and ATC%. By splitting the results by the CV factor and executing ANOVA for the M one, significant differences among treatments were found in the Ha cultivar, whereas no differences in Ru were shown. More in depth, the Ha cultivar showed higher biomass production in the living mulch treatments compared to the control (4.44 and 5.15 t ha^{-1} in the Early and Late treatments against 3.37 t ha^{-1} in the No lm - $P \leq 0.05$). Similarly, the RBc showed the highest value for Early (0.68) and Late (0.79) treatments than No lm (0.52) ($P \leq 0.05$). The ATC % showed the highest value for Late treatment (88.3%) than Early (63.8%) and No lm (48.7%) ones ($P \leq 0.01$). This evidence underlined the capability of the Ha cultivar to tolerate the competitive environment during the experiment, and demonstrated its ability to grow in the living mulch intercropping system.

Table 3. Experiment 2. Danish leek. Biomass and competitive indices.

	C	LM-W	RBc	ATC%	C_bc
LM management (M)					
No lm	3.22	2.57[(1)]	0.53	50.2 b	-0.47
Early	3.37	2.72	0.54	52.3 b	-0.69
Late	3.90	2.65	0.63	68.4 a	-0.36
Level of significance	n.s.	n.s.	n.s.	**	n.s.
Cultivar (Cv)					
Ha	4.32 a	2.33	0.66 a	66.9 a	-0.19 a
Ru	2.67 b	2.98	0.47 b	47.0 b	-0.82 b
Level of significance	***	n.s.	***	***	***
Mean	3.50	2.65	0.56	56.9	-0.50
M x CV Sig.	**	n.s.	**	**	n.s.

Notes: [(1)] aboveground dry weed biomass. Early = early living mulch sowing treatment; Late = late living mulch sowing treatment; No lm = control treatment; Ha = Hannibal; Ru = Runner. LM-W = living mulch and weed above ground dry mixed biomass(t ha^{-1}); C = crop above ground dry biomass (t ha^{-1}). The mean values in each column followed by a different letter are significantly different according to LSD (CV comparison) and DMRT (M comparison) at the $P \leq 0.05$ probability level. n.s., **, *** non-significant or significant at $P \leq 0.01$, 0.001.

Discussion

The results highlighted the role of agricultural choices in the living mulch introduction in obtaining an effective weed suppression. Both the living mulch timing of sowing and the cultivar had a key role in the competitive success of the crop against both weeds and living mulch. These preliminary outcomes showed the late sowing of the LM ensuring an unfavorable environment for weeds avoiding crop suppression. Moreover, our findings indicated similarities in competitiveness between hybrid and open pollinated/local adapted cultivars.

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