Combined agro-ecological strategies for adaptation of organic horticultural systems to climate change in Mediterranean environment

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Abstract

Agricultural biodiversity and related agro-ecological measures could play a crucial role in the agro-ecosystems adaptation to climate changes, thus sustaining crop production. The objective of this study was to assess the suitability (and the best combination) of agro-ecological techniques as potential resilience strategies in organic horticultural systems in a Mediterranean environment. A long-term experimental device called MITIORG (*Long-term climatic change adaptation in organic farming: synergistic combination of hydraulic arrangement, crop rotations, agro-ecological service crops and agronomic techniques*) is set-up at Metaponto (MT), testing the following agro-ecological measures as well as organic and conservation farming *best practices*: i) hydraulic arrangement by a kind of ridge-furrow system; ii) cash crop rotations; iii) agro-ecological service crops (ASC) introduction; iv) ASC termination techniques (green manure *vs* roller crimper); and v) organic fertilisation. The research here reported was carried out during the 2014-2015 season in the MITIORG device, on a rotation of cauliflower (*Brassica oleracea* L.) and tomato (*Solanum lycopersicum* L.) crops. A detailed description of the scientific cognitive process that led to setup of the device, its components explanation, as well as preliminary yield results are reported. The outcomes suggest that organic vegetable cropping systems, designed following agro-ecological principles, are able to sustain yield of cash crops in rotation, in spite of changes in temperature and rainfall of the study site. Experimental data available in the next years will allow a deeper integrated analysis of the manifold effects of agro-ecological measures on horticultural systems.

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Introduction

Paris hosted the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21/CMP11), from 30 November to 11 December 2015. The conference is crucial because the expected outcome is a new international agreement on climate change, applicable to all, to keep global warming below 2°C. The last report of the Intergovernmental Panel on Climate Change (IPCC) indicates that the rise of carbon dioxide (CO_2) and associated greenhouse gases could lead to a 1.4 to 5.8°C increase in global surface temperatures, with subsequent effects on precipitation frequency and amounts (IPCC, 2014). The predicted changes in temperature and increased frequency of extreme events (*e.g.*, droughts and floods) will reasonably lead to reduced crop yields, depending on specific site conditions and cultivated crops, by influencing plant growth as well as weed, insect pest and pathogens pressure and invasiveness, thus affecting global food security (Altieri *et al.*, 2015).

To be sustainable, an agro-ecosystem requires production systems that are resilient to different stressors such as climatic variability as well as disease and pests. Adaptation can be considered a key factor that will shape the future severity of climate change impacts on food production. According to Heinemann *et al.* (2014), most of the crops are grown under monoculture systems of a handful of varieties, which are highly vulnerable to climate change due to their ecological homogeneity. Conversely, agricultural biodiversity and knowledge preserved by traditional farming systems are essential to strengthen the resilience of agro-ecosystems and help them in climate change adaptation. Agro-ecosystem adaptation is obtained through a number of (often combined) strategies, such as the sustainable use of water resource, soil organic matter management and the diversification of farming systems (Jarvis *et al.*, 2013; Mijatovic *et al.*, 2013). The use of these strategies is crucial, particularly the farming systems diversification, since biodiversity performs different ecological services, including recycling of nutrients and regulation of microclimate and local hydrological processes.

Several agro-ecological management practices (*e.g*., promoting local genetic diversity, crop rotations, cover crops and crop/livestock mixing) increase agro-ecosystem diversity and complexity both over space and time, allowing adapting to extreme climatic events (Altieri and Koohafkan, 2013). In particular, in sustainable/organic farming systems, cover crops maintained as living mulches, and introduced as buffer zones or break crops can provide beneficial services to the agro-ecosystem. These crops can promote in-field biodiversity, contribute to weed, pest and diseases management, NO_3^- leaching reduction, *etc*. Thus, according to Canali *et al.* (2015b) they can be defined agro-ecological service crops (ASC). In addition, the selection of different ASC species and families, because of their different specific features and potential mineralisation rate, is an effective tool to manage N nutrition. As an example, the use of leguminous ASC can sustain subsequent crops production, by improving soil nitrogen (N) fertility (due to the fixation of N in often low C:N residues) and resource use efficiency, and increasing the soil organic matter when ploughed into the soil (Davis, 2010; Ciaccia *et al*., 2015a). Soil organic matter is of utmost importance for resiliency (and can be important for agricultural systems adaptation), since it improves the soil water retention capacity, enhancing the drought tolerance by crops. Moreover, it increases infiltration and surface soil aggregation, thus diminishing soil losses through runoff (Diacono and Montemurro, 2011).

Therefore, in a climate change context, the objective of this research was to study the suitability of a set of agro-ecological techniques (*i.e*., soil hydraulic arrangement; crop rotations; ASC and their termination methods; organic fertilisation) as potential adaptation strategies for organic agro-ecosystems in a Mediterranean environment.

A substantial part of this paper concerns the description and knowledge base of the innovative MITIORG (*Long-term climatic change adaptation in organic farming: synergistic combination of hydraulic arrangement, crop rotations, agro-ecological service crops and agronomic techniques*) experimental device, in which different combined strategies are being tested in a site characterised by high temperature and drought in summer, and extreme rainfall events in winter season. The aim is to identify the best synergistic combination of the adopted agro-ecological measures, thus assessing the agronomic effectiveness of this innovative experimental device. The second part of the present work regards some preliminary yield results both on cauliflower and tomato crop. The ultimate goal of the ongoing research is to ensure the adaptation of horticultural systems to climate change.

Materials and methods

Experimental device design

The MITIORG experimental device consists in a long-term field trial in organic horticulture, which is ongoing at Metaponto (MT), in southern Italy (lat. 40° 24' N; long. 16° 48' E), on the research farm *Azienda Sperimentale Metaponto* of the Research Unit for Cropping Systems in Dry Environments, Council for Agricultural Research and Economics (CREA-SCA). This experimental device tests different agro-ecological techniques, as well as organic and conservation farming *best practices*. It is the sum of different functional integrated layers, namely: i) hydraulic arrangement; ii) crop rotations; iii) ASC introduction and their termination techniques; and iv) organic fertilisation.

The base layer is the soil hydraulic arrangement, that is a kind of ridge-furrow system in which vegetable crops are cultivated both above three raised (convex-shaped) soil strips and between them in four furrowed (concave-shaped) soil strips. This system is obtained through ploughing on the left-hand side of a strip and, as the plough turns the soil over, it moves it to the right. On reaching the end of the strip, the plough is taken back down the other side, determining the soil to build up in the centre of the strip.

To design sustainable cropping systems that consider the specific climatic features of the study site, the cash crops are being cultivated by introducing the ASC *functional layer* in the crop rotations, defined as living mulch (LM) and break crops on the raised and furrow strips, respectively. In the LM systems, the ASC is intercropped with a cash crop and maintained as a living ground cover throughout its growth cycle. Conversely, since the break crops need to be terminated prior to the subsequent cash crop planting, MITIORG tests ASC termination by green manure *vs* flattening by roller crimper.

Finally, the last component of MITIORG is the organic fertilisation, using commercial and experimental fertilisers and amendments, to maintain or increase soil fertility.

A more detailed description of the experimental device, designed on the basis of previous studies, is provided in the *Results* and *Discussion* sections.

Study site

The Metaponto site is characterised by an *accentuated thermo-Mediterranean* climate (Unesco-FAO, 1963). The total rainfall (221 mm) was lower than the 30-year long-term average (267 mm), over the period August-December 2014, whereas the peak rainfall was reached at beginning of October (63 mm in 24 h). Mean temperatures were higher (18.6°C) than the long-term average of 17.1°C (data not shown). Conversely, during tomato cropping cycle (over the period April-August 2015), both the total rainfall and mean temperatures values (116 mm and 21.8°C, respectively) were very close to the 30-year long-term averages (117 mm and 20.8°C, respectively; data not shown).

Soils are classified as *Typic Epiaquerts* (Soil Survey Staff, 1999).

Experimental setup and treatments

The research here reported was carried out during the 2014-2015 season in the MITIORG experimental device on a rotation of cauliflower crop (*Brassica oleracea* L. cv. *Triunphan*) cultivated above the convex-shaped soil strips and tomato crop (*Solanum lycopersicum* L. cv. *Donald*) in the concave-shaped soil strips.

As regards cauliflower crop, the experiment was carried out according to a strip-plot design, where two factors were tested with three replications (Gomez and Gomez, 1984). The experimental area was made of three blocks (vertical strips) corresponding to the LM (burr medic, *Medicago polymorpha* L. var. *anglona*) sowing time treatments: i) early sowing (ES; 20 days before cauliflower transplanting); and ii) concurrent sowing (CS; at cauliflower transplanting), which were compared to a no living mulch control (NMC). Moreover, each block was subsequently divided, as a randomised block design, in four horizontal strips corresponding to the following organic fertilisers and amendments, allowed in organic farming: i) anaerobic digestate fertiliser, based on cattle slurry (AD); ii) composted municipal solid organic wastes from the city of Laterza (*Fertileva*; Progeva s.r.l., Laterza, TA, Italy) (MSW); iii) commercial humified organic fertiliser (ORG), based on dried cattle manure (*Italpollina*; CRAI s.r.l., Rivoli Veronese, VR, Italy); all compared to iv) an unfertilised control (NFC). Additional information about production processes for MSW is reported in Montemurro *et al.* (2013). The organic materials were applied to soil one month before cauliflower transplanting, at the rate of 100 kg N ha^{-1}. To account for the potential contribution of burr medic biological N fixation in the first two treatments, the fertilisation applied in ES and CS was compared to an application rate of 200 kg N ha^{-1} of the same organic materials in the NMC plots. Each burr medic sowing times × fertiliser combination plot (intersection plot) resulted in a 24 m^2 area. The cauliflower crop was manually transplanted on 2 September 2014 and it was harvested four times, at the crop commercial maturity, from 28 November to 3 December 2014.

As regards tomato crop, the experiment was carried out according to strip-strip-plot design where two factors were tested with three replications. The ASC crops, vetch (*Vicia sativa* L. cv Marianna), barley (*Hordeum vulgare* L. cv Lutece) and a mixture of them were cultivated in the winter period, before tomato (cash crop) transplanting (compared to a no-ASC control). In particular, the field area was divided into four blocks and each block was further split, as a randomised complete block design, into four vertical strips corresponding to each ASC tested. Each strip was then horizontally divided into the following ASC termination treatments: i) ASC incorporated as green manure, in which the biomass was chopped and ploughed (to a 15-20-cm depth) at the end of ASC flowering (GM); ii) flattened ASC mulch, obtained by roller crimper technique (RC), in which the mulch layer remained in place covering the soil surface and, after tomato harvest, it was incorporated in the soil with surface tillage (15-cm depth). These two experimental treatments were compared to iii) a fallow-control, in which ASC was not sown and the soil was tilled before tomato transplanting (CT). Moreover, each management block was divided into three horizontal strips corresponding to the following organic fertiliser treatments: i) AD; ii) the same ORG as for cauliflower; compared to iii) NFC.

The organic materials were applied four days before ASC termination, at the rate of 75 kg N ha^{-1}. To account for the potential contribution of ASC for N, the fertilisation applied in AD and ORG was compared to an application rate of 150 kg N ha^{-1} of the same organic materials in the NFC. Each ASC termination management × fertiliser combination plot (intersection plot) resulted in a 30 m^2 area.

The tomato crop was manually transplanted on 27 April 2015 and it was harvested three times at the crop commercial maturity, from 14 July to 26 August 2015.

Yield determination and statistical analysis

Cauliflower heads were collected from three randomly selected plants in each plot during the cash crop harvest and cauliflower head yield (t ha^{-1}) was determined. Similarly, tomato yield (t ha^{-1}) was obtained from three randomly selected plants in each plot, by collecting marketable red fruits.

Analysis of variance (ANOVA) was carried out in both experiments, with ASC management strategies and cultivar/fertiliser as factors. To compare differences obtained, means were further analysed by Tukey's honest significant difference test (P<0.05). The selected analysis was performed by SAS/STAT software, release 9.3, 2012 (SAS Institute Inc., Cary, NC, USA).

Results

An innovative experimental device from design to practice

The input knowledge for planning our complex experimental device was derived from previous studies on agro-ecological strategies, which were carried out by the CREA-SCA and CREA-Research Centre for the Soil-Plant System research groups (Table 1). These studies represent the starting point on the basis of the *pros* and *cons* of the tested strategies, as indicated in the results column of the reported table.

Figure 1 shows a synthetic scheme of the MITIORG long-term experimental device, as it was set up in the light of the acquired knowledge. On the top of two of the three planned soil *convex* strips, a leguminous ASC (*e.g.*, burr medic) is intercropped as LM with a winter cash crops (*e.g.*, cauliflower), in comparison with a no-living mulch control on the third strip. Time of sowing of the ASC (anticipated *vs* concurrent), in respect to the transplanting of the associated cash crop, is a tested factor, since it may determine the effectiveness of this technique in providing agro-ecosystem services.

In three *concave* soil strips, pure ASC or mixtures of species belonging to different botanical families (different proportions of legume and non-legume crops) are utilised in the winter period, in comparison to a control strip without ASC. The cash crops in rotation are always summer crops (*e.g.*, tomato and lettuce), and the ASC are cultivated as break crops between two consecutive cash crops. ASC incorporated as green manure, in which the cover crop is chopped and ploughed (to a 15-20-cm depth) at the end of flowering, is compared with flattened ASC by roller crimper technique, in which the mulch layer remains in place covering the soil surface (the main crop is sown or transplanted in it) till to cash crop harvest.

In the experimental design, each (minimum tilled) vertical block, both on the convex and concave strips, is further divided into horizon-

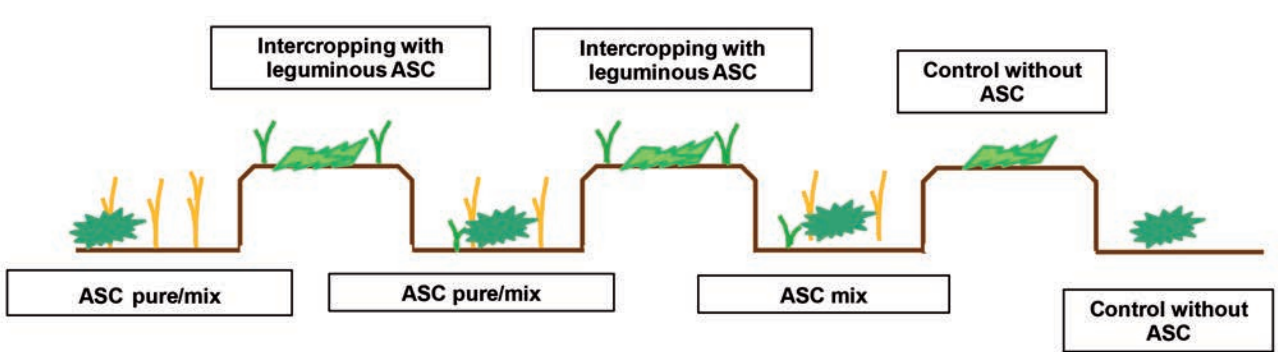

Figure 1. Distribution scheme of the agro-ecological service crops (ASC) on the convex-shaped soil strips and in the wide-furrow strips within vegetable crop rotations (vertical section of the field).

Table 1. Previous studies on agro-ecological strategies tested on organic horticultural systems (selected references by project creators).

Treatments	Cash crop	Main results	Reference
- ASC management (vetch grown as GM; RC vetch; no cover control) - Organic fertilisers and amendments (no fertiliser; MSW; ORG; AD)	*Cucurbita pepo L.*	The variable climatic conditions affected the results, suggesting the need to diversify the agronomical strategies in different environments. The ASC termination method seemed to be able to influence the weed presence, its impact on crop N uptake and the weed-crop competitive relationships. The AD showed comparable results in comparison with ORG for yield and, when combined to vetch management (*i.e.*, GM and RC), in terms of N balances	Ciaccia *et al.*, 2015a
- Living mulch (*Medicago polymorpha* L.) sowing time (AS; CS; NL) - Organic fertilisers and amendments (no fertiliser; MSW; ORG; AD)	*Brassica oleracea L.*	The climatic conditions notably influenced cauliflower cultivation and reduced the mean yield. AS and CS treatments showed significantly higher yields than NL and a strong weed biomass decrease. An inverse trend between the growth of the cash crop and that of the ASC was observed for CS. Comparable yield results of MSW with ORG were observed	Canali *et al.*, 2015a
- Different autumn-winter ASC (wheat, barley, spelt, rye, their mixture and a no cover control) - Termination of ASC by flattening with RC, at flowering stage	*Cucumis melo L.*	The ASC species significantly affected weed density before and after flattening, although no difference on their biomasses was recorded at termination. At melon harvest, weed biomass was significantly lower in ASC treatments than in control	Ciaccia *et al.*, 2015b
- ASC management (vetch grown as GM; RC vetch; no cover control) - Organic fertilisers and amendments (no fertiliser; MSW; ORG; AD)	*Cucurbita pepo L.*	Averaging over 2 years, marketable zucchini yield increased by 15.2% and 38% with the RC mulch and GM, respectively, compared with control. The findings indicated that both ASC and organic fertilisers and amendments are constrained by environmental conditions and their effects are most valuable when a typical or favourable weather pattern occurs	Montemurro *et al.*, 2013
- ASC management (barley grown as GM; RC barley; no cover control) - Two different zucchini hybrid: dietary and every	*Cucurbita pepo L.*	Zucchini cultivated by the RC technique yielded 69% more than the zucchini preceded by the GM and similarly to the control. Weed aboveground biomass was 22 and 91% lower than the control in the GM and in the RC treatments, respectively. The RC also increased the N system use efficiency of 29% compared to the GM treatment	Canali *et al.*, 2013
- Subterranean clover GM vs no cover control - FYM or green compost (C) at 3 different rates, corresponding to N at 0, 50 and 100 kg ha^{-1}	*Solanum tuberosum L.*	The cultivation of clover GM and the application of FYM increased the total potato yield of 22.5% and 25.1%, respectively. The highest dose of organic amendments increased the potato production and N use efficiency by 43.3% and 16.9%, compared with unfertilised control. The combination of clover GM and amendments did not increase the soil mineral N at the end of the cropping cycle. Therefore, it is possible to modify the agronomical practices without enhanced potential environmental risks due to N leaching	Canali *et al.*, 2010

ASC, agro-ecological service crops; GM, green manure; RC, flattened by roller crimper; MSW, municipal solid waste compost; ORG, commercial animal manure; AD, anaerobic digestate fertiliser; N, nitrogen; AS, anticipated sowing, 20 days before crop transplanting; CS, concurrent sowing, concomitant to cash crop transplanting; NL, no living mulch control; FYM, farmyard manure; C, carbon.

tal strips corresponding to different organic fertiliser treatments allowed in organic farming, in comparison with an unfertilised control. Among them, commercial organic fertiliser, anaerobic digestates and composted municipal solid organic wastes from separate collection are provided to be used.

Treatment effects on cauliflower and tomato crop performance

Significant main effects of LM sowing time and fertiliser treatments on cauliflower head yield, as well as significant two-way interactions, were found (Table 2). The highest head yield value was obtained in NMC-AD combination (24.7 t ha^{-1}), which was significantly different from all ES-fertiliser treatment interactions and the other interactions with NMC treatment (Figure 2). In particular, NMC-AD value was significantly higher by 108% than ES-MSW. Among fertilisers, the best results were found for AD, which showed values in combination with NMC and CS (19.4 t ha^{-1}) that were comparable with CS-ORG (21.66 t ha^{-1}).

Significant main effect of ASC termination management on tomato yield was found, showing the highest value in GM, which was significantly higher by more than 140% and 124% in comparison with RC and CT treatment, respectively (Table 2).

Discussion

MITIORG long-term experimental device

In the last decades, extreme rainfall events occurred in the Metaponto area, during autumn and winter periods, which greatly influenced crops productivity in horticultural systems. Therefore, the MITIORG innovative experimental device has been conceived to adapt organic horticultural systems to unfavourable climatic conditions, by combining different agro-ecological measures and best practices.

The soil hydraulic arrangement is carried out to increase the rooting depth layer in periods with high rainfall, thus allowing the survival of the crop, particularly in the event of flooding. In addition, it can eliminate the risk of water stagnation, making easier the lateral outflow of the excess water, and it may reduce the leaching potential of inorganic N in autumn and winter (Giardini, 2004; Henriksen *et al*., 2006).

As regards the ASC management, in MITIORG the LM is intercropped with the winter cash crop and maintained as a living ground cover, managing time of ASC sowing (Hartwig and Ammon, 2002). According to Canali *et al*. (2015a), this practice can contribute to improve the effectiveness of the LM technique in providing agro-ecosystem services without competing with the cash crop. By contrast, the ASC cultivated as break crops in the concave strips need to be terminated prior to the subsequent cash crop planting, in order to provide their services to the system and avoid competition (Montemurro *et al*., 2013). Therefore,

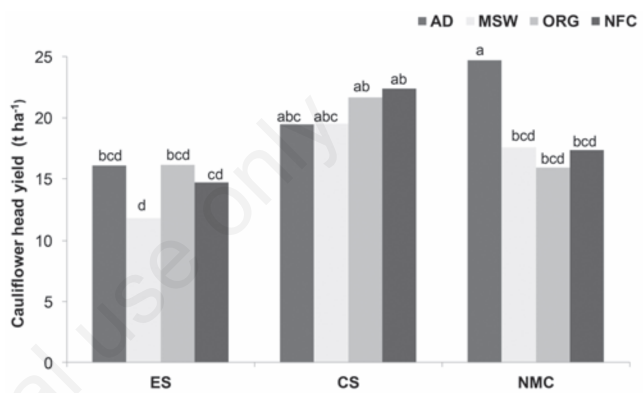

Figure 2. Interactions between living mulch sowing times and fertilisers on cauliflower head yield (t ha^{-1}). Bars with different letters are significantly different according to Duncan's multiple range test at the P≤0.05 probability level (ES, early sowing 20 days before cauliflower transplanting; CS, concurrent sowing, at cauliflower transplanting; NMC, no living mulch control; AD, anaerobic digestate fertiliser, based on cattle slurry; MSW, composted municipal solid organic wastes; ORG, commercial humified organic fertiliser; NFC, unfertilised control).

Table 2. Effects of living mulch sowing times (agro-ecological service crops management for tomato) and fertilisers on cauliflower head yield and tomato yield (t ha^{-1}).

Caulifower head yield (t ha^{-1})		Tomato yield (t ha^{-1})	
Living mulch		ASC management	
ES	14.7[b]	GM	21.2[a]
CS	20.7[a]	RC	8.74[b]
NMC	19.7[a]	CT	9.48[b]
Significance	***	Significance	**
Fertiliser		Fertiliser	
AD	20.1[a]	AD	14.4
MSW	16.3[b]	-	-
ORG	17.9[ab]	ORG	16.0
NFC	18.1[ab]	NFC	11.3
Significance	*	Significance	n.s.
Interactions	**	-	n.s.

ASC, agro-ecological service crops; ES, early sowing 20 days before cauliflower transplanting; GM, green manure; CS, concurrent sowing, at cauliflower transplanting; RC, roller crimper; NMC, no living mulch control; CT, control; AD, anaerobic digestate fertiliser, based on cattle slurry; MSW, composted municipal solid organic wastes; ORG, commercial humified organic fertiliser; NFC, unfertilised control; n.s., not significant. *, **, ***Significant at P<0.05, 0.01 and 0.001, respectively. [a,b]The probability levels are presented by living mulch sowing time, fertiliser and their interactions.

different ASC termination treatments are compared in the experimental field, *i.e.*, GM and flattening by RC. The incorporation as GM into the soil, by chopping and ploughing, is the traditional technique used to terminate the cropping cycle of the ASC cultivated as break crops (Watson *et al*., 2002). Conversely, the innovative RC technology terminates ASC by flattening them, with one or two passages of the roller crimper, leaving a thick mulch layer into which the next crop is sown or transplanted (Teasdale *et al*., 2012).

As regards the organic fertilisers and amendments used in the experimental device, several studies have shown promising yield results from their application, particularly for municipal solid waste compost (Montemurro *et al.*, 2005, 2007) and anaerobic digestates (Montemurro *et al.*, 2010) in different crops. The combination with the above-described agro-ecological practices should sustain and improve the expected services to the agro-ecosystem.

Cauliflower and tomato crop performance

The cauliflower production results were better with CS than with ES treatment, confirming the role of LM sowing period highlighted by other authors in different vegetable crops (Kolota and Adamczewska-Sowińska, 2004) and suggesting that no competition was determined between cash crop and ASC in the CS treatment. Moreover, the obtained yields were (on average) close to the values (13-22 t ha^{-1}) recorded in organic farms of more fertile areas in central Italy, and they were also comparable to productive levels detected in the Metaponto area (20-30 t ha^{-1}) under conventional agriculture.

The comparable yield results of AD with ORG fertiliser indicated that both are viable options for organic farmers in the study site. Similarly, different studies have found that, in organic farming, commercial fertilisers could be effectively replaced by locally available organic fertilisers and amendments (Montemurro *et al.*, 2005, 2015). Moreover, from the productive results in ES and CS combinations, it can be inferred that the ASC could mitigate the peaks and deficit of N, since it is a N-fixing crop.

In the tomato cropping cycle, the GM showed best results than RC treatment likely because total amount of N was more available in the traditional treatment, since much of the N comes from the above-ground biomass decomposition (Ciaccia *et al*., 2015a). Conversely, according to Shirtliffe and Johnson (2012), the lower yield in RC than in GM might be associated to a reduced N mineralisation of the ASC residues left on soil surface. No consistent information about tomato yields is available by organic farms of Metaponto area. Anyway, yields were comparable to productive levels (on average: 11 t ha^{-1}) for organic tomato in similar climatic conditions (Puglia, Italy). However, it should be considered that different biotic and abiotic variables could have interacted with the complex MITIORG experimental device, thus determining the observed yield results.

Conclusions

Despite the wide acknowledgement of the contribution of the ASC to sustain agricultural production and to promote environmental protection, the dissemination of knowledge on appropriate agro-ecological measures and ASC management for adapting agriculture to climate change is still limited. Therefore, to empower the use of ASC particularly within organic and sustainable systems, research activities in a wide range of agro-climatic conditions should be encouraged.

The preliminary results obtained in our study suggest that organic vegetable cropping systems are able to sustain yield of cash crops in rotation, when they are designed in accordance to agro-ecological principles. This result can be obtained in spite of changes in temperature and rainfall recorded in the Mediterranean environment. As a matter of fact, an innovative approach is crucial to this end, by combining different agronomic strategies (*e.g.*, proper selection of ASC sowing time and termination methods, organic fertilisers and amendments application, *etc.*) as in the described experimental device. However, as the reported crop rotations period could be considered not sufficient to draw general conclusions on the findings observed, it is necessary to point out that more data will be available by the ongoing research to assess long-term effects. In fact, the MITIORG is a long-term experimental device (Diacono and Montemurro, 2015), thus, data available in the next years will allow a deeper integrated analysis of manifold effects of the agro-ecological measures on horticultural systems. This could help to evaluate the potential of the tested strategies to provide agro-ecological services in the short, medium and long-term periods.

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