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Challenges for the European research in organic fruit production

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1 Introduction

The market for organic products in the European Union (EU) has recorded a growth rate of 8% in 2019, to reach a value of retail sales of about EUR 41.4 billion (Trávníček et al., 2021), in line with the global trend (Willer and Lernoud, 2021), transforming the sector from a niche into one of the pillars of agri-food production systems. The production sector has responded with a more than 50% increase of the share of EU agricultural land managed according to organic farming rules over the period 2012-2020, achieving 14.8 million ha (9.1% of the total EU agricultural land) in 2020, with fruit, olives and grape crops representing 11% of the organic land area (European Commission, 2023). This situation has been reached also as a result of several EU policies (e.g. through the Common Agricultural Policy) developed since the first enactment of EU rules on organic products in 1991, up to the recent Green Deal and Farm to Fork strategies (European Commission, 2020) and the Action Plan on organic farming (European Commission, 2021).

To achieve the target of 25% of total agricultural production by 2030 set in the above-mentioned EU policy documents, the number of organic producers in the EU needs to increase at a faster rate and organic fruit growers need to increase their share of market supply. However, converting from conventional to organic production systems is a challenging path, as, particularly for fruit crops, organic fruit production is technically demanding and knowledge-intensive, thus requiring knowledge sharing as well as dedicated research (Malusà et al., 2022). Research activity shall particularly focus on the topics that are mostly demanded by farmers and advisors, as recently emerged from an EU-wide survey: plant protection, management of soil and its fertility, improvement of functional biodiversity, varieties and rootstocks suitable for organic cropping systems (Furmanczyk et al., 2022; Parveaud et al., 2022). However, it is our opinion that since the research activity shall support transdisciplinary professional skills in fruit growers and advisors, the correct approach of future research in organic fruit production shall take into consideration also some challenges deriving from the overall trends currently occurring within different domains, i.e. legal (including different implementing measures at member state level of the EU legislation), market-driven, social.

2 The need for biodiversity

Organic farming is considered a system of farm management that combines a high level of biodiversity and the preservation of natural resources with best environmental and climate action practices, where organic plant production shall be based on nourishing the plants primarily through the soil ecosystem (Regulation EU 848/2018). The beneficial effect of organic agriculture on overall biodiversity has been frequently reported (Gabriel et al., 2010; Gangatharan and Neri, 2012; Ponzio et al., 2013). Enhanced biodiversity is a concrete tool to strengthen farm efficiency by enabling important ecological services as pollination or shelter to beneficial arthropods, pests and weed control (Simon et al., 2011; Campbell et al., 2017; Herz et al., 2019; Mia et al., 2021; Fountain, 2022) and maintenance of soil fertility (Mia et al., 2020). However, increased biodiversity in organic farms is generally not sufficient to adequately control harmful pests, which forces the farmer to use authorized plant protection products that can also negatively affect the biodiversity, including that of soil, even though likely to a lesser extent than conventional farming (Malone et al., 2017; Brühl et al., 2022). Research is thus needed to identify site adapted strategies reducing pests' occurrence in organic systems while keeping high the degree of on farm biodiversity. An interesting approach in this respect could be that of integrating several measures that could strongly limit the need of pesticides (Andrivon et al., 2018; Alaphilippe et al., 2021). However, a better understanding of the impact of the surrounding environment on farm biodiversity, including pests, is also a challenging topic that needs to be addressed. Indeed, within-farm biodiversity is influenced by both management of the farm and management of surrounding farms or the natural landscape (Markó et al., 2017; Nicholson et al., 2017; Katayama et al., 2019), which highlights the relevance of the landscape in the agricultural management of organic orchards.

Restoring functional biodiversity of the agricultural landscape at the farm level (e.g. avoiding mono-cropping) can lead to agroecosystems capable of sustaining their own soil fertility and productivity (Neri et al., 2021; Giorgi et al., 2022). Soil is, indeed, acknowledged as a limited resource, which determines crop productivity and ecosystem sustainability through various ecosystem services. Accumulation of residues from a single crop can disrupt the humification process, delaying the stabilization of the organic matter and favor the release of toxic metabolites (Neri, 2013). These processes may induce specific allelopathic effects (dispathy) accounting for 'soil sickness', a complex symptomatology and etiology, commonly observed in several fruit crops, influenced by soil, agronomic conditions, soil and microbiome disfunctions (Cartenì et al., 2016; Cesarano et al., 2017; Polverigiani et al., 2018). However, a conclusive technical solution to them is still lacking also in case of intensive organic orchards.

Soil health is closely related to soil fertility, which, from an agronomical point of view, is associated to the processes of organic matter decomposition, immobilization and mineralization of nutrient elements to be exploited by the plant. However, these processes in organic orchards are seldomly synchronized with the nutrients' needs of the crop frequently resulting in nutrient imbalances due to biased element composition of fertilizers not matching the overall specific offtakes of crops (Möller, 2018). Practices of soil management aiming at improving the orchard biodiversity (e.g. living mulches or cover crops) can also contribute to reduce nutrient losses by leaching (Thapa et al., 2018), or improve nutrients availability in a variable amount along their growing cycle with benefits for the fruit crop. However, to increase synchronization between nutrients supply and plant demand there is the need to adapt general principles to local conditions and cropping systems, which requires further research.

The application of organic fertilizers or biostimulants (as they are currently defined by the new EU Regulation on fertilizing products) derived from agroindustrial by-products represents an interesting opportunity in organic farming (Polverigiani et al., 2014) that can foster the circular economy approach in organic production related to fertilizers, energy, packaging and other uses (Schifani et al., 2018; Nattassha et al., 2020; Vetroni Barros et al., 2020; Morais et al., 2021). Nevertheless, a key role in this respect is played by the microbiome biodiversity in the soil, which takes part in the biogeochemical cycles and strongly affect soil fertility and plant health (Vassilev et al., 2021; Malusà et al., 2023). The soil, its microbiome and the plants present in the orchard (both the crop and the accompanying species) are involved in direct and indirect relations, which are difficult to predict, and in many cases depend on environmental factors (Kaisermann et al., 2017; Valencia et al., 2018; Tartanus et al., 2021). A comprehensive understanding of these interrelated and context-dependent mechanisms requires studies on management practices and selection/production/application of specific microorganisms to increase crop resilience against different biotic and abiotic stresses. The study of plant–microbiome-soil interactions is now considered fundamental to explain the vegetation dynamics that influence ecosystem composition and functioning. This is leading to enhanced understanding of ecological-evolution and allows better prediction and mitigation of consequences of human-induced global changes, such as climate warming, invasions of alien species and land use changes. To this end, the challenge to be addressed by the researchers in organic fruit production is to acquire a complex set of data to be used as a tool in assessing impacts of introduced formulates (organic and microbial biostimulants, biopesticides, organic fertilizers) on the soil and the plant, to facilitate the efficient application of commercial products in practice. The integration of practices fostering functional biodiversity with the application of pro- or pre- or postbiotics (Vassileva et al., 2020) could lead to new practices with lower environmental impact. However, several practical aspects (e.g. the mode of application, the relation between microbial inocula and rootstocks, etc.) still need to be addressed by research work and to be validated under field conditions to transform a potential opportunity into a successful practice.

3 A sustainable intensification

The research for sustainable production is mandatory to cope with climate change and its impact on the organic fruit cropping systems (Neri et al., 2020). The effects of climate change can be limited by developing innovative strategies (Balafoutis et al., 2017; Roy and George, 2020; Rumpel and Chabbi, 2021; Singh et al., 2022) or adapting traditional techniques in organic orchard and vineyard management (Scialabba and Müller-Lindenlauf, 2010; Polverigiani et al., 2018). However, among the future challenges of sustainable organic farming systems we need to consider the provision of social services.

Social support and consumers appreciation of organic farming systems are crucial to match food safety and security requirements with the conservation of biodiversity and the improvement of the ecosystem services that can be provided by organic farming. The increased concern about contaminants (e.g. PFAS or antibiotics) introduced into the cropping systems through external inputs (e.g. fertilizers, irrigation water) (Cycon et al., 2019; Ghisi et al., 2019) can foster consumers choice favoring the transition toward organic farming, as aspired by the EU strategies. However, a threat to this transition could derive from the development of new certification schemes with appealing names, for both the consumers and the retailers, characterized by less demanding implementing requirements for farmers (e.g. the regenerative agriculture) (Newton et al., 2020). The challenge in this respect will be to prove the higher benefit of organic farming in terms of value of ecosystem services (Meng et al., 2016; Borsotto and Malusà unpublished), food quality (Zikeli et al., 2014) and health (Ferretti et al., 2017). Consumers wishing to reduce their exposure to potentially harmful pesticide residues, nitrates and food additives should be aware that choosing organic produce assures their demands. For this reason, the consumers understanding of the characteristics of the organic cultivation systems has become crucial to the effort in enhancing public health through modern nutrition (i.e. utilizing fruits containing more beneficial metabolites or nutraceuticals) (Brandt et al., 2011; Mditshwa et al., 2017; Sangiorgio et al., 2021). Available data demonstrate the potential for a substantial positive impact on public health and healthcare costs by switching to organic food consumption (Rempelos et al., 2021) but controlled clinical trials confirming a mechanistic understanding of this positive health impact are still missing. Therefore, research is urgently needed to clarify the relationship between agricultural management and the nutritional quality of organic fruit crops, including effects on health protection and the prevention of chronic diseases. The One Health approach (Van Bruggen et al., 2019; Banerjee and van der Heijden, 2023) could be a suitable framework to be applied in this regard, linking environmental health to the animals and human health, as embedded in the holistic principles of organic farming. It is our opinion that this would allow to conclusively rebut the conclusions of Trewavas (2001) or the concerns of Kirchmann (2019). Indeed, in the past twenty years it has been proved that the benefits of organic production are far more reaching than the simple impact on the crop (Wassermann et al., 2019; Krause et al., 2022) and the lower yield of organic crops would be still sufficient to cover food demand when food waste is decreased (Dou and Toth, 2021).

4 Conclusions

Organic horticulture shall promote a shift in the paradigm of fruit production, addressing challenges in the whole food production chain while minimizing environmental pollution and supporting fairness for producers (Arbenz et al., 2017). However, organic fruit production systems currently face the risk of a “substitution” approach, applying products authorized in organic production instead of those allowed in conventional farming, as orchard management methods largely depend on external inputs. However, obtaining these inputs through a circular economy approach could make them less controversial and more efficient in improving soil fertility and health, lowering at the same time also the carbon footprint of the organic cropping systems. The conventionalization of organic food-chains may challenge the credibility of the sector as it highly depends on consumers’ perception. The research efforts should thus embrace a complex approach that could limit the risk of losing this authenticity. Nevertheless, the crucial question of whether organic is “worth the extra cost” will remain on the consumers’ side.

Notwithstanding the focus on avoiding the conventionalization of organic fruit production, it shall be underlined that some regulatory issues are considerably limiting the exploitation of traditional or new “active substances” for plant protection that express multi-functional properties (Kowalska et al., 2020), as well as the possible use of new breeding approaches to support varieties’ evolution (Ristel and Satter, 2014; Kellerhals et al., 2016), which is an obstacle for the improvement of organic orchard management strategies. Engaging in the dialogue with policy makers to support the development of legal provisions could thus be an important challenging role for researchers, which could positively impact on the organic horticultural production systems.

Author contributions

EM and DN contributed to conception and design of the work. EM and DN wrote sections of the manuscript and contributed to manuscript revision, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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