Cost and energy evaluation of organic cauliflower in sole crop and living mulch systems

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Abstract

This paper presents the findings of an assessment aimed to evaluate, in term of cost and energy consumption, the introduction of living mulch in different organic vegetable systems producing cauliflower. The study was carried out in three European countries (IT, SLO and DK) in the frame of the InterVeg project (Core Organic II). The achievements demonstrated that, in economic terms, farmers' choice of a specific technique, like living mulch instead of sole cropping, can be influenced by two key elements: human labor and fossil fuel consumption. Different organic systems have a different proportion in using the two inputs depending on the specific farm strategy.

Introduction

Cost and energy consumption have important roles when assessing an agro-ecological technique. Their increase or decrease can strongly influence the farmers' decision in choosing a specific technique for both economic and environmental reasons. The literature already provides evidence on the ability of living mulch (LM) to reduce the use of pesticides and fertilizers contributing in the reduction of pest population, soil erosion and weed pressure, and the increase of soil organic matter and nitrogen conservation (Hartwig and Ammon, 2002). These features make LM an interesting tool in organic farming systems. However, the application at farm level is often constrained because farmers perceive the living mulch as a costly technique. This paper presents the findings of an assessment aimed to evaluate, in terms of cost and energy consumption, three different organic vegetable systems located in three European countries.

Material and methods

Within the InterVeg research project, in the season 2011-2012, three different organic cropping systems were set up to produce organic cauliflowers in Italy, Slovenia and Denmark. For details about the experimental sites and layouts see Canali et al. (in this book of proceedings). The 3 locations were different for climate, soil characteristics, management practices and socio economic conditions. Data about energy consumption and costs were collected in each experimental site following a similar standardized procedure. In detail, during the cauliflower cropping cycle, all the field operations were recorded and the consumption of energy (fossil fuel and human power) calculated in each site. In order to emphasize similarities and differences among the sites, the list of field operations was assessed and a common operation list was set up. Moreover, since the main aim of the study was to look at the elements that can influence the decision makers in the application of the LM technique, neither the energy embedded in the machinery, which represents a fixed cost, or the differences in the type of human labor, depending on the worker gender and on the type of work done were not taken into account (Giampietro and Pimentel, 1990). Many conversion factors to MJ are available for both fuel and human power. The energy equivalent of human power used was 2.3 MJ unit-1 (Ozkan et al.2004) and of 47.8 MJ kg-1 for diesel (Ortiz-Cañavate and Hernanz 1999). The unitary cost of fuel in the different Countries was used in order to calculate the cost. They were: 1.36/1.38/1.46 € l-1 for Slovenia, Italy and Denmark, respectively. Higher differences were observed for labor cost, which were: 5.2/11.9/22.0 € h-1 for Slovenia, Italy and Denmark, respectively.

Results

The energy consumption resulted for around 80% due to the fossil fuel and for a minor part to human power, in each system. This can easily be explained by the higher cost of work in developed countries compared to more traditional societies where the human power is part of the family and the investments for machineries

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are less available (Giampietro and Pimentel, 1990). In the Italian system the fossil fuel reached 90% of the total energy consumption, while in Slovenia and Denmark it was 85%. However, looking in absolute terms, the total fuel consumption in Denmark was twice that in Italy and Slovenia. This should be explained considering that the Danish system had the higher labor cost of the three systems. Slovenia had a lower consumption of fossil fuel energy than Italy, because of the larger consumption of human power. Results reported in Table 1 show an increase in the use of human power in the LM treatment with compared to the sole crop one in both the Italian and Danish systems, while an opposite trend occurred in Slovenia.

Table 1: Human power employed for organic cauliflower cultivation (MJ ha^{-1}).

Field Operations	IT				SLO				DK			
	Sole Crop		LM		Sole Crop		LM		Sole Crop		LM	
	MJ	%	MJ	%	MJ	%	MJ	%	MJ	%	MJ	%
Soil tillage	18	2	18	2	11	1	11	1	121	5	121	4
Sowing at/after trans	0	0	253	24	0	0	2	0	0	0	2	0
Root cutting	0	0	0	0	0	0	0	0	0	0	46	2
Transplanting	232	29	232	22	173	13	173	13	299	11	299	11
Hoeing	30	4	15	1	221	16	106	8	414	15	414	15
Spray irrigation	92	11	92	9	25	2	25	2	86	3	86	3
Fertilizer application	33	4	33	3	6	0	6	0	46	2	46	2
Spraying/insect net	55	7	55	5	7	1	7	1	69	3	69	3
Harvesting-threshing	334	41	334	32	874	65	955	73	1553	58	1553	57
Transportation	12	1	12	1	21	2	22	2	35	1	35	1
Chopping residues	7	1	7	1	5	0	5	0	58	2	58	2
Total	813		1051		1341		1310		2680		2728	

In fact, the Slovenian sole crop system used hand hoeing instead of mechanical weeding and, consequently, the introduction of LM allowed reducing about 50% of work. The Italian system made the opposite choice: the shift from sole crop to LM system reduced mechanical weeding introducing LM, which was sown manually (Table 1). In the Danish experiment the larger difference between the sole crop and the LM systems occurred because of the introduction of two additional mechanical operations (i.e. LM sowing and root cutting) without any other change. On the other hand, the Slovenian LM system increased the use of machinery in the mechanical sowing (Table 2).

Table 2. Fuel energy consumption for organic cauliflower cultivation (MJ ha^{-1}).

Field Operations	IT				SLO				DK			
	Sole Crop		LM		Sole Crop		LM		Sole Crop		LM	
	MJ	%	MJ	%	MJ	%	MJ	%	MJ	%	MJ	%
Soil tillage	2803	43	2803	44	1741	27	1741	28	5891	46	5891	39
Sowing at/after trans	0	0	0	0	0	0	89	1	0	0	406	3
Root cutting	0	0	0	0	0	0	0	0	0	0	2032	13
Transplanting	130	2	130	2	2032	31	2032	33	1016	8	1016	7
Hoeing	266	4	133	2	488	7	81	1	894	7	894	6
Spray irrigation	0	0	0	0	358	5	349	6	203	2	203	1
Fertilizer application	329	5	329	5	203	3	203	3	813	6	813	5
Spraying/insect net	1495	23	1495	24	244	4	244	4	0	0	0	0
Harvesting-threshing	0	0	0	0	0	0	0	0	406	3	406	3
Transportation	650	10	650	10	731	11	772	12	1097	9	1097	7
Chopping residues	781	12	781	12	731	11	733	12	2438	19	2438	16
Total	6454		6321		6527		6244		12758		15196	

Field operations contributed differently to the energy consumption in the three systems (Table 3). The field

operation, which required the largest amount of fuel energy, was the soil tillage and the transplanting bed preparation. However, in the case of Slovenia, the transplanting had the highest energy consumption, close to 30% of the total. Therefore, a study focused to reduce the consumption of this specific operation would relevantly contribute to increase to overall energy use efficiency of the system.
The Danish system had the best distribution of energy consumption among different field operations and, excluding the soil tillage; the other operations were never contributing for more than 15% to the total amount of energy. This indicates that further improvement of energy efficiency of a specific operation is not required.

Table 3. Total energy consumption for organic cauliflower cultivation (MJ ha^{-1}).

Field Operations	IT				SLO				DK			
	Sole Crop		LM		Sole Crop		LM		Sole Crop		LM	
	MJ	%	MJ	%	MJ	%	MJ	%	MJ	%	MJ	%
Soil tillage	2821	39	2821	38	1752	22	1752	23	6012	39	6012	34
Sowing at/after trans	0	0	253	3	0	0	92	1	0	0	409	2
Root cutting	0	0	0	0	0	0	0	0	0	0	2078	12
Transplanting	362	5	362	5	2204	28	2204	29	1315	9	1315	7
Hoeing	296	4	148	2	708	9	187	2	1308	8	1308	7
Spray irrigation	92	1	92	1	382	5	374	5	289	2	289	2
Fertilizer application	363	5	363	5	874	11	955	13	1959	13	1959	11
Spraying/insect net	1550	21	1550	21	251	3	251	3	69	0	69	0
Harvesting-threshing	334	5	334	5	874	11	955	13	1959	13	1959	11
Transportation	662	9	662	9	752	10	794	11	1132	7	1132	6
Chopping residues	788	11	788	11	736	9	737	10	2495	16	2495	14
Total	7267		7372		7868		7554		15437		17923	

Hoeing had the higher fossil fuel consumption in Denmark than the other two systems, however the use of pesticides, allowed in organic farming, is the second field operation in term of fossil fuel consumption for the Italian system. The use of insect net instead of spraying in the Danish system, allows a significant reduction of energy consumption in this operation, with a little increase of human power for net management. This could represent an interesting result for the Italian system. However, as far as the costs are concerned (Table 4), the higher difference in total cost was obtained in the Italian system. In this case the human labor, which represents the highest cost input, is increased in the LM system, with a decrease of the fossil energy used.

Table 4. Total cost for organic cauliflower cultivation (€ ha^{-1}).

Field Operations	IT				SLO				DK			
	Sole Crop		LM		Sole Crop		LM		Sole Crop		LM	
	€	%	€	%	€	%	€	%	€	%	€	%
Soil tillage	188	4	188	3	82	3	82	3	1367	5	1367	5
Sowing at/after trans	0	0	1309	23	0	0	5	0	0	0	37	0
Root cutting	0	0	0	0	0	0	0	0	0	0	513	2
Transplanting	1206	27	1206	21	455	14	455	14	2897	11	2897	11
Hoeing	165	4	89	2	512	16	257	8	3992	15	3992	15
Spray irrigation	474	11	474	8	68	2	70	2	832	3	832	3
Fertilizer application	184	4	184	3	20	1	20	1	469	2	469	2
Spraying/insect net	336	8	336	6	24	1	24	1	660	3	6660	2
Harvesting-threshing	1726	39	1726	31	1961	61	2141	68	14865	57	14865	56
Transportation	82	2	82	1	71	2	78	2	369	1	369	1
Chopping residues	63	1	63	1	35	1	39	1	638	2	638	2
Total Costs	4423		5656		3226		3171		26088		26638	

The substitution of fossil fuel with human power has a positive effect for social welfare both for environmental concerns and employment levels. The Slovenian system reduced the use of labor even if resulting in a small difference in total costs due to the low cost of labor in the country. On the other hand Denmark had an increase in costs due to the cost of root-cutting included in the LM system.

Conclusions

This study highlighted different effects on cost and energy consumption, depending on socio economic conditions and agricultural systems in which the LM system substituted the sole crop one. In the three studied systems, the introduction of LM determined a difference in total energy consumption ranging from +14 to -4% and a cost difference ranging between +22 and -2%. Moreover, the use of LM determined the change in proportion between human power and fossil fuel energy consumption. These findings have to be considered together with the yield results and in a social perspective in the specific local context where the LM is introduced.

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