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Review

The Impact of COVID-19 on Horticulture: Critical Issues and Opportunities Derived from an Unexpected Occurrence

Roberta Bulgari [1,*], Alice Petrini [1,2], Giacomo Cocetta [2], Carlo Nicoletto [3], Andrea Ertani [1], Paolo Sambo [3], Antonio Ferrante [2] and Silvana Nicola [1]

[1] Department of Agricultural, Forest, and Food Sciences DISAFA, Vegetable Crops and Medicinal and Aromatic Plants VEGMAP, University of Torino, 10095 Grugliasco, Italy; alice.petrini@unito.it or alice.petrini@unimi.it (A.P.); andrea.ertani@unito.it (A.E.); silvana.nicola@unito.it (S.N.)
[2] Department of Agricultural and Environmental Sciences, Università Degli Studi di Milano, Via Celoria 2, 20133 Milano, Italy; giacomo.cocetta@unimi.it (G.C.); antonio.ferrante@unimi.it (A.F.)
[3] Department of Agronomy, Food, Natural Resources, Animals and the Environment, University of Padova, 35020 Legnaro, Italy; carlo.nicoletto@unipd.it (C.N.); paolo.sambo@unipd.it (P.S.)
* Correspondence: roberta.bulgari@unito.it

Abstract: The COVID-19 pandemic is causing many victims worldwide and has generated a serious economic crisis. Substantial changes have occurred in the food and ornamental production chains. The aim of the present review has been to summarize some of the main effects that the pandemic is having on horticulture and on the new habits of people. Infections and quarantine measures have prevented the regular flow of certain goods and of connected services. Cases of shortages and/or surpluses, a lack of the availability of labor, and a reduction in demand for some food products and flowers have occurred. New food production approaches have emerged and a reconnection between farmers and consumers has been spreading, thereby facilitating product distribution. Moreover, during the forced isolation, people have had to face periods of stress. The benefits that can be derived from leisure activities related to flowers and ornamental plants, and from access to nature and urban green spaces are increasingly being recognized as relevant. The seriousness of the pandemic will inevitably lead to lasting changes. Therefore, the vulnerability of the pre-COVID-19 distribution chains should be considered and a new food production chain should be drawn up, to increase the resilience of such systems.

Keywords: food supply chain; home gardening; horticultural sector; floriculture; pandemic; resilience; urban farming

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1. Introduction

The world's population is currently facing the new coronavirus (SARS-CoV-2) infection, which is responsible for the disease known as COVID-19 [1,2]. The first cases of the infection were reported in December 2019, in Wuhan (China), and, at present, it is the main global health problem [3–5]. Countries have responded in different ways to the pandemic, including the introduction of total or partial lockdowns [6,7]. As for other pandemics in the past (Spanish Flu, Asian Flu, SARS, Ebola, Swine Flu, etc.), the necessary quarantine measures are having a strong negative impact on human activities and consequently on the global economy [8,9]. Health and economic indicators have been compromised and all types of industries have been affected in some way [10]. World merchandise trading is believed to have declined by 13% to 22% due to COVID-19 [11]. As expected, negative effects have also been observed in the agricultural sector [12–14]. Agriculture is crucial to guarantee food security, but also plays an essential role in population development [12,15]. The pandemic has affected agriculture to a great extent, causing significant economic losses and notable changes that are likely to persist over time [16–18].

The vulnerability of food production chains under sanitary emergencies has clearly been demonstrated [19]. For example, the supply chains of the most advanced and emerging economies have been optimized from a cost-effectiveness point of view with long distribution chains [20]. Post-COVID-19 food security may be guaranteed through a strategic and enduring production plan that could involve increasing urban and peri-urban production systems, which could expand rapidly to satisfy the needs and to ensure a vicinity of food supply [9]. Moreover, the pandemic has affected food habits and, in some cases, people have been oriented to a more healthy diet, aiming to protect their immune system. This phenomenon has led to an increased demand for functional foods that contain bioactive compounds [21].

The purpose of the present review is to summarize some of the main effects that the COVID-19 pandemic is having on the global horticultural sector. This investigation has been conducted considering the changes observed to date in the entire food production system as well as the new habits of people/consumers. This approach allowed us to highlight both the weak points and the possibilities resulting from the crisis. The present review offers a glance toward the pre and post pandemic situation, reporting available economic data, examples of organizational changes adopted by producers in order to counteract the negative effects of the pandemic and examples of people's modification in food habits. Changes in the ornamental sector, related to the flower industry and to the newfound pleasure of people toward leisure activities, such as gardening and grow-your-own, were also analyzed. Due to the lack of consolidated information and data, to date it is not possible to provide a complete view of the pandemic implications on the horticultural sector. In fact, reports and documents from institutions and governments are not yet available. Nevertheless, a large number of articles, reports and websites were analyzed in a time period of 9 months (from September 2020 to May 2021), aiming to collect valuable information, data and case studies on topics. The outcome of this study will provide some food for thought and suggestions to determine short-term and long-term strategic plans to overcome or mitigate the pandemic impact and to develop resilience in the food supply chain.

The review was structured as follows:

- Section 2: an extensive literature review of the pandemic effects on the horticultural sector was provided. In particular, we have developed this section distinguishing three main themes: the impact on the food supply chain, loss of revenue from ornamental plants and flowers, and the impact of COVID-19 on horticulture as a hobby and on ordinary people. We wanted to describe how the different production sectors were differentially affected and we reported specific potential strategies to consider;
- Section 3: the importance of the relisience of the horticultural sector during adverse circumstances, such as in the case of COVID-19, was explained;
- Section 4: perspectives and opportunities of the horticultural sector were analyzed;
- Section 5: finally, the main conclusions resulting from this overall analysis have been summarized.

2. Analysis of the Effects of the Pandemic on the Horticultural Sector

2.1. The Impact on the Food Supply Chain

COVID-19 has prevented and modified the normal food supply chain [22,23] (Table 1). Infections, quarantine measures and restrictions have led to the delayed delivery of agricultural inputs, the lack of arrivals of seasonal laborers, the non-harvesting of crops, the accumulation of products, and the disruption of the distribution grid, thereby sometimes causing shortages of products in grocery stores [18,24–27]. It is therefore evident that problems may emerge at different stages in the food supply chain and could interfere with the regular flow of food and services, from primary production to final consumption [28,29]. Starting from the availability of agricultural inputs, farmers are facing a shortage of seeds, fertilizers and pesticides. This depends in particular on the restrictions to global trade that have occurred due to the pandemic. Considering that China is one of

the major fertilizer producers and exporters in the world, the lockdown has had a severe effect on its international trade [12]. The pandemic has also affected the workforce, due to restrictions on the movement of seasonal and migrant workers around the world [30–32]. The sectors most affected by the lack of a labor force are livestock production, horticulture, planting, harvesting and the processing of crops [33]. As the production of staple crops is highly mechanized in the developed world, it has been less affected by the pandemic than the production of more labor-intensive crops, such as fruit and vegetables, which require larger amounts of human labor ([7] and references therein). Due to the lack of labor availability in the fields, several crops have been left unharvested. This in turn has caused severe food and economic losses. Conversely, in other cases, an accumulation of produce occurred after harvest, so farmers were forced to store their unsold products for a long period, causing a reduction in the quality of vegetables and fruits, as well as an increase in production costs. According to the FoodService Instituut [34], the foodservice industry in the Netherlands lost €7.1 billion in 2020. The hospitality industry lost 41.5% of its turnover, while supermarkets increased their turnover by €1.8 billion. Such an increase may in part be due to the phenomenon of consumer panic buying, a behavior commonly exhibited by people who purchase large amounts of products in anticipation of or during a disaster [35]. In addition, e-commerce may also have contributed to such an increase. A study from the Italian Institute of Services for the Agricultural and Food Market (ISMEA) [36] showed that in Italy sales in local and street markets, which remained closed in certain critical periods of the pandemic, declined dramatically during the peak of the pandemic, while around 50% of purchases were concentrated in big grocery stores and supermarkets. After the shortage of such products as flour, eggs and yeast, a scarcity of some fruit, vegetables and perishable goods was also observed. This implied a shift in the purchasing of food by families, especially with regards to nonperishable and highly processed food, and less fresh food (fruits and vegetables) [37]. Several studies have shown changes in consumers' food habits and everyday behavior [38–40]: frozen vegetable sales increased by 25% during the peak of the lockdown and was higher than the year before (+14.6%) after the lockdown [22]. Bracale and Vaccaro [38] reported a lower fruit and vegetable intake during the early stages of COVID-19, which was later followed by an increase. The adoption of policies that forced people to stay at home allowed them to have more free time than usual. The perception of having more hours available in the day led to a newfound pleasure in cooking; preparing food can also function as a creative activity to relieve stress [41]. A positive increase in those activities related to preparing and selecting healthy foods has been observed [41,42]. People started to look for products that could improve their immune system, characterized by a high concentration of nutrients, such as vitamins, minerals and antioxidants.

The closure of the Horeca (Hotel-restaurant-catering/café) also contributed to the disruption of supply chains. The closing measures introduced by the government for restaurants, hotels, catering and bars further depressed the sales and the price of fresh products. The exceptional pandemic condition that was created weakened high-value food products in particular, due to their short duration [43] in terms of shelf-life. In order to prevent produce shortage and to prevent consumers from panicking (i.e., panic buying), many governments have restricted the sales and export of food and increased the importation of basic products [23]. It is important to consider that most EU fresh produce is consumed locally or within the EU. However, out of the 80 Mt produced per year, 5 Mt are exported to non-EU country markets (6.25% of the total EU production). The global outbreak of COVID-19 is putting these exports at risk [18]. A reduction in the movement of goods and people, and of border crossing, has also contributed to making some produce unavailable, as in the case of exotic products or those that are imported from extra EU markets. The EU has imported in 2019 about 15 Mt of fruits and vegetables with a market value of € 16 billion [18]. The continuation of production and trading operations from non-EU suppliers is therefore a key to provide EU consumers with a wide range of fresh produce. Imports are strongly dominated by fruit and vegetables like onions (623,000 t), tomatoes (556,000 t) and beans (183,000 t). An 82% proportion of all imports

(12.3 Mt) originate from South America, Central America, North Africa, South Africa, and EU neighboring countries [18]. All these regions and countries are currently experiencing effects caused by the implementation of emergency measures to prevent the further spread of COVID-19, which will radiate on EU supplies in the short and long term. The effects have not yet been visible [18] and the impact on the availability of goods will start to be fully revealed in the upcoming months. In the study "Evaluation of the impact on the agri-food sector of the COVID-19 containment measures" carried out within the National Rural Network Program, with the contribution of the Council for Agricultural Research and Agricultural Economics Analysis (CREA), the results of the medium-term forecasts for the agri-food sector were reported and the main challenges for the sector were indicated [44]. Depending on the expansion of the pandemic that is affecting the entire globe, in the test effected, different scenarios were considered in which the contraction in the Gross Domestic Product (GDP) growth was included in a range between −1.5 and −5 percentage points. In particular, (a) a "middle" scenario, in line with the OECD forecasts at the beginning of March, which envisages a reduction in the global GDP growth by 1.5 percentage points; and (b) a "worst" scenario, with a larger contraction, equal to 3 percentage points in 2020 and a partial recovery in subsequent years. In particular, in 2021 the decline forecasted is 1.5 percentage points and in 2022 it is 0.5 percentage points, while in the following years the growth rates expected before the coronavirus emergency situation was confirmed. This scenario derives from the spread of the virus, declared a pandemic, and from the uncertainty of the trend of the economy throughout 2020. (c) a "worst & ITA-5" scenario, which differs from the previous one due to the greater contraction of GDP attributed to Italy (-5 percentage points). In the study, an analysis was carried out at the EU level, in which the percentage variation between pre- and post-COVID-19 forecasts was considered by the three-year average value 2020–2022. The fruit and vegetable sector, according to the results of the study, would be less affected by the contraction of GDP worldwide, with a drop in income, both in the EU and in Italy, of just over 1% in the "middle" scenario and of 2, 3% in the "worst" scenario. The authors assessed the impact on income (per ha) in the EU 27 fruit and vegetable sector, resulting from the decline in GDP worldwide -% variation compared to pre-crisis forecasts. According to the model, the states most affected by the pandemic are Slovenia (−3.9%), Portugal (−3.7%), Bulgaria (−3.5%) and Spain (−3.7%). Conversely, the least affected states are Denmark (−0.7%), Poland (−1.40%) and the Czech Republic (−0.8%) [44].

Import and export exchange has become slower or has stopped. Italy, for instance, has been affected by the main channel in which the "Made in Italy" agri-food products have a medium-high position, and which covers a large part of export flows [45]. In Italy, all the direct purchasing losses that have occurred have only partially been balanced by the observed increment in home deliveries (+160% in 2020), which was only limited by a lack of supplies [36]. Moreover, the closure of the entire Horeca sector during the lockdown was accompanied by a 6% increase in home food consumption [36]. A similar pattern was observed in the US, as reported by the U.S. Department of Agriculture (USDA) [32]. In fact, during the COVID-19 pandemic, US consumers increased their purchases of food from grocery stores (and other retail food establishments) and decreased the expenses for food consumed away from home. In addition, with the shift in the demand from food services to retail, the demand for packaging materials has also changed dramatically, as more tin, glass, and plastic were needed for packaging purposes [34].

Table 1. Impact of the sanitary emergency on ornamental and vegetable production. Different production sectors were differentially affected and specific potential strategies must be considered.

Horticultural Sector	Pre-COVID-19	During COVID-19 Pandemic Emergency	Potential Post-COVID-19 Organization
Fruit and vegetables (F&V) supply chain	Most fresh horticultural crops are available all year around: logistics are optimized for connecting short and long distance production sites and markets. The production costs, labor, transport and product storability define the commercialization opportunities.	For most products, the long distance distribution chains have been interrupted due to frontier closures and the reduction in transportation channels. Moreover, because of the generalized lockdown in the early stage of the COVID-19 emergency, many workers were obliged to reduce the working hours for respecting distances and avoiding any potential risk of exposure.	Markets should consider mutiple supply channels, including local production and activation of protected cultivations or indoor production in urban and peri-urban areas. A percentage of the supply chain was reserved for local production, even if the production costs were higher.
Fresh-cut or minimally processed F&V	Field production is connected with the working ability of the industry and the supermarket orders. These ready-to-eat products have a good and established supply chain that guarantees the cold chain and daily availablity in the supermaket shelfs.	The growers had fewer workers available in the field, for harvesting in open field and greenhouses as well as for the industrial product valorization. The increase of percentage of COVID-19 people infected slowed down the whole distribution chain. The remote-working and home-working conditions reduced the consumption of ready-to-eat products.	Worker availability is an important issue to guarantee the distribution chain. In the future, growers and industries have to face these situations by means of contracts with agencies that can ensure the worker substitution buffer. Special contracts should be defined on the basis of the horticultural sector specialities.
Cut flowers and ornamental plants	Cut flowers, cut greens and potted plants have worldwide markets with an important logistic distibution organization. Cultivations follow strict programmed production schedules that ensure commercialization in the most suitable way, with higher prices.	Since ornamental products are not essential for human nutrition, most of their production was lost and growers had to destroy crops and products. During the early days of the COVID-19 emergency, florists were closed and no ornamental items were commercialized.	Producers should increase the online commercialization with home delivery. Improving the distribution chain, with optimized transportation for reducing the quality losses, should be a goal.

At present, the agri-food sector is closely connected internationally, but the COVID-19 crisis has highlighted some critical issues in the system related to the flow of goods, thus encouraging some countries to adopt a more domestic 'food sovereignty' approach, towards greater local food production [43,46], and inevitably changing the logistics of the entire food system [47]. In Italy, after an initial difficult phase (middle of March 2020), resulting from all the above-mentioned facts, the overall fruit and vegetable markets became operationally stable in many areas. This was related to two phenomena: from one side, the increasing demand for fresh fruit and vegetables from the retailers, due to the increasing consumers' demand, and on the other side, the reopening of neighborhood stores, which was stimulated by the increased number of customers, due to mobility restrictions and long queues at supermarkets. As reported in a survey conducted by Colorado State University [48], 35% of the respondents admitted to new shopping behaviors, skewed toward farmer markets, community-supported agriculture, or local, independent restaurants. These new buying habits seem to have lasted over time in many areas [23,49]. It is possible that the COVID-19

crisis will result in a new and lasting attention to the infrastructures and the workforce at the base of food supply chains, to where food comes from, to produce seasonality and to the expansion of alternative food chains [24,50–52], with a reduction in intermediaries from the producer to the consumer and, possibly, with a significant reduction in wasted food.

2.2. Loss of Revenue from Ornamental Plants and Flowers

As well as for the food sector, an impact of the sanitary emergency on the ornamental sector was observed, and a reduction in the demand of cut flowers, ornamental plants, trees and bulbs has occurred during the COVID-19 pandemic [28] (Table 1). The restrictions on international flights and cargo transport have affected the logistics of the supply chains to a great extent. Weddings, funerals and other public/social events have been stopped or severely curtailed around the world, causing a marked reduction in the demand for these products. Substantial financial losses for some "luxury" perishable agricultural items, such as cut flowers, have been observed. For example, the New York Times has reported that from the beginning of the lockdown until April 2020, Dutch flower growers destroyed about 400,000,000 flowers that remained unsold as a result of the pandemic [7], or donated them to hospitals or even to passers-by in the streets. The ornamental sector has a strong socio-economic value worldwide. In fact, ornamental products positively affect the quality of life, and also have considerable benefits on mental health and on socialization activities. In some cases, the sales of houseplants have increased, most probably because these goods are thought to help overcome the stress derived from being confined at home during the lockdown. In a survey conducted by Pérez-Urrestarazu et al. [53], the interviewees declared that their motivation for having plants at home changed in favor of an increase in indoor plants, during the confinement period. The total number of participants who answered the questionnaire was 4205. Responses were obtained from 46 countries from all over the world; in particular, most responses were received from Brazil (29.6%), Greece (23.8%), Spain (19.6%) and Italy (9.4%).

The need for ornamentals and flowers has probably not decreased, but the availability on the market was almost zero. From April 2020, the Royal FloraHolland sales dropped by 50% on average each week compared to the previous year [54].

With the highest plant density per hectare, the EU is amongst the larger producers, but is also trader and consumer of flowers and of ornamental plants [55]. The value of the total production is estimated to be around €20 billion, which accounts for the 44% of the total world flower and pot plant production. The most important EU production countries are the Netherlands, Italy, Germany, France and Spain [55]. The EU ornamental sector is estimated to have lost around € 4 billion since the beginning of the pandemic. Kenya and Ethiopia are also important producers of ornamentals and flowers, especially roses [56]. Seventy percent of the cut flowers from Kenya are sold to Europe, mostly through auction sales in the Netherlands. It should be considered that the pandemic began around March 2020, at the beginning of the spring season, a time of the year in which most of the turnover was achieved for this sector. In addition to the reduction in sales, due to the closure of shops and the inability of people to leave their houses, due to restrictions, there has been a lack of requests for ornamentals. In Italy, since 22 March 2020, new regulations have been enacted (Legislative Decree of 22 March 2020) in favor of the sector, whereby the production, transport and marketing of "agricultural products" is allowed, as well as the retail sales of seeds, ornamental plants and flowers, potted plants, fertilizers etc. On 4 May 2020, the European Union announced a package of measures to support the food and agriculture sector and mitigate the effects of the COVID-19 outbreak.

2.3. The Impact of COVID-19 on Horticulture as a Hobby and on Ordinary People

People are facing stressful and difficult times because of the COVID-19 pandemic. Their routines have been totally upset, they often have a great deal of spare time, and feel bored or unproductive [57]. Those people who are not able to take advantage of a terrace, garden or a small balcony, have often suffered great stress during quarantine. It is

known that the lack of light and outdoor space has important implications on the mood and health of people. In fact, stress and anxiety are inversely proportional to space. In the course of the lockdowns, elderly people have suffered much more than the younger population, due to their reduced ability to maintain regular contacts with family and friends. Among the elderly, those affected by dementia have been negatively influenced by the sudden changes in routine and the lack of access to services. This situation has led to a rapid deterioration in their cognitive functions, which has affected their memory, sleep and general behavior. A survey conducted by the Alzheimer's Society in Great Britain on people with dementia has found similar results, with 82% of the people with dementia reporting an increase in their symptoms during the lockdown, including memory and concentration losses, and increased agitation or restlessness [58]. The benefits that may be derived from the plants and from contact with nature are becoming more and more important, especially in exceptional periods of forced isolation [59]. Consequently, as a result of the global health crisis, leisure activities are becoming associated with dedicating more time to flowers and ornamental plants. In fact, access to nature and urban green spaces is increasing, as it has been recognized as relevant in COVID-19 recovery plans. Lades et al. [60] reported gardening to be one of the most effective activities for mitigating the negative effects of social isolation due to COVID-19 on people's emotional well-being. As shown by Niles et al. [61] and Montefrio [57], home food procurement from gardening and foraging had spread during the pandemic, with positive benefits for food security and diet quality. It is known that growing one's own produce is linked to an increase in fruit and vegetable intake. During the lockdown, there have been cases where government agencies and non-government organizations distributed seeds to the population to boost home gardening [57,62], especially in poor and disadvantaged areas. Moreover, many home gardeners who did not have yard spaces shifted to soilless systems, using all sorts of containers readily available at home (plastic bottles, boxes, etc.), thus leading to the so-called 'Container Gardening'. In this sense, the role of social media and blogs, whereby information, instructive material and experiences are exchanged, has also been important. To cite another example, in the UK, gardening businesses have been booming during the last period. Britain's Royal Horticultural Society's website has seen a five-fold rise in queries about gardening advice during the lockdown. Because of social distancing and the lasting closure of non-essential businesses, many communication and support networks have been cut off from the gardening community [63]. The internet has partially counterbalanced these closures. Many people have in fact joined web community gardens or Facebook groups to talk about cultivation techniques with experts [63]. The spread in home gardening has had several benefits for the body and mind, as well as creative advantages. Gardening may have contributed toward giving people a sense of reality, helping them to reduce stress and anxiety [64]. Ultimately, home food production and gardening can provide more opportunities for scattered, local and fresh food in a pleasant self-made landscape, thereby contributing to the resilience of such a system.

3. Resilience

In the context described so far, it is clear that it has been appropriate to work toward increasing the resilience of a system during the pandemic but also, in general, in all those circumstances that change or influence the equilibrium of such a system. Therefore, it appears suitable, starting from the very definition of resilience, to address this issue and try to provide solutions in order to improve the resilience of a system and to try and increase the food security of the population itself. The etymological root of resilience comes from the Latin word *resilio*, meaning "to bounce back" [65]. As is well known, the concept of resilience has recently begun to be used at various levels, such as at the social, environmental and political levels, with particular relevance for the world of climate change [66]. However, this area has already been extensively dealt with and the term resilience is now considered in many other sectors, as recently shown by several authors [67,68]. Among these, the one that is most involved in the context that has arisen following the COVID-19

emergency is linked to "urban resilience", a topic recently analyzed by Meerow et al. [69], and which will be particularly emphasized, in terms of production and access to food, in this review. Meerow et al. [69] enunciated a new definition of "urban resilience", which is reported hereafter: *"Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity"*. Thus, it is evident that research activities into food production in the urban context, in order to speed up its availability, are key elements in the attempt to prevent the multiple inconveniences that COVID-19 has caused in the system. The food production, shortness of the supply chain and speed of reaching the consumer concepts are summed up in the concept of urban farming and indoor farming. These production approaches represent one of the fastest growing sectors in the social context and can contribute significantly to increasing the resilience of a system and food security, even in the pandemic context. From an academic point of view, experimentation in this area is constantly growing, as can be seen in all the major scientific databases. Since 2000, the number of publications containing the keywords "urban and indoor and farming" in the title of papers testifies a continuous increase in research activities in this area, with over 80 articles having been published [70].

Urban and indoor farming represents a potential resource, especially in megacities (with more than 10 million inhabitants), where it is estimated that more than 5 billion people will be located by 2030 [71]. In these very populous contexts, the possibility of growing food in urban environments would allow waste and fossil resources for transportation to be reduced, with a consequent advantage in CO_2 emissions into the atmosphere. Modern food crop production is rapidly evolving into new models, characterized by a high level of innovation and by great adaptability to new cultivation areas, including sub-optimal cultivation environments such as cities. New forms of food production are emerging in cities to satisfy consumers' requests, in terms of quantity, quality, possibility of choice and added services. Indoor cultivation systems allow a total isolation from the environment and, as a consequence, the energetic and productive inputs must be provided entirely by the grower. On the other hand, independence from soil and the complete control of environmental parameters prevents any kind of contamination and make it possible to move agricultural production from rural to urban areas, where food consumption is concentrated, with positive repercussions on food security in the city and the impact of produce transportation from production areas. Urban indoor farms may be characterized by different structures, including the set-up of hydroponic systems inside abandoned buildings (building-integrated agriculture). In this respect, the aim is to increase the sustainability of crop production by saving already-available resources [72]. Another technique that has been developed and which is spreading is the vertical farm [73]. The strategy, in this case, is to exploit the production area by developing the system upwards and using artificial lighting, which is usually provided by LED-based illumination systems. This is certainly a system which makes use of a high innovative and technological content. The most modern vertical farms are in fact equipped with fully automated management systems that allow an optimal management of the production cycles. An integrated control system used to monitor all the environmental parameters, including light (quality and quantity), humidity, temperature, and CO_2 concentration, needs to be provided [74,75]. The yield, quality and nutritional density of crops grown in protected and indoor cultivation systems can thus be tailored through the optimization of several agronomic factors and through an accurate management of the production inputs, such as water, mineral nutrition and the required energy. However, on the one hand, the high level of complexity and technological innovation entails the optimization of the production process, and on the other, a strong impact on the economic and environmental sustainability of urban production. Even though technology and innovation offer a wide array of possibilities and solutions to growing plants almost anywhere, sustainability is still the main limiting factor of urban indoor cultivation systems. The sustainability of a production system depends on the efficient use of limited resources,

including energy, water and fertilizers. In high technology cultivation systems, such as vertical farms, the efficient use of resources should be higher than in greenhouses or open fields, mainly because a more rational use of water, cultivated area and fertilizer is obtained at the expense of an additional energy consumption. For this reason, it is necessary to evaluate and consider the feasibility of these solutions in an appropriate context, and appropriate measures should be taken to improve the sustainability of the productive system, without affecting the yield or quality requirements of each product.

Apart from these elements, Redwood [76] and Orsini et al. [77–79] reported that the cultivation of fresh vegetables in urban areas allows significant quantities of food to be produced. If we consider, for example, the possibility of managing urban gardens by exploiting the useful surfaces of roofs, there are numerous examples in which considerable productions have been estimated for urban populations. For example, in the city of Bologna, which is characterized by an urban center that is populated by almost 400,000 people, the useful surface area of roofs capable of hosting urban gardens is equal to 82 ha, and has the potential to satisfy 77% of the urban vegetable requirements [78].

A second issue that should be considered, especially in moments of social crisis or, in this case, a pandemic, is linked to the healing and regenerative aspects, from a mental and psychological perspective, associated with the opportunity of cultivating plant products. This aspect has recently been studied by several authors who indicate it as a solution to such health problems as psychiatric deficits [80–82] or as a sustainable solution to take care of health issues in a highly industrialized or urbanized context [83,84] for different age groups, ranging from infancy [85] to the third age [86]. In fact, it has been shown that horticultural activities can reduce anxiety states and depression and improve people's sociability [87]. The possibility of interacting and participating in projects that include contact with 'nature', i.e., with cultivated plants, can represent an important source of relief against some alterations and disorders such as anxiety, depression and stress, and the quality of life [88]. Reference is often made to the concept of "green care" programs, which normally include therapeutic activities based on the management and care of plants, even for food purposes. Recent studies have reported that engagement in therapeutic horticulture not only depends on a personal interest in gardening, but that the social dimension of therapeutic horticulture is also a primary reason for engagement [83]. Horticulture-related activities have been reported to be effective in attenuating the stress levels of maladjusted elementary school children [89] and also for the recovery of stressed children [90].

There have been several evident cases of anxiety in the population, due to the inability to go out and make contact not only in the social context, but also with nature itself, in this period characterized by the presence of COVID-19, and especially under lockdown conditions. In fact, considering the main requests for help received from help centers during the first phase of COVID-19, it can be seen that, during the first month, most of the problems were related to a state of anxiety, and this was followed by logistical concerns, travel restrictions and medical problems [91]. Subsequently, these requests for help can be summarized in such themes as panic, anxiety and depression [92]. Therefore, urban and indoor farming represents a potential relief valve that is capable of neutralizing dangerous psychological and behavioral issues, since it is able to absorb the accumulated discomfort and support the need for contact with nature that human beings have always required.

As reported above, in addition to mental and emotional problems, the pandemic has considerably limited the normal freedom of movement of citizens and caused significant logistical problems. In this context, numerous authors have pointed out the considerable consequences linked to the limitation of travel. Choi et al. [93] prepared an analytical model that is capable of evaluating how the virtuous combination of logistics and new technologies is able to transform the pre-COVID-19 context, defined as "static service operations", into an active and functional model for the consumer at the COVID-19 time defined as "bring-service-near your home mobile service operation". There has been a notable development of home delivery as a first resilience reaction [94], to replace direct purchasing

in person, with a consequent development of new applications for smartphones [95], to manage and order the desired products, thereby allowing the consumers to remain at home and maintain social distancing. These dynamics have also developed in the urban farming context, thus not only bypassing conventional transport, but at the same time also replacing transportation, since food can be produced directly in the environment where it is consumed (e.g., houses or condominiums), thereby ensuring a timely supply and reduced user movement.

Urban farming can also provide services related to the possibility of using the drive-in and pick-up service for fresh produce, which allows consumers to pick up previously ordered products from a farm without incurring the need to stop for a long time, as occurs inside a supermarket. As Bakalis et al. [96] pointed out, in 2020, before the pandemic, 50% of food was purchased in supermarkets and 50% from food services; currently, about 100% of purchased food is acquired in supermarkets, which often suffer from restricted entrances and are at risk of crowding. Consequently, the ability to produce and sell vegetables in the city also improves this aspect by ensuring a fresh product while limiting the negative aspects connected to purchasing at supermarkets.

Another element of importance is the innovation that urban farmers themselves have implemented to guarantee the supply of fresh vegetables, not only to the average consumer, but also to consumers who are facing some difficulties and are unable to acquire food themselves for personal or health reasons. Farmers have implemented innovative sales and market opportunities to sell as much of their highly perishable produce as they can. The main solutions adopted involve direct sales, such as in farmer's markets and farm stands, thus exploring a market other than that of large-scale distribution [97]. The pandemic crisis has also offered a chance for community-supported agricultural organizations, and urban farming in particular, to seize a market opportunity by expanding local delivery services. In this context, there has been an evolution in the sales channel using social media (i.e., whatsapp, facebook) and home delivery, or even online sales via a website or apps offering home deliveries. Although the urban farming will obviously not be able to completely replace agricultural production, which is derived from a more peripheral or even international production context, from the quantity, economy and crop choice points of view, it should be noted that this new concept of production allows the inconveniences and difficulties of acquiring food during critical periods that society has to face over time to be limited.

An acceleration of the transformation of the urban environment has also been observed during the pandemic. As was reported in several case studies, the use of green infrastructures significantly increased in 2020 [98–100]. As a result of the closure of cinemas, restaurants, gyms, libraries, cultural centers etc., people have shifted their recreational activities to parks, yards, and urban forests, in part with the aim of relaxing. The aforementioned reaction has contributed to increasing citizens' resilience. Moreover, this has led to tactical urbanism actions, including the extension of sidewalks, the planning of new bike lanes and the creation of new public spaces to facilitate social distancing [100]. Furthermore, some countries, including New Zealand, are planning on allocating funding to transform tactical urbanism into official government policy [100].

4. Perspectives and Opportunities

4.1. Horticulture Production

The COVID-19 sanitary emergency has impaired the logistics and distribution chains of horticultural products. This has created food insecurity, due to breaks in the food supply chain and, consequently, to the difficulty of a large part of the population accessing fresh food at reasonable prices. Horticulture is the primary agriculture sector involved in supplying fresh products to the market and to shelves. According to FAO, the availability of food throughout the world, in developed countries, has so far been adequate and world stocks, especially of the main crops, do not seem a cause for concern. Nonetheless, there has been a slight decline in the production of high value goods, such as fruit and

vegetables [101]. Lockdown, as a defense strategy against COVID-19, has changed the lifestyle of humans since, wherever possible, working at the normal worksite has been transformed into working remotely, which mostly means working from home. Many people, spending more time at home [53], have thus been inspired to explore nature in their neighborhoods as they refocus on their immediate surroundings.

As seen, an important issue is the psychological impact on individuals and populations, in terms of the damage that can result from the conditions caused by lockdown [101]. The short-term effects of social isolation on the health of individuals have not yet been studied to any great extent, but it is known that, if prolonged over long periods of time, it may increase the risk of specific disorders, including cardiovascular disease, depression and dementia [101]. In this context, the adoption of resilient food systems has in turn led to the growth of domestic horticulture and urban agriculture, thereby improving family and community production. Several strategies can be introduced to increase local food production within cities, including indoor growing modules [102], rooftop gardens, local community gardens, and vertical farming [46]. Home gardens, which provide various ecosystem services, such as plant biodiversity, microclimate, water runoff, water quality and human health [59], have played an important role in food procurement during the pandemic. According to literature reviews, there has been a great increase in interest in the search term "gardening" since the pandemic [57]. With the expansion of home gardens, some observers believe that this trend could help resolve food insecurity issues and open new prospects for the food system [103]. Even before the pandemic, some researchers had suggested that the constant growth in interest in home and community gardens over the past decade suggests the potential for a persistent movement to create resilient and safe communities [104]. In the cities, growing crops on rooftops and inside tall buildings makes it possible to achieve an efficient use of the restricted space available. In some cases, initiatives have sprouted from local communities, while in other cases, prestigious architectural firms have designed innovative projects that make use of technology to incentivize local self-sufficiency from a nutritional standpoint, as well as to reduce the impact of urban demands on rural areas. Self-safe production in urban gardening may be important, due to the opportunity of controlling the whole plant productive cycle. Vertical farming can ensure crop production all-year round in an air-conditioned facility, thereby reducing transportation costs, with a greater control of food safety and biosecurity, and substantially reduced inputs [73]. The most critical aspects are related to the production costs and, among such costs, that of energy is the major issue. Large-scale indoor production requires the use of soilless systems and advanced ICT technologies integrated with production systems [105]. Urban agriculture promotes an improvement in dense and extensive social networks characterized by solid and weak ties, social capital and a sense of community [104,106]. The present sanitary emergency has affected the fresh horticultural product supply to a great extent. New logistic and production systems need to be designed, and local productions will be required to be flexible enough to ensure enough food is produced for the population. A pandemic horticultural production plan should be drawn up by the various nations to ensure the food security of their citizens. The delocalization of production is one strategy that has been used to lower production costs [107], but long-distance logistics becomes vulnerable in the case of a sanitary emergence, as has been experienced in the present pandemic situation.

4.2. Horticultural Plants and COVID-19 Patients

According to the dashboard of Johns Hopkins University, at the time of writing (data updated in mid-May 2021), the confirmed global cases of COVID-19 had exceeded 160 million, while the global number of deaths had exceeded 3.4 million. The country affected the most, in absolute terms, is the United States, with over 33 million cases and over 580,000 victims, and this is followed by Brazil and India, with over 15 million cases each, and more than 440,000 deaths in Brazil and more than 287,000 in India. Mexico counted almost 220,000 deaths and the UK had more than 127,000 victims, and this is followed by

Italy (more than 124,000). In this tragic scenario, the concept of environmental health should be applied in hospitals and nursing homes, to improve the mental health of the hospitalized COVID-19 patients. Environmental health is a key issue in the debate in hospitals going green. According to a 1995 Institute of Medicine report, environmental health is "freedom from illness or injury related to exposure to toxic agents and other environmental conditions that are potentially detrimental to human health" [108]. Hospitals have a direct effect on the health of those within their walls and on the environment itself. Eco-therapy refers to techniques that lead to a mutual healing between the human mind and nature. It includes horticultural therapy, wilderness excursion work, long-term stress management and some types of animal-assisted therapies [109]. In fact, plants can significantly reduce the presence of the dust, bacteria and molds that are responsible for certain allergies and which can worsen a patient's symptoms. Thanks to greenery, it will be possible to increase the level of oxygenation in the air in hospital rooms. Plants can ensure the removal of dangerous toxins from the air, such as carbon dioxide, carbon monoxide, formaldehyde and benzene, which are known to be responsible for such symptoms as headaches, sore throats, drowsiness, dizziness and irritation of the skin, and eyes, bad moods, mental fatigue and poor concentration; these symptoms will improve in the presence of indoor plants. Patients in hospital rooms with plants and flowers have demonstrated lower systolic blood pressure and lower pain, anxiety and fatigue ratings than patients in plant-free rooms. Park and Mattson [110] also reported, on the basis of patients' comments, that plants illuminated the room environment, reduced stress and conveyed positive impressions to hospital employees.

Lockdowns and curfews to contain the spread of the virus have forced people to remain closed in their homes, which are often occupied by several people, for long periods of time. In view of the above, it is important that the homes of citizens meet the air quality requirements and, at the same time, should be a relaxing and pleasant environment in which people can spend long periods of time together. The fact that people have to spend up to 90–95% of their time in the living space and in the residential space requires great attention to both the quality of the air they breathe and to the materials and substances that characterize the objects and boundaries of their environments. As reported earlier, there has been a huge increase in the number of people who have bought plants and bulbs during lockdown, and medicinal plants have proven particularly popular. People around the world are turning to gardening as a soothing, family friendly hobby that also eases concerns over food security, as lockdowns slow the harvesting and distribution of some crops. Fruit and vegetable seed sales are increasing worldwide. Plants can represent a sustainable solution to improve the quality of air in homes, especially in cities where various pollutants, such as CO, CO_2 and volatile organic compounds, are present in high concentrations [111]. In addition, newly built energy efficient homes are often not efficiently designed to allow an indoor–outdoor air exchange, and this results in increased concentrations of indoor pollutants [112]. Several studies [59,104] have reported the positive effects on plant-mediated indoor air quality. Data on this topic have been obtained from experiments conducted by the U.S. National Aeronautics and Space Administration [112]. Several plants can be useful for this purpose, such as the Areca palm (*Chrysalidocarpus lutescens*), Lady palm (*Rhapis excelsa*), Bamboo palm (*Chamaedorea erumpens*), Rubber plant (*Ficus elastica*), Dracaena (*Dracaena decremensis* 'Janet Craig'), English ivy (*Hedera helix*), Dwarf date palm (*Phoenix roebelenii*), Ficus (*Ficus macleilandii* 'Alii'), Boston fern (*Nephrolepis exaltata* 'Bostoniensis') and the Peace lily (*Spathiphyllum wallisii*) [112]. English ivy, Sunflowers, Chrysanthemums, Lilies and Palm Straw have been found to be the best species for the purification of air from benzene [113]. White Lily Farm, Sunflower and Palm Straw are very effective in treating trichlorethylene [113]. In addition, it has been revealed that Reed palm, *Sansevieria trifasciata*, White Lily Farm, golden pothos, and Spider plants are effective for formaldehyde purification purposes [113].

5. Conclusions

The seriousness of the COVID-19 pandemic, its continuation over time, and its impact on the life of civilians, will inevitably lead to short- and long-term changes. Moreover, the horticultural sector throughout the world will also be affected. Some substantial problems have already been highlighted: the fragility of a market that is, at present, too interconnected and dependent on imports and exports and which, in times of crisis, can cause serious shortages and/or surpluses and wastage; the collapse of the labor supply, especially of migrant and seasonal workers; and the reduction in demand for some food products and flowers. It is clear that to face such problems, and any future crises, governments will need to develop emergency response plans and strengthen their economic support. The crisis has highlighted areas of inequalities of the food system and business cannot continue as usual. As reported by FAO, the Committee on Food Security is currently working on guidelines to re-orient and transform the food system to be more resilient and sustainable [17]. As suggested by Lioutas and Charatsari [7], a new winning strategy could be to promote the diversity of agri-food production and to encourage the reconnection of farmers and consumers, through community marketing schemes, to facilitate the distribution of products during periods of crisis, while co-existing with the mainstream distribution channels. The above-mentioned solutions are very suitable for the horticultural sector, certainly less so for staple foods (rice, maize, exotic fruits etc.) Vegetable production is best suited to become more local, allowing the shortening of food chains [17]. As we have witnessed, peasant markets, traditional 'wet' markets, and new forms of e-commerce are circuits that favor trade directly between producers and consumers, and make the latter more aware of, and demanding about, the quality of produce. Moreover, these informal marketplaces are more sustainable, as they reduce transport and limit waste and the amount of packaging. It is surely important to consider that, in each form of food product trade, hygienic practices must be guaranteed and implemented to ensure food safety and public health [114]. Moreover, there are also more and more examples of food production in the urban context that are contributing to shortening the food supply chain [115]. Horticulture production chains should take into consideration the possibility of enforcing urban and peri-urban production sites in a sanitary strategy plan. New indoor production opportunities, such as vertical farming, should be considered and implemented for local production, also with a view to increase resource use efficiency [116,117]. However, the energy requirements for such a cultivation system still represent a major limitation, and innovative strategies need to be elaborated to overcome this issue. It should not be forgotten that a crisis not only has an economic dimension but also has a significant impact on human life. The COVID-19 crisis has pointed out the importance of contact with nature, and of the presence of green spaces in cities and houses [53,118]. These aspects can certainly help to revitalize the ornamental sector, and such activities as urban gardening, social horticulture and therapeutic horticulture.

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