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Review

The Evolution of Soilless Systems towards Ecological Sustainability in the Perspective of a Circular Economy. Is It Really the Opposite of Organic Agriculture?

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Abstract: Soilless cultivation systems were primarily developed in response to the excessive spread of soil pathogens; however, they also allow an optimal control of plant grow, high productivity and product quality as well as very high efficiency of water and fertilizer use. At the same time, consumers remain critical towards soilless-cultivated vegetables, mainly due to the perception of these techniques as unnatural, resulting from artificial growth and consequently characterized by low quality. This mini review analyzes the evolutionary process of soilless cultivation within a vision of agriculture that supports environmental sustainability as the central theme of the discussion. Current knowledge suggests that, although apparently opposite, organic and high-tech soilless cultivation have several common or converging points in view of a sustainable use of resources on the planet. As a consequence, new policies should be oriented toward a reduction of environmental "pressure" by introducing a process certification of low environmental impact, which, together with an adequate product certification, related not only to the environmental aspect but also to product quality, can reduce the opposition of the two cultivation systems.

Keywords: high-tech cultivation; inputs efficiency; land sparing/sharing model; product certification; renewable growing media; urban horticulture

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1. Need for Food Security and Sustainability Versus Scarcity of Soil and Resources

The world is facing two great challenges: the increasing number of people on Earth and climate change. Both challenges affect the availability of food, which is expressed in terms of food security and the sustainable use of resources on the planet. This implies a substantial change in agricultural activities towards the increase of agrotechnical inputs efficiency and a more environment-compliant agriculture. The strategy should involve the use of sustainable practices, such as precision agriculture, organic farming and agroecology; however, this leads to two contrasting methods of action aimed at reducing the impact of farming on the health of the planet (in terms of preservation of biodiversity, wild species, natural environment and intact resources). The two possibilities are "making farmland itself more wildlife-friendly, or making more space for unfarmed habitats" using the exact words reported by Phalan [1]. This translates into the concrete consideration that we can practice wildlife-friendly farming, up to a limit where yield is reduced; however, lower yields mean more land needed to produce food. This concept is the basis of the land sparing-sharing model [1]. Land sparing concerns interventions that combine increasing yields on farmed land, sparing the conservation and/or restoration of wild nature on other lands. Land sharing involves intentional conservation actions to make farmland more wild nature-friendly so that crops and wildlife coexist on farmland [1].

In horticultural production, the main cropping system is the conventional one, integrated by the organic and the soilless systems, both with a lower degree of diffusion. Organic farming represents 4.6% of the total agricultural area in the world, with 71.5 million hectares all over the world [2]. In the European Union, 7.7% of total agricultural area is under organic management. Horticultural crops grown in organic farming represent 1.6% and 3.1% of the total organic area in the world and in EU, respectively [2]. On the other hand, soilless cultivation covers a very small area, with only 95,000 ha worldwide [3], but it is gaining more and more interest in the horticultural sector due to some cultural advantages.

In the context of the sparing-sharing model, organic farming can play a role according to the land sharing mechanism, since it makes the cultivated area more favorable to wildlife due to the lower use of pesticides and fertilizers [4]. On the other hand, precision agriculture involves means to obtain very high efficiency from technical inputs and high yield increase, thus requiring theoretically less soil to produce food. In this context, cropping systems, including precision agriculture, can be placed within the land sparing model. At this point we need to give a rightful place to soilless systems in this model. Soilless cultivation is applied mainly in protected production as a technology suitable to solve the problems associated with greenhouse soil, such as soil-borne diseases, soil exhaustion or poor fertility and salinity [5]. An exhaustive description of the main features (classification, growing media, nutrient solution, fertigation management) of soilless cultivation is given in the review by Savvas and Gruda [5]. A specific aspect of soilless cultivation is the high degree of innovation it brings to farms through the control of climatic and plant parameters and the management of fertilization via the application of high-tech tools. Sensor control of the water status of growing media and crops (tensiometers, dielectric sensors, plant-sensing for physiological parameters, hyperspectral machine vision technologies), ion-selective sensors capable of monitoring the availability of nutrients in the substrates, automation of fertigation together with remote control and monitoring of greenhouse and soilless devices via the Internet of Things (IoT) make soilless cultivation a successful application of precision agriculture in horticultural production with impressive potential. The integration of soilless cultivation with these tools allows one to reduce consumption of water and nutrients and increase efficiency [6].

The aim of the present mini review is to analyze the evolutionary process of soilless cultivation within a vision of agriculture that supports environmental sustainability as the central theme of the discussion. Once soilless systems have proven to be a sustainable food production method, we will try to shorten the distance between soilless and organic production in terms of environmental impact and product quality.

2. Advantages and Limits of Soilless Agriculture in the Process towards Sustainability

Introduced to overcome the soil-borne problems in protected cultivation, the soilless techniques were first improved based on performance and economic convenience, but soon afterwards, sustainability became the main driver of their refinement, aimed at identifying more environmentally sound alternatives. Changes from open to closed recycling nutrient solution management or from peat-based growing media to renewable organic substrates represent some steps of this process. Where soilless systems are applied with a high degree of innovation, they use less water than soil cultivation, firstly due to avoidance of water losses by infiltration over the root zone that occur in soil cultivation [7], then due to the lower volume of substrate in soilless systems, thus requiring less water [8,9]; at last, the recirculation of the nutrient solution and the extremely reduced or nihil evaporation of water from the isolated environment of the root system noticeably reduce water consumption in soilless culture. This point is particularly relevant to ensure a low environmental and production cost impact for soilless techniques. Closed systems provide the best performance regarding the issue of water and nutrient losses in soilless cropping, but also open loop systems are more efficient than soil cultivation [10]. In the Mediterranean area, the main obstacle to recirculating nutrient solution is the presence of saline ions (Na^+

and Cl^-) in the irrigation water at high concentrations, thereby increasing the electrical conductivity of the recirculating nutrient solution. Strategies to overcome the problem consist in collecting rainwater from greenhouses or applying some technologies to improve the quality of the available water [6]. Other solutions may come from different approaches; for example, the use of zeolite, expanded clay or biochar as substrates contributes to the removal of Na^+ thanks to their cation exchange capacity, increasing the availability of Ca^{2+} and Mg^{2+} in substitution of sodium [11,12]. The use of properly treated wastewater, both from soilless and municipal wastewater, can contribute to save freshwater [13,14].

The search for different components of alternative growing media is a further step towards increased sustainability of soilless systems. The two most widespread materials used as substrate are peat and rockwool, respectively, organic and inorganic. Peat is a non-renewable resource and the exploitation of peatlands has a high environmental impact due to the role of peat bogs in the global carbon cycle, as they represent the most important long-term carbon sinks of terrestrial ecosystems [10]. At present, there are strong limitations to extraction by national and EC legislation [15]. Rockwool has a disposal problem as main criticism of its use in soilless cultivation, though recovering and recycling processes have been proposed to overcome this objection [10]. Various inorganic and organic materials have been tested in soilless cultivation in the last decades with the aim of finding growing media equally effective in supporting the root system and providing short-term storage of water and nutrients, but also possibly recyclable, renewable and with low environmental and economic costs. For example, seaweed-based composts can be usefully used as a sustainable peat substitute for the formulation of soilless mixtures to grow potted plants, even up to a complete peat replacement (Figure 1).

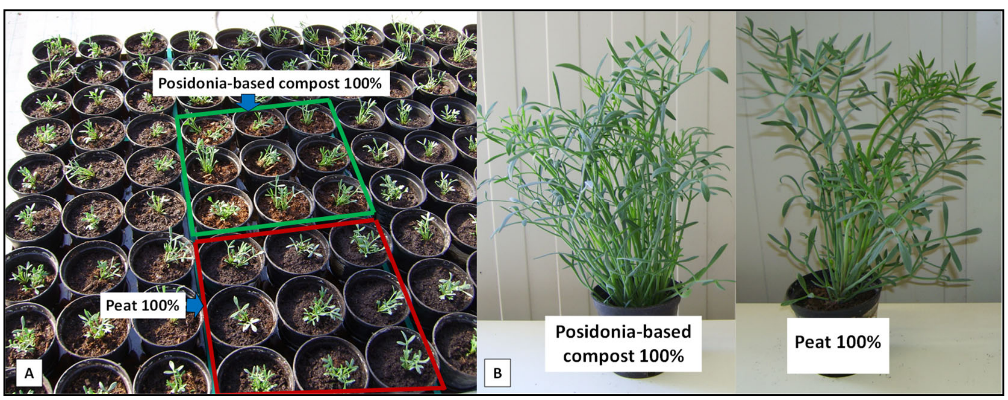

Figure 1. Example of organic renewable materials tested in soilless cultivation: potted sea fennel (*Crithmum maritimum* L.) grown by using posidonia-based materials as a peat substitute without any negative effect on plant growth in comparison with a commercial peat substrate; sea fennel plants after transplanting (**A**) and at harvesting time (**B**) [16].

There is a very rich literature on alternative materials tested for mixed or standalone use as growing media. Exhaustive reviews are given by Barrett et al. [17] and Gruda [10]. In this context, what is interesting is the added value of some constituents in the view of increasing sustainability or overcoming some troublesome aspects of soilless cultivation. Beyond the performance characteristics of a growing medium (physical, chemical and biological), the economic and environmental aspects also have high weight in the examination. Among the performance properties, for organic materials the absence of pathogens (for plant growth and human health) and biological stability (e.g., variations of volume or structure due to microbial decomposition) have non-negligible relevance. In the economic aspects, the processing costs related to the operations required to make raw materials suitable to work well as growing media (e.g., from milling to composting) are overriding, followed by the transportation costs. At last, the environmental points include different factors, from the distance of the origin of materials (preferably the locally sourced matrices) to the source as waste material from industrial, agricultural and municipal waste streams, possibly assuming a role in a circular economy process [17]. This last aspect characterizes composts produced from urban, green, agricultural and food wastes. Their production, already standardized, provides some kinds of materials with optimal features for use as growing media. Location is one aspect with increasing importance in the evaluation of the environmental impact of a growing medium, mainly due to the CO_2 footprint caused by transportation from the site of production to the site of cultivation. From this point of view, compost is less critical as it can be produced close to the greenhouse cultivations. A wide range of organic green waste materials is used in composting plants, given the abundance of the available waste, otherwise allocated to the incineration process. Literature about experimental trials on composted green waste used as growing media for soilless culture has been reviewed by Barrett et al. [17]. These substrate constituents cover a considerable part of commercial organic growing media, but some specific aspects need to be solved, such as high salinity, biological instability or the presence of impurity (plastic or glass fragments). Some organic waste materials, such as sewage sludge, may be more favorably treated as a source of biomass for energy generation in a pyrolysis process and converted into a safer and more suitable constituent of growing media, the biochar, which is the byproduct of the pyrolysis. In this context, one significant point is that the processing costs can be externalized (held by the energy producer) instead of being charged by the growing media manufacturer [17]. Biochar is a source of organic matter, nitrogen and other nutrients that can be beneficial for use as growing substrate [12,18–20]. The initial nutrient content and its rate of release into the nutrient solution should be computed in the final nutrient supply count. This is a common feature of most organic growing media. Beyond the influence on nutrient availability, water holding capacity [21] and physical-chemical properties of the resulting substrate mixture [22] are also affected by the addition of biochar. Indeed, the effects are different, depending on the properties of the starting feedstocks and the biochar percentage used in the mixture. It has been observed that biochar counteracts the development of algae in hydroponic units (specifically in floating using perlite as substrate) [23] and seems to be resistant to decomposition: the initial physical properties should remain stable, similar to some mineral components of substrates such as vermiculite, perlite and sand [24]. This could suggest that it can be stable after recycling in successive growing cycles. A negative feature can be high alkalinity [12,19,22,25].

A renewable resource available to partially replace peat in soilless culture but above all in the production of transplants is represented by wood fibers and wood chips, coming from the woodworking industry [10]. To achieve the best results in terms of plant growth and physical and chemical properties of the substrate, wood fibers are blended with peat at rates of 10–40% (by volume), obtaining an excellent water-holding capacity and increased air space in the substrate mixture [26]. Wood fibers can have two drawbacks: presence of phytotoxins and immobilization of nitrogen with consequent initial tie-up of the nutrient. In the first case, a substrate washing pretreatment is recommended, while in the second case, additional nitrogen fertilization at the beginning of the cultivation can be the solution. However, manufacturers directly employ a nitrogen impregnation technique during the thermo-mechanical process that transforms wood chips to fibers [10,26].

Among the waste materials tested as alternative constituents of growing media in soilless crops, almond shells have been proposed to replace rockwool [27] or perlite [28] with fluctuating results in terms of yield, suggesting that some technical tricks (mainly related to milling or blending of shells, useful to define an ideal balance in particle size) should be developed to improve their performance, given the potential role that these materials could play as substrate in the development of strategies of the circular economy, especially in the regions where they are abundant and immediately available, overriding the transportation costs. Other constituents of substrates with similar potentialities in soilless cultivation could be olive or hazelnut husks, rice or peanut hulls or sheep's wool [28].

The increase in the sustainability of soilless systems also passes through the suitability of the growing media to be recycled and the feasibility of treatments required for their reuse. The last factor changes according to the different materials used as substrate and the effects on their physical and chemical properties [10]. In general, inert substrates are more suitable for reuse, given the higher effectiveness of disinfectant treatments and the absence of absorption or retention processes on their surfaces. Rockwool and perlite are typically inert materials that could be theoretically disinfected and reused numerous times, but are actually reused for up to three growing cycles, bearing in mind that the success of growing with reused substrates also largely depends on the experience of the grower [28]. Organic substrates are subject to biological instability both after reuse in crop cultivation and after applied treatments such as steam disinfection. Probably some organic constituents, such as almond shells and biochar, can meet the requirements for recycling but, to the best of our knowledge, a targeted study has not yet been carried out on this aspect.

Organic media carry a saprophytic microbial community that can affect the nutrient status of plants during the growing cycle. Appropriate selection and mixing of organic media constituents should be carried out to ensure balanced nitrogen turnover from the growing media and the organic fertilizers [29]. The authors found that mineral media lacked microbial activity capable of ensuring nitrogen release from organic fertilizers. In contrast, organic constituents (such as coconut fiber or green waste compost) or their mixture contained bacterial ammonia oxidizers and nitrifiers [29]. In any case, among organic growing media, each substrate drove nitrogen mineralization and nitrification after organic fertilization according to its own chemical and biological features: peat was distinguished for a weak nitrification due to its low pH, while bark showed low microbial enzyme activities independently on the added organic fertilizer [30]. In most cases, organic fertilizer types modulated microbial activity of growing media, finding, for example, lower activities and nutrient release with horn meal than with plant-based fertilizers [30]. It is generally concluded that it is relevant to define an adequate fertilization strategy, made by selected media components and organic fertilizer type, to obtain a known nitrifying community that allows one to predict and control the microbial nitrogen conversion and delivery to plants [29,30]. When compared to an organic soil growing system, soilless cultivation of tomato on prevalent peat-based substrate organically fertilized (with fish effluent or liquid organic fertilizer) showed that a bacterial and fungal community promptly occupied the growing medium and the whole rhizosphere. Contrary to what occurred in soil, where microbiome remained unaltered over time and independent of fertilizer (different organic fertilizers had similar behavior in soil as regards microbial community), in soilless growing medium microbiome was mainly impacted by the fertilizer type [31]. The authors observed that soilless systems showed a microbial vacuum in the first sampling time (at the beginning of the tomato cycle), followed by a rapid equilibrium reached in the microbial structure [31]. In the study published by Grunert et al. [31], fish fertilizer derived from aquaponics used in a long-term fertilizer regime resulted in higher tomato yield compared to the other systems (organic soil and soilless cultivation). The application of solid or liquid digestates from biogas production also represents an interesting source of organic fertilizers for soilless cultivation. However, it requires an optimal definition of ratios between digestate formulate and nutrient solution under the several aspects of microbial load, pH and EC alterations induced on the final nutrient solution and the potential phytotoxicity towards crops [14,32]. Furthermore, this kind of byproduct is admitted as fertilizer in organic cultivation according to the EC Regulation n. 2164/2019, amending the EC Regulation n. 889/2008 laying down rules for organic production [33]. Therein, it is recommended that biogas digestate should not be applied to edible parts of the crop, but this should not contrast to its use in soilless nutrient systems where a net separation between rhizosphere and shoot exists. At last, microalgae-based fertilizers have been shown to be able to increase the nutritional and taste properties of tomato grown under greenhouse. The association of greenhouse soilless horticulture with outdoor microalgal cultivation in raceway ponds can offer advantages in the transition of vegetable production toward a more sustainable system, especially if the production of microalgal biomass exploits greenhouse waste water, allowing the transformation of waste nutrients into sustainable high-value fertilizers [34].

High-tech greenhouse management often pairs with robust integrated pest management, including various means of biological pest control (from predators to antagonistic and parasitic microorganisms) and a reduced use of chemical pesticides. This strategy is essential for the cultivation of leafy vegetables for ready-to-eat processing for which a minimal number of treatments and chemicals is allowed, due to short cultivation cycles and low/zero detectable pesticide residues imposed by regulatory restrictions or by processors [3]. Considering that soilless cultivation is being adopted by an increasing number of farms involved in leafy vegetables for ready-to-use production, this is a non-negligible point. Pressure on this issue is becoming more and more relevant for every vegetable, since mass market retailers are imposing chemical residues lower than the maximum residue levels (MRL) fixed by EU legislation and with very few molecules among residues. On the other hand, one of the most sensitive points in the sustainability of soilless systems is energy consumption, required to manage the greenhouse equipment for climate control (light, temperature, humidity, ventilation, CO_2, including the control unit for electrical circuits and PC) and the distribution of nutrients and water to plants. It has been calculated that the cost of energy accounts for 40% of the entire cost of greenhouse cultivation [35]. In the estimation of ways of reducing the carbon footprint of greenhouse soilless cultivation, some points were highlighted by Manos and Xydis [36]:

- Reducing the use of electrical energy (for example, increasing the exploiting of natural sunlight; using LED light bulbs; producing solar energy inside the farm—Figure 2);
- Reducing the use of fresh water (collecting rain water; adopting low-flow water distribution; recirculating water in closed cycle cultivation with filters and UV sanitation; using treated wastewater from urban plants);
- Reducing the use of fertilizers, pesticides and consumable products;
- Adopting the most energetically efficient passive and active climatic conditioning equipment (including insulation and shading);
- Using all available organic byproducts;
- Decreasing the distance of transports of raw materials and products (greenhouse plants near to urban areas);
- Enhancing direct contact with local markets and consumers to guarantee immediate collocation of soilless products.

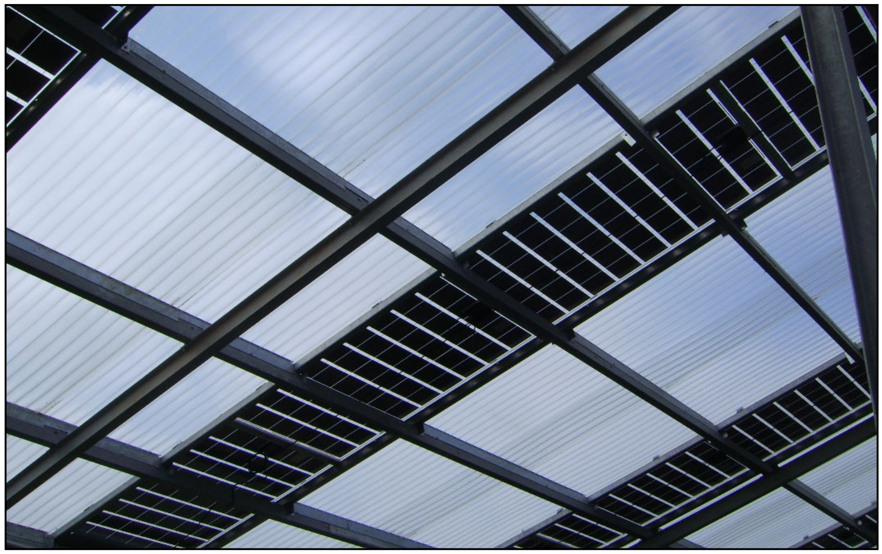

Figure 2. Example of producing solar energy inside the farm: innovative photovoltaic modules used as greenhouse cover material [37].

Most of the aspects summarized in this list have been discussed above, but they can refer to both soilless and conventional greenhouse horticultural crops. The level of innovation of soilless systems is expected to be closely linked to the degree of the economic investment in agricultural activity that a geographic area or country can guarantee. The application of high-tech soilless systems will be easier and more feasible in developed countries, especially where they are introduced into an advanced greenhouse production reality, than in underdeveloped ones. The same can be expected for investments in more sustainable solutions [5]. In further detail, high-tech soilless systems are hardly applied where land is widely available and financial capital not abundant for farmers (see Figure 1 in Muller et al. [38]).

Soilless systems represent a valid approach to producing vegetable food for sale in local markets in urban and suburban environments. Urban horticulture is gaining relevance in food production [20]. The rising trend is driven by the increase in global population and by the projection that 70% of the population will be living in urban areas by 2050 [39]. Urban horticulture encompasses a range of cultivation systems, from urban gardens (managed by individuals or communities) [40] to real enterprises, such as plant factories with artificial lighting (PFAL) [41]. Under a general point of view, the most advanced food production systems, such as vertical farming and PFAL, could address a number of current and urgent problems, such as unemployment in urban areas, the promotion and development of small and medium-sized enterprises and direct access to fresh food for city residents [36]. From a strictly agronomic point of view, soilless systems applied to urban agriculture, mainly in vertical farming systems (within a wide range of solutions exhaustively described by Beacham et al. [42]), have the main result of increasing the quantity of products obtained per unit of land surface and reducing the pressure on agricultural land, already threatened by the subtraction of useful land due to the expansion of urban areas [43]. Furthermore, they allow the usage of abandoned buildings (e.g., old factories, dismissed industrial sites), rooftops and unused and unsuitable soils for agricultural production (contaminated, depleted, poor soils, areas with ground surface covered with concrete) within cities. Urban and periurban production of fresh vegetables under protected structure contributes to increase resiliency of the food production system regarding climate instability as it guarantees local fresh food availability independently of unpredictable climate changes. Urban horticulture conducted through high-tech cultivation systems mainly concerns leafy vegetables (salads), aromatic herbs, microgreens, strawberries and soft fruits, according to recent crop trends. On the other hand, fruit crops, such as tomato or pepper, have limited potential, as they are theoretically suitable for vertical farming systems, but are hampered by the large size of the plant and by the relatively long growth cycles [42]. It is generally believed that vertical farming systems have high costs and high greenhouse gas emissions, due to the costs for building construction (for glasshouses or controlled environments) and for water and energy use (especially for artificial lighting and water pumping circulation), but it has been estimated that solar panels could provide enough power for the latter two energy requirements [42]. Further research is needed on the environmental and economic impact of vertical farming systems to maximize productivity and reduce costs related to different technical factors and to reduce the weakness points of this cropping system which will have more and more relevance in the future of food production in urban areas.

3. Where and Why Soilless Cultivation Can Be Compared to Organic Farming

In addition to the environmental and economic analysis, soilless vegetable production should be characterized for product quality, which is a complex issue defined by at least three aspects, which are safety, nutritional aspect and sensorial traits (taste, color, shape, texture). Safety in soilless production can be easily controlled through lower contact with pests, accurate sanitation operations and the integration of sustainable methods of control of pathogens in the growing protocols. All the three actions lead to a lower use of pesticides in soilless crops. Furthermore, the safety aspect concerns the absence of contaminants from soil and air, although in urban horticulture this is true for production inside high-tech greenhouses, less true in regions where fewer technological structures are used for vegetable production. A remarkable number of research studies are available in literature as regards the influence of genotype and each external factor (regarding techniques and environment) on nutritional and organoleptic traits of soilless products [41]. Based on these premises, it is demonstrated that it is feasible to obtain soilless vegetables of high quality [44]. However, consumers remain critical towards these products, mainly due to the perception of soilless production techniques as unnatural, resulting from artificial growth and consequently characterized by low inner quality, as concerns taste and nutritional value, for example. A great number of experimental results attests that, comparing soilless and soil grown crops, the first are noticeably prevalent under several traits of product quality [44,45]. The remarkable progress of soilless growing techniques carried out in the last two decades towards greater sustainability has made soilless cultivation environmentally friendly and able to produce high-quality products. In most cases, the only difference between soilless and conventional cultivation is the absence/presence of soil. Indeed, it is not rare that soilless production is carried out organically. In the USA, soilless grown vegetables can be effectively certified as organic if grown in compost-based growing media (compost or compostable plant materials which are considered comparable to soil) in containers [46]. From 2010 to today, the question of whether bioponic (including hydroponic, aeroponic and aquaponic) products can be allowed to be certified as organic for USA growers is greatly debated without reaching an agreement [47]. In detail, though the National Organic Standards Board took strong recommendation to exclude hydroponics from organic certification, in 2014 the USDA's National Organic Program (NOP) stated unequivocally on its website and in the *Organic Integrity Quarterly* that organic hydroponic production is allowed [48]. However, without a firm regulation or guidance from NOP, great uncertainty has been created between organic producers and accredited certifier agencies, since a number of them in the USA are going ahead to certify hydroponic products as organic. In the European Union, the restrictions are clear and fixed: organic certification is allowed only for products coming from a soil-related ecosystem [33]. In the rest of the world, Mexico, Canada, Japan and New Zealand prohibit hydroponic vegetable production from being sold as organic in their own countries, but this does not avoid the fact that hydroponic producers coming from Mexico, Canada and Holland sell their products on the USA market [48]. On the international level, a large movement of growers aiming to extend organic certification to soilless products obtained through sustainable methods (based on high water saving closed-systems, using organic substrates and organic products as fertilizers) is working hard to obtain the label of soilless organic products. The movement also includes the urban soilless growers that give a relevant contribution to providing fresh food in urban environments facing reduced availability of suitable land to produce in soil. It has already been observed that urban horticulture in most cases responds to the four principles of organic agriculture [49]: health (for soil, plant, people), ecology (for ecosystems and recycling), fairness (sharing and efficient use of resources, consumer interaction) and care (social health and wellbeing outputs) [40].

A SWOT analysis [50] that summarizes the many aspects examined in this discussion on soilless systems is reported in Figure 3. In particular, the last two aspects listed in the weakness points have already been discussed, referring to the absence of soil and perception of this cultivation system as unnatural. We have reported only a few examples from the vast literature concerning the positive interaction between organic media, organic fertilizers and biostimulants (of mycorrhizal, fungal, bacterial origin) aimed at making the cultivation conditions increasingly similar to the conventional ones. In any case, when taking stock of all the agents affecting the environmental sustainability of the crop and the product quality, the most relevant discriminating factor for the success of soilless cultivation is the farmer's skill, which collects and holds together all the others, giving rise to a high-value product and is also awarded with a high market price (Figure 4). The opportunities section collects most of the prospects, which can increase the positive impact of soilless cultivation on the environmental, economic and social front.

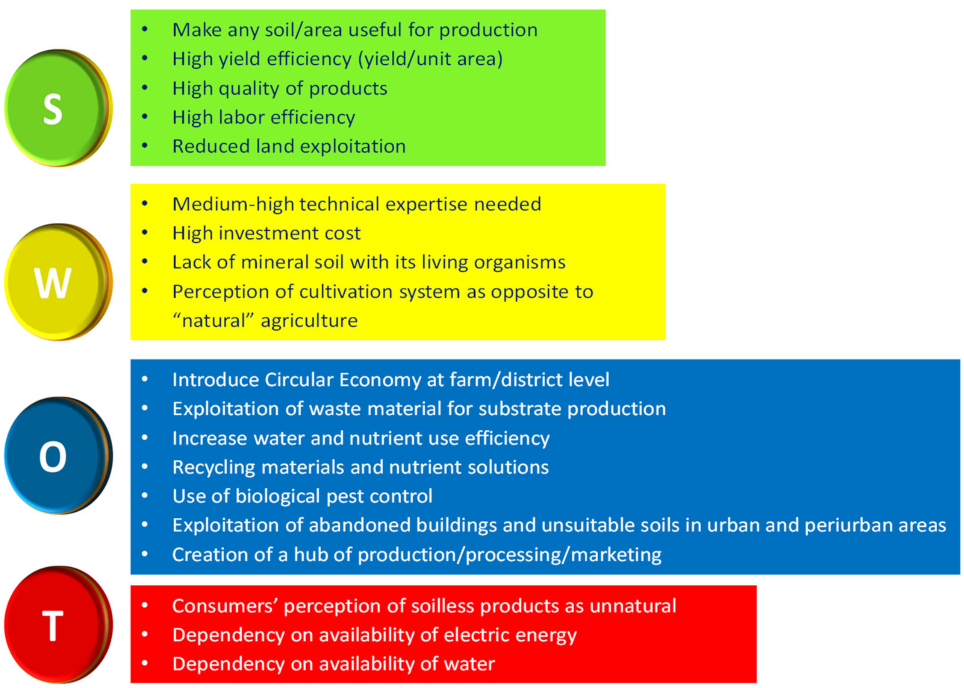

Figure 3. SWOT analysis related to the adoption of soilless systems in horticultural production. S, strengths; W, weaknesses; O, opportunities; T, threats.

Figure 4. Example of tomatoes with high quality standards in soilless produced by "Lapietra" company [51,52]. Picture published under permission by F.lli Lapietra Company.

4. Conclusions

Although apparently opposite as cultivation techniques, organic and high-tech soilless cultivation have several common or converging points in the view of a sustainable use of resources on the planet. The aspects examined regarding high-production efficiency close the discussion that started at the beginning of this review through the concept of land sparing/sharing model. Probably, both production systems will be useful for saving the planet's resources. To support organic production, the European Commission provides financial aid that compensates for the lower income due to lower yields. It is known that the increase in yields brought about by the Green Revolution was not directed to sparing land in favor of natural landscapes. Conversely, higher yields have spurred increasing exploitation of lands to produce cheap food in ever greater amounts [1]. At present, stronger environmental policies targeted to support land sparing for conservation purposes, equivalent to those directed at organic production, should be introduced in order to support a limited expansion of agriculture not legitimized by a real need for more food, higher than the real market capacity. The new policies should be stronger than the greening payments foreseen in the current Common Agricultural Policy. The current greening payments have been more effective in increasing the positive environmental externalities of sustainable farming systems (such as organic production and the maintenance of extensive production systems such as permanent grassland) rather than in mitigating the environmental "pressure" factors deriving from the most intensive agricultural activities. The new policies should invert this trend, reducing the pressure of the latter. They could be strengthened by introducing a process certification of low environmental impact, which, together with an adequate product certification, related not only to the environmental aspect but also to product quality, can reduce the opposition of the two cultivation systems.

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