Renewable Agriculture and Food Systems: 32(3); 197–199 doi:10.1017/S1742170517000126

Enhancing multifunctional benefits of living mulch in organic vegetable cropping systems

S. Canali[1]*, M. Diacono[2], F. Montemurro[2] and K. Delate[3]

[1]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria—Centro di ricerca Agricoltura e Ambiente, Via della Navicella, 2 00184 Rome, Italy.
[2]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria—Centro di ricerca Agricoltura e Ambiente, Via Celso Ulpiani 5, 70125—Bari, Italy.
[3]Departments of Agronomy and Horticulture, Iowa State University, IA 50011, USA.
*Corresponding author: stefano.canali@crea.gov.it

Accepted 22 February 2017 **Themed Content: Living Mulch**

Over the last several decades, agriculture in industrialized countries experienced a significant intensification as a result of the diffusion of mechanization, the widespread use of genetically improved genotypes, and the large-scale use of off-farm inputs, mainly in the form of fossil fuel energy and synthetic fertilizers and pesticides. Under the pressure of the growing agro-industrial sector, which has been oriented to promote models based on large volumes and long-distance supply chains, intensification was accompanied by progressive specialization of farms and cropping systems (Ratnadass et al., 2012). Indeed, the reduction of diversity at the field, farm, and territory level, a result of a low number of crops, the shortening of crop rotations, and a decrease in the number of cultivated genotypes, is becoming evident in many agro-environments in developed countries.

More recently, the recognition of negative environmental and social externalities associated with specialized, intensive agriculture production systems has emerged and is fostering a debate in civil society. This debate has led public authorities to consider the challenges involved in promoting more social and environmental performing agriculture models based on diversification and agro-ecologically sound approaches (Altieri, 1995). Diversified cropping systems, which rely on the rotation and association of cash crops (i.e., multiple cropping, intercropping) and the introduction of agro-ecological service crops [i.e., complementary or break crops, relay cropping, living mulches (LM)] can fulfill the need for producing food, feed and fiber, as well as ecosystems services (Meynard et al., 2013).

The issue of diversification of farming systems is relevant to the organic farming sector as well. Despite guidelines asserting that plant production in organic farming should be based on the use of long rotations with cover crops, as underscored by organic farming principles and relevant sector regulations implemented across different continents (i.e., E.U. Regulation 2007/834), the potential benefits of diversification have not been fully realized. The risks and consequences associated with the conventionalization of organic farming, including limiting diversity, concomitant with specialization and intensification, has been deeply debated (Darnhofer et al., 2010). This topic is particularly relevant in the case of organic vegetable production, as it is often based on specialized systems, relying heavily on intensive use of energy, water and other inputs, including processed organic fertilizers and plant protection products for direct pest and disease control (Tittarelli et al., 2016). Thus, there is a need to improve the use of natural resources and reduce the dependency on external inputs, while still increasing the economic performance of organic vegetable systems. In accordance with the re-designed approach (Wezel et al., 2014; Gliessman, 2016), the challenge is to implement agro-ecologically sound solutions to improve nutrient cycling by using appropriate crop combinations (e.g., intercropping, mixtures with different rooting depths and ecological service providing crops) and recycling of quality waste materials available at the local level. These innovative systems should improve the quality and stability of production, even at limited external nutrient levels, to meet the high standards of environmental sustainability, along with supplying products in closer alignment with the organic principles.

LM, found in the intercropping of a cash crop with a cover crop, is introduced in the vegetable cropping system to provide ecological services to the agroecosystem (Leary and DeFrank, 2000). LM systems are one of the agroecologically-sound techniques that can be used at the field/cropping system scale in accordance with the system (re)design approach. However, despite the growing interest in LM from organic farmers, the diffusion of LM techniques has been limited due to a number of constraints, namely difficulties with efficient weed control; increased energy consumption in LM implementation and management; and potential yield reduction due to competition between cash and cover crops (Wezel et al., 2014). These constraints, which have been principally studied in arable systems, could limit the successful implementation of LM in organic vegetable systems, due to the low competitive ability of vegetable species with other plant species and their high nutrient demand (Mortensen et al., 2000). In addition, any yield and product quality penalty creates issues, especially for vegetable crops, in which the relationship between product quality and value along the supply chain is not linear and a slight reduction in quality may have a great impact on marketable value (Maggio et al., 2013).

In order to overcome the current constraints of LM and to enhance the potential for its integration into organic—agroecologically-based—cropping systems, multidisciplinary research is needed to fully evaluate advantages and disadvantages of intercropping and develop techniques that could make it feasible, socially acceptable and convenient. This Issue contains six selected papers concerning a wide range of topics linked to living mulch intercropping, including the impacts on nitrate leaching, the rihzosphere, arthropod fauna, weed control, yield and product quality, along with energy usage and farmers' perceptions of LM systems. These studies contribute to the body of knowledge about LM in organic vegetables systems.

In the first paper by Canali et al. (2016), the effects of LM on cash crop yield for different genotypes, along with product quality, energy usage and farmers' perception of LM feasibility and applicability, were investigated in different European vegetable cropping systems. Responses of the LM introduction were both crop (system) and site specific. Results showed that the LM substitutive design can be effectively implemented in vegetable production, when the value of the agro-ecological services delivered by LM counterbalances the yield loss due to the cash crop density reduction, whereas with additive design the LM should be sown several weeks after cash crop planting. What is interesting about this study is the combination of research evidence and farmers' perception. Despite the increased use of human labor and fossil fuel energy in the LM systems, farmers' acceptance of the LM techniques was quite high due to perceived agroecological value.

The subject of the Trinchera et al. (2016) paper is the effect of a LM on rhizosphere interactions in two organic artichoke cultivars. In particular, it was found that LM did not reduce yields of artichoke when compared with the no LM control. Furthermore, LM induced structural changes in artichoke roots, through a proliferation of root hairs, resulted in nutrient uptake optimization. It also promoted rhizosphere arbuscular mycorrhizal fungi (AMF) colonization, with many extra-radical and intra-radical AMF hyphae, thus improving P uptake. These interactions, which were found to be cultivar-dependent, may be considered an example of functional agrobiodiversity operating at crop species or habitat level and supporting sustainability.

Xie et al. (2016) deal with the introduction of LM to control plant competition and to reduce potential nitrate leaching. This study investigated the effects of different intercropping system designs (i.e., addition design—ADD, and substitution design—SUB) with different cover crops and sowing periods, both in continental and temperate areas, for two vegetable crops (cauliflower and leek). The complexity of this investigation resulted in the identification of best strategies for enhanced performance. The two system designs showed potential in managing competition and reducing nitrate leaching, depending on the level of inter-specific competition and local conditions. The authors suggest that the key factor for success may be to identify suitable growing periods, sometimes combined with root pruning, for each LM species and system design.

The impact of LM on soil biological properties was investigated by Depalo et al. (2016), which investigated arthropod dynamics and biodiversity on cauliflower crops, in the same European countries (Italy, Denmark, Germany and Slovenia) as the Xie et al. paper. An interesting result of this study was that canopy pest infestation (e.g., *Pieris* spp.) was not increased in the LM system, and was reduced in some cases (e.g., aphid infestations in Denmark). Moreover, a generally positive influence on diversity and activity density of arthropod fauna, mainly the Carabidae group, in the plant/soil systems was found.

Ciaccia et al. (2016) focused on different LMs (e.g., different cover crops species, sowing times and system approaches) and the potential to suppress weeds in organic vegetable crops under Mediterranean and Northern European conditions. The authors found that LM systems were effective in managing weeds and avoiding competition with the vegetable crop, both for F_1 hybrids and open-pollinated, locally adapted cultivars, thus limiting the need for mechanical cultivation to control weeds. This result was obtained particularly with delayed LM sowing.

The last paper, by Montemurro et al. (2016), studied the suitability of LM (testing different sowing times) combined with organic fertilizers for organic cauliflower production in two sites in a Mediterranean environment. No competition was observed between the late-sown LM and the cash crop (particularly for the hybrid cultivar), as well as an increase in crop N uptake, and weed mitigation were observed. The authors pointed out that in LM systems, commercial organic fertilizers could be replaced with locally available organic fertilizers and amendments without a yield penalty. On the whole, the effectiveness of LM strategies depended on several factors, such as type of LM, vegetable cultivar, weather, soils and length of growing season.

It is the hope that this themed Issue, which offers studies on LM addressed from different angles, will stimulate further research in the area of organic vegetable cropping system redesigned in accordance with agroecologically-sound approaches.

Acknowledgements. This article reports a synthesis of the results obtained in the frame of the InterVeg research project: Enhancing multifunctional benefits of cover crops-vegetables intercropping (Core Organic II ERA-NET).

References

Altieri, M.A. 1995. Agroecology: The Science of Sustainable Agriculture. Instituto Hondureño del Café, Tegucigalpa (Honduras). IICA, Guatemala. PROMECAFE.

Canali, S., Ortolani, L., Campanelli, G., Robačer, M., von Fragstein, P., D'Oppido, D., and Kristensen, H.L., 2016. Yield, product quality and energy use in organic vegetable living mulch cropping systems: Research evidence and farmers' perception. Renewable Agriculture and Food Systems. doi: 10.1017/S1742170516000314. Published online: 09 September 2016.

Ciaccia, C., Kristensen, H.L., Campanelli, G., Xie, Y., Testani, E., Leteo, F., and Canali, S., 2016. Living mulch for weed management in organic vegetable cropping systems under Mediterranean and North European conditions. Renewable Agriculture and Food Systems. doi: 10.1017/S1742170516000016. Published online: 15 February 2016.

Darnhofer, I., Lindenthal, T., Bartel-Kratochvil, R., and Zollitsch, W. 2010. Conventionalisation of organic farming practices: From structural criteria towards an assessment based on organic principles. A review. Agronomy for Sustainable Development 30:67–81. doi: 10.1051/agro/2009011.

Depalo, L., Burgio, G., von Fragstein, P., Kristensen, H.L., Bavec, M., Robačer, M., Campanelli, G., and Canali, S. 2016. Impact of living mulch on arthropod fauna: Analysis of pest and beneficial dynamics on organic cauliflower (*Brassica oleracea* L. var. botrytis) in different European scenarios. Renewable Agriculture and Food Systems. doi: 10.1017/S1742170516000156. Published online: 15 June 2016.

Gliessman, S. 2016. Transforming food systems with agroecology. Agroecology and Sustainable Food Systems 40:187–189. doi: 10.1080/21683565.2015.1130765.

Leary, J. and DeFrank, J. 2000. Living mulches for organic farming systems. HortTechnology 10:692–698.

Maggio, A., De Pascale, S., Paradiso, R., and Barbieri, G. 2013. Quality and nutritional value of vegetables from organic and conventional farming. Scientia Horticulturae 164:532–539. doi: 10.1016/j.scienta.2013.10.005.

Meynard, J.-M., Messéan, A., Charlier, A., Charrier, F., Fares, M., Le Bail, M., Magrini, M.-B. and Savini, I. 2013. Brakes and levers to diversification of cultures in France: Study of agricultural farms and chains. OCL—Oilseeds Fats Crops Lipids 20:3–10. doi: 10.1051/ocl/2013007.

Montemurro, F., Diacono, M., Ciaccia, C., Campanelli, G., Tittarelli, F., Leteo, F., and Canali, S. 2016. Effectiveness of living mulch strategies for winter organic cauliflower (*Brassica oleracea* L. var. botrytis) production in Central and Southern Italy. Renewable Agriculture and Food Systems. doi: 10.1017/S1742170516000107. Published online: 14 June 2016.

Mortensen, D.A., Bastiaans, L., and Sattin, M. 2000. The role of ecology in the development of weed management systems: An outlook. Weed Research 40:49–62. doi: 10.1046/j.1365-3180.2000.00174.x.

Ratnadass, A., Fernandes, P., Avelino, J., and Habib, R. 2012. Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: A review. Agronomy for Sustainable Development 32:273–303. doi: 10.1007/s13593-011-0022-4.

Tittarelli, F., Ceglie, F.G., Ciaccia, C., Mimiola, G., Amodio, M.L., and Colelli, G. 2016. Organic strawberry in Mediterranean greenhouse: Effect of different production systems on soil fertility and fruit quality. Renewable Agriculture and Food Systems. doi: 10.1017/S1742170516000417. Published online: 05 December 2016.

Trinchera, A., Testani, E., Ciaccia, C., Campanelli, G., Leteo, F., and Canali, S. 2016. Effects induced by living mulch on rhizosphere interactions in organic artichoke: The cultivar's adaptive strategy. Renewable Agriculture and Food Systems. doi: 10.1017/S1742170516000119. Published online: 10 June 2016.

Wezel, A., Casagrande, M., Celette, F., Vian, J.-F., Ferrer, A., and Peigné, J. 2014. Agroecological practices for sustainable agriculture: A review. Agronomy for Sustainable Development 34:1–20. doi: 10.1007/s13593-013-0180-7

Xie, Y., Tittarelli, F., von Fragstein, P., Bavec, M., Canali, S., and Kristensen, H.L. 2016. Can living mulches in intercropping systems reduce the potential nitrate leaching? Studies of organic cauliflower (*Brassica oleracea* L. var. botrytis) and leek (*Allium porrum* L.) production across European conditions. Renewable Agriculture and Food Systems. doi: 10.1017/S1742170516000211. Published online: 18 July 2016.