agronomy

MDPI

*Article*

# Nursery Plant Production Models under Quarantine Pests' Outbreak: Assessing the Environmental Implications and Economic Viability

**Michel Frem [1,2], Vincenzo Fucilli [2,3], Alessandro Petrontino [2,3,*], Claudio Acciani [3], Rossella Bianchi [3] and Francesco Bozzo [2,3]**

1 Lebanese Agricultural Research Institute, El Roumieh Zone, Qleiat, Lebanon
2 Spin off Sinagri s.r.l., University of Bari-Aldo Moro, Via Amendola 165/A, 70126 Bari, Italy
3 Department of Soil, Plant and Food Sciences, University of Bari Aldo Moro, Via Amendola 165/A, 70126 Bari, Italy
* Correspondence: alessandro.petrontino@uniba.it

**Abstract:** The Apulia (southern Italy) ornamental sector has been facing regulatory obligations and trade limitations due to a *Xylella fastidiosa* (Xf) outbreak since 2013. Alternative options to encounter these constraints include the implementation of novel and sustainable ornamental production (NSM) practices. In this context, the purpose of this study is to assess simultaneously the environmental implications and economic viability of these options versus the conventional production options (CMs) among eight ornamental species (*Abelia grandiflora*, *Bougainvillea* cv Don Mario, *Lantana camara* cv Bandana rosa, *Jasminum officinalis*, *Photinia fraseri* cv Red Robin, *Loropetalum chinense* cv Black Pearl, *Trachelospermum jasminoides*, *Viburnum lucidum*). Life cycle assessment (LCA) and cost–benefit analysis (CBA) were used for this purpose. LCA revealed that NSM induced relatively less environmental impacts at the nursery level towards agricultural land occupation, climate change, fossil depletion, and water depletion. CBA showed that NSM increases moderately nursery business profitability in an economic sustainable way. An overall annual average gross margin of about EUR 192/1000 plants can be generated using NSM over the CM model. In general, this research provides a useful decision-support, helping nursery growers under the pressure of the threat of quarantine pests such as Xf to adopt NSM practices, which could be useful to produce ornamental and landscape plants with high sanitary quality.

**Keywords:** bio stimulants and growth regulators; biotic stress management; cost–benefit greenhouse cultivation; life cycle assessment; sustainable agriculture; *Xylella fastidiosa*

check for updates

**Citation:** Frem, M.; Fucilli, V.; Petrontino, A.; Acciani, C.; Bianchi, R.; Bozzo, F. Nursery Plant Production Models under Quarantine Pests' Outbreak: Assessing the Environmental Implications and Economic Viability. *Agronomy* **2022**, *12*, 2964. https://doi.org/10.3390/agronomy12122964

Academic Editors: Pradeep Kumar, Giuseppe Colla, Mariateresa Cardarelli, Pratapsingh Khapte and Belen Gallego-Elvira

Received: 3 October 2022
Accepted: 23 November 2022
Published: 25 November 2022



## 1. Introduction

The nursery sector is an intensive polyculture system of multiple fruit, vegetable, and landscape species in a relative short production period with a considerable allocation of resources [1–3]. In the European Union countries, this production system constitutes a particular export-oriented economic sector. Within this region, the Netherlands leads the ranking of ornamental plants and flowers production with EUR 2378.87 million in 2019. The Netherlands is followed by Germany and Italy with EUR 1390.58 million and EUR 1269.4 million, respectively. Italy's ornamental plants and flowers area was estimated at 8.31 thousand hectares in the same year [4]. During 2016–2020, the Italian average annual exports of live plants, bulbs, roots, and cut flowers were valued close to USD 943 million (www.resourcetradeearth.com (accessed on 2 October 2022)). At the same time, the nursery sector is highly susceptible to potential plant diseases and pests that are implicated in increasing the loss of nursery productivity and profitability due to the trade restrictions of horticultural plants and other nursery stock [5] from outbreaks areas. Since the high-impact outbreak of *Xylella fastidiosa* (Wells et al. [6], hereafter Xf), a vector-bacterial plant pathogen of almost 655 plant species [7], the Apulian (southern Italy) nursery sector, an example of this process, is facing serious economic damages.

Improving plant health status against quarantine pests such as Xf in an eco-friendly way becomes a crucial challenge facing the Apulian nursery growers that are not willing to compromise the economic and environmental viability of their nurseries as well as the consumer interest and preferences [8]. On the one hand, there are no current direct treatments against this bacterium at open-field farms [9]; on the other hand, developing effective control measures against its vectors seems plausible and increases management costs [10,11]. Following the spread of Xf in the southern Apulia region, the local authority has implemented many risks management options, mainly in the containment areas, to counter this biological invasion process. The range of management control options, at nursery level, for excluding Xf vectors, consists of sampling and laboratory testing, conducting ongoing surveillance for signs of Xf diseases, monitoring regularly for the presence of vectors, the use of well-timed chemical insecticides against vectors (at the juvenile stage as preventive measures), weed management (if applicable) to prevent any dissemination, the production of planting material of high genetic and sanitary quality under insect-proof screens, and growing plants under exclusion conditions in terms of screen barriers for which their effectiveness and technical feasibility are assessed as high [12]. Despite these interventions, the reputation of the Apulian ornamental sector has been perturbated among the global plant trade network. Indeed, there endures a risk that Xf could continue to enter and become established in new non-infected countries through the importation of potentially infected or asymptomatic host plants from Italy [13]. Moreover, the serological and molecular testing diagnostic techniques, before (i.e., at nursery level) and after (i.e., at entry points) shipment, remain unrealistic to certify that all plants are free from harmful pathogens. Therefore, there is a need to produce plants [5] free of diseases such as Xf to counter Apulian nursery production losses, through the adoption of innovative and sustainable protocols, combining agronomic and phytosanitary practices, and to provide on overall assessment of the impacts that novel protocols may have in the economic, environment, and social spheres.

Over the past 20 years, the few published studies that have carried out economic viability assessments of the sustainable production of ornamental species and, particularly, the use of plant regulators (Indole Butyric Acid), for the financial returns of horticulturists, are limited to one or two ornamental species [14]. On the contrary, there have been several worldwide scientific studies that assess separately the environmental implications towards sustainable practices of ornamental plant cultivation [15–18]. These include but are not limited to the use of the following: (i) new technologies in terms of renewable energy sources and innovative automation climate control [19,20], soilless media [15,21,22] that may positively impact the cultivation process of landscape species, (ii) agricultural waste (i.e., olive-mill waste, cotton gin trash, tobacco dust waste) instead of peat as growing media [23–25] that reduce GHG emissions at the nurseries level, (iii) integrated pest management in terms of the early detection of potential plant pathology and pests through rigorous monitoring and continuous surveillance, biological approaches, abiotic elicitors to induce plant defense mechanisms that decrease the application of chemical treatments, production losses and attenuating the direct toxicity to nursery workers and consumers [26,27], and (iv) the propagation of native or wild landscape species that contribute successfully to sustainability [28,29]. In this context, the purpose of the current study is to investigate simultaneously the environmental impact and economic viability of the adoption of innovative and sustainable practices at the level of Italian nursery production at the time of the Xf invasion for a set of eight landscape species.

By investigating these issues, the present research may be used as a conceptual framework in adopting novel and clean strategies and in the assessment of other quarantine pests to support nursery growers for appropriate cost-effective management. For these purposes, the techniques used for environmental impact and economic viability assessments are environmental life cycle assessment (LCA) and cost–benefit analysis (CBA), respectively. LCA constitutes a popular reference tool to assess the environmental impact of such horticultural practices and focus on adjustments or aspects that would be improved over the whole production and transportation cycles of the products [30–35], giving the nursery growers considerable insights to successfully achieve sustainability and cleaner production [36]. CBA is simple, transparent, and reveals the direct impact of any changes [37] or best practice implementations [38] in the ornamental cultivation process in terms of costs and net benefits to nursery facilities.

## 2. Materials and Methods

### *2.1. Environmental Implications Assessment*

In line with the ISO 14040 and 14044 standards [36], LCA was implemented here in four interrelated phases as follows: (i) goal(s) and scope statements, (ii) inventory of resources use and emissions, (iii) impact assessment, and (iv) interpretation [2,39]. In what follows, we address how these phases have been entrenched in this research.

#### 2.1.1. Goals and Scope

This phase includes the aims, the functional unit, the boundaries system, and the interpretation of the study [36,40]. Accordingly, this research evaluates the environmental implications towards eight ornamental species (*Abelia grandiflora*, *Bougainvillea* cv Don Mario, *Lantana camara* cv Bandana rosa, *Jasminum officinalis*, *Photinia fraseri* cv Red Robin, *Loropetalum chinense* cv Black Pearl, *Trachelospermum jasminoides*, *Viburnum lucidum*), with the adoption of innovative and improved nursery management practices. The link [41] would grasp the description of each species included in this study. Their selection is based on the following: (i) their relative economic importance in the Apulia nursery sector, (ii) their relative abundance in the Apulia region, and (iii) their evergreen status as potential Xf hostplants. The scenarios we assessed concern the following: (i) the use of cuttings from sanitized/certified mother plants (i.e., free from harmful quarantine pathogens) produced by the National Research Centre of Bari and University of Bari Aldo Moro, (ii) the adoption of rapid multiplication through the use of bio stimulants/plant regulators (i.e., auxin precursor Indole-3-Butyric Acid, which is able to affect the anticipation of the rooting phase and the reduction in cuttings mortality), and (iii) the implementation of a continuous surveillance biosecurity arrangement against quarantine pathogens (i.e., under protected, isolated, and controlled conditions). In such scenarios, the study aims to investigate two closely interlinked issues: (i) the environmental impacts of production processes and (ii) cost–benefit analysis (Figure 1).

Therefore, the impacts of these extreme scenarios were compared using two models: the "conventional model (hereafter CM)" (i.e., cultivation with the protocol commonly used by nursery growers) and "novel and sustainable model (hereafter NSM)" (i.e., application of innovations and sustainable practices able to affect the anticipation of rooting/−20 days and the reduction in the mortality rate of cuttings/−20% as mentioned above). We performed this research at "Vivai Capitano" [41], a representative pilot Apulian nursery plant, which aimed to achieve the cost-effective, healthy, and eco-friendly production of ornamental species with less use of inputs/resources (pesticides, nutrients, energy, manpower, etc.). The production area of this nursery study site was 40 hectares of open areas and 10 hectares of greenhouses providing annually rooting for almost 4 million young plants. This nursery was employing 80 workers that managed the entire life cycle of production, from plant propagation to sales, in terms of 500 varieties of shrubs, bushes, ground covers, trees, saplings, creepers, and succulents [41]. The functional unit used was equal to the production of 1000 potted plants [31,42], d16, for each of the eight species mentioned above. We used this functional unit (product/plant) instead of surface unit ($m^2$) due to their similarity of production system and appurtenance to the same commercial target [2].

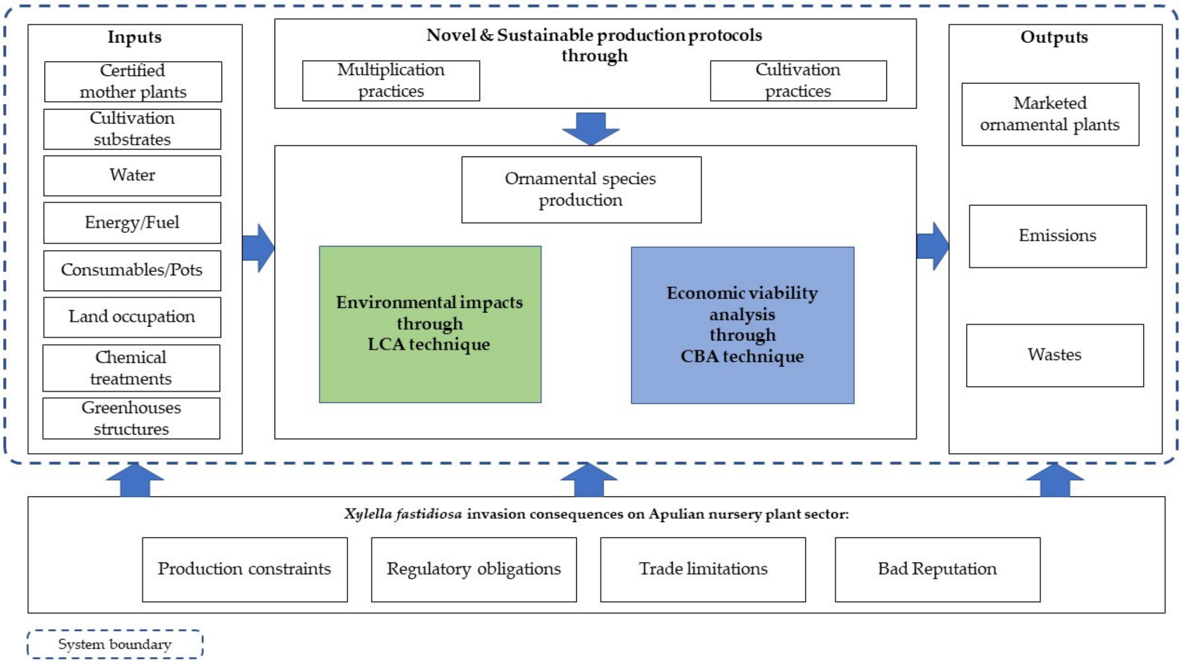


**Figure 1.** Overview of the categories of inputs and outputs that were considered in our ornamental production assessment. The diagram also highlights the main consequences of Xylella fastidiosa invasion on the nursery sector in Apulia region (Southern Italy).

Furthermore, the boundaries system (i.e., production process) considers all the phases from cutting to the achievement of commercial maturity of the plant, defined as the time when the aesthetic and dimensional characteristics of the plants are such as to be able to be marketable (Tables 1 and 2). Greenhouse structures were excluded owing to their minimal significance for the goals of this research.

**Table 1.** Technical parameters used to calibrate the number of inputs to produce 1000 potted plants through the conventional ornamental production model (CM).

| **Production Phase** | **Rooting** | | | **Growth** | | | **Commercial Maturity** | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Duration (day) | Mortality (%) | Surface ($m^2$) | Duration (day) | Mortality (%) | Surface ($m^2$) | Duration in the greenhouse (day) | Duration in the open field (day) | Surface ($m^2$) |
| *Abelia grandiflora* | 40 | 0% | 1.60 | 60 | 0% | 5.13 | 0 | 90 | 100 |
| *Bougainvillea* cv Don Mario | 70 | 50% | 3.56 | 120 | 10% | 5.70 | 180 | 0 | 100 |
| *Jasminum officinalis* | 60 | 10% | 1.78 | 120 | 0% | 5.13 | 0 | 90 | 100 |
| *Lantana camara* cv Bandana rosa | 30 | 10% | 1.78 | 60 | 0% | 5.13 | 40 | 0 | 100 |
| *Loropetalum chinense* cv Black Pearl | 70 | 0% | 1.89 | 120 | 15% | 6.03 | 0 | 120 | 100 |
| *Photinia fraseri* cv Red Robin | 60 | 25% | 2.14 | 120 | 0% | 5.13 | 0 | 120 | 100 |
| *Trachelospermum jasminoides* | 60 | 5% | 1.69 | 120 | 0% | 5.13 | 0 | 180 | 100 |
| *Viburnum lucidum* | 70 | 0% | 1.60 | 120 | 0% | 5.13 | 0 | 120 | 100 |

**Table 2.** Technical parameters used to calibrate the number of inputs to produce 1000 potted plants through the novel and sustainable ornamental production model (NSM).

| Production Phase | Rooting | | | Growth | | | Commercial Maturity | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Duration (day) | Mortality (%) | Surface ($m^2$) | Duration (day) | Mortality (%) | Surface ($m^2$) | Duration in the greenhouse (day) | Duration in the open field (day) | Surface ($m^2$) |
| *Abelia grandiflora* | 20 | 0% | 1.60 | 60 | 0% | 5.13 | 0 | 90 | 100 |
| *Bougainvillea* cv Don Mario | 50 | 30% | 2.54 | 120 | 10% | 5.70 | 180 | 0 | 100 |
| *Jasminum officinalis* | 40 | 0% | 1.60 | 120 | 0% | 5.13 | 0 | 90 | 100 |
| *Lantana camara* cv Bandana rosa | 10 | 0% | 1.60 | 60 | 0% | 5.13 | 40 | 0 | 100 |
| *Loropetalum chinense* cv Black Pearl | 50 | 0% | 1.89 | 120 | 15% | 6.03 | 0 | 120 | 100 |
| *Photinia fraseri* cv Red Robin | 40 | 5% | 1.69 | 120 | 0% | 5.13 | 0 | 120 | 100 |
| *Trachelospermum jasminoides* | 40 | 0% | 1.60 | 120 | 0% | 5.13 | 0 | 180 | 100 |
| *Viburnum lucidum* | 50 | 0% | 1.60 | 120 | 0% | 5.13 | 0 | 120 | 100 |

In this context, the main stages involved in the production protocols (Figure 2) are as follows: (i) cutting, (ii) rooting, (iii) 1st transplanting, and (iv) 2nd transplanting. Descriptions of the stages are as follows:

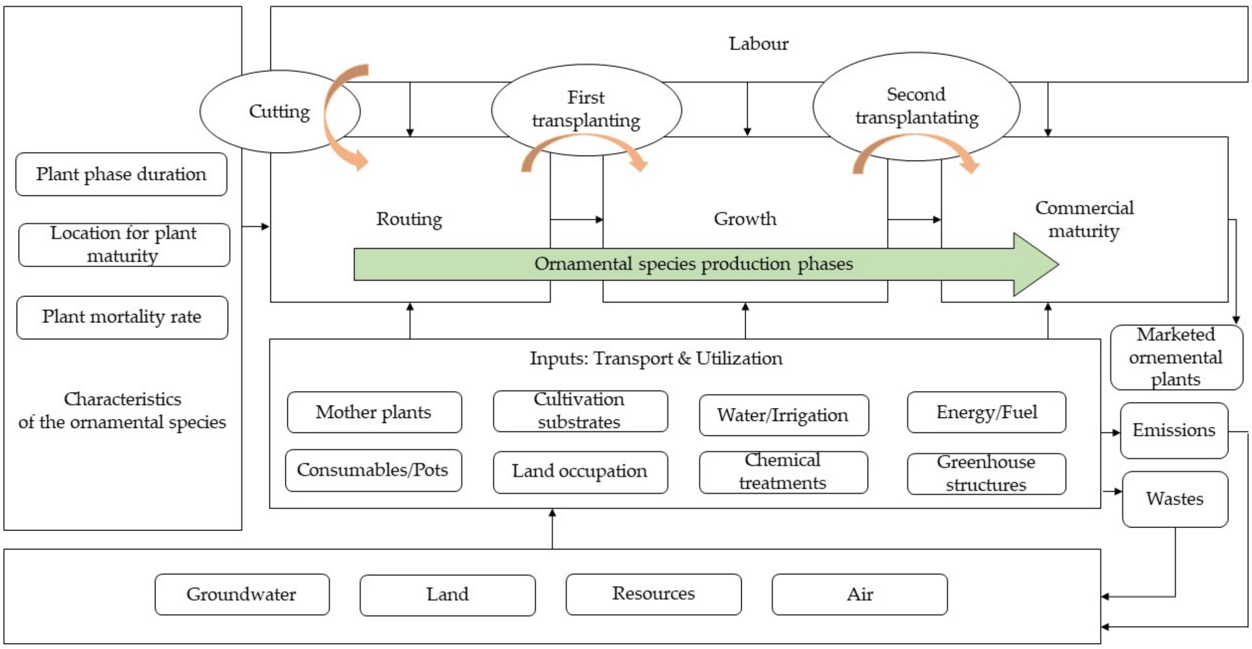


**Figure 2.** Flows of information used for our life cycle inventory for which the greenhouse structures were excluded owing to their minimal significance for the goals of this research.

- Cutting stage: With respect to the CM, cuttings are sourced from pot-bred mother plants from previous production cycles and selected from those with better physiological and bearing features. For all species, cuttings are produced exclusively from the middle-lignified portion of the branch. Hence, the cuttings are prepared for the next stage in a very short time that usually does not exceed 24 h. Regarding the NSM, cuttings are sourced from mother plants raised permanently in the open field, kept in isolated portions of the farm, and protected from harmful pathogens and external agents using specific expedients (i.e., anti-aphid nets, protective sheeting, etc.). For some species such as Lantana, the innovative protocol also involves finding the cutting from the apical part of the branch. For both models, the composition of the substrates mixture used at this stage is as follows: peat (90%) and perlite (10%).

- Rooting stage: Concerning the CM, the rooting stage involves here planting the cuttings in honeycomb containers placed in controlled environment rooting greenhouses equipped with basal heating, a fog system, and a manual irrigation system. The operating temperature of the greenhouse is set according to the species introduced, varying within a range of 12 to 30 °C. Humidity is kept between 60 and 70%. The heating system is composed of a burner of 5 Hp with split ventilation in the greenhouses. The cuttings are immersed in the forementioned substrate, respectively, after treatment with a rooting powder hormone, IBA 0.5% *w*/*w* (commercial name: Rhizopon AA). As preventive or robust curative measures, a biocontrol fungus agent for soil borne diseases such *Trichoderma* spp. (commercial name: Triash) is used to enhance and improve plant health even in the absence of pathogens. Chemical fungicides are also applied at this stage, such as the following: Azaka/Azoxystrobin to protect plants against stem rot (*Sclerotinia sclerotium*) and dark leaf and pod spot (*Alternaria* spp.); Omix/Propamocarb Hydrochloride; Alias DG/Mancozeb; and Pindarus 25 WDG/Tebuconazole against the damping-off of seedlings such as *Phytophthora* spp. and *Pythium* spp. (Table 3). The NSM at this stage differs only in the application of the Rhizopon AA whose optimal concentration (1%) has been applied.
- First transplanting: For the CM, the first transplanting takes place in d7 polyethylene pots with a substrate mixture of peat (70%) and pumice (30%) to which scheduled-release fertilizer is added. The plants are moved to another greenhouse where treatments are like those in phase 2. In addition, Radicifo, a bio activator of root and plant growth, mixed with Omix, is used at this stage (Table 3). In respect to the NSM, this stage presumably differs only in what concerns timing and mortality.
- Second transplanting: For the CM, the second transplanting takes place in a d16 polyethylene pot with the same mixture substrate and treatments as mentioned in the previous stage (Table 3). Regarding the NSM, this stage presumably differs only in what concerns timing and mortality.

Overall, Table 4 summarizes the differences between the two systems CM and NSM in this study, in which we highlighted and justified the consideration/importance level (i.e., least, low, medium, high, highest) of each variable for the economic viability or the LCA analysis.

**Table 3.** Chemical treatments used at each stage of the two ornamental production models: conventional production model (CM) and novel and sustainable production model (NSM).

| Stage | Commercial Product | Concentration | Quantity (1000 Plants) | Rate of Application |
|---|---|---|---|---|
| Rooting | Rhizopon AA | 0.5% | 20 g | One-off |
| | Omix | 300 Ml·hL$^{-1}$ | 5 mL | Each 2 weeks |
| | Azaka | 100 mL·hL$^{-1}$ | 1 mL | 1 per month |
| | Alias DG | 200 g·hL$^{-1}$ | 2 g | 1 per month |
| | Pindarus 25 WG | 50 g·hL$^{-1}$ | 0.5 g | 1 per month |
| | Triash | 200 mL·hL$^{-1}$ | 2 mL | 1 per month |
| 1st transplanting | Omix + Radicifo | 300 mL·hL$^{-1}$ | 5 mL + 5 mL | Each 2 weeks |
| | Azaka | 100 mL·hL$^{-1}$ | 1 mL | 1 per month |
| | Alias DG | 200 g·hL$^{-1}$ | 2 g | 1 per month |
| | Pindarus 25 WG | 50 g·hL$^{-1}$ | 0.5 g | 1 per month |
| | Triash | 200 mL·hL$^{-1}$ | 2 mL | 1 per month |
| 2nd transplanting | Omix + Radicifo | 300 mL·hL$^{-1}$ | 5 mL + 5 mL | Each 2 weeks |
| | Azaka | 100 mL·hL$^{-1}$ | 1 ml | 1 per month |
| | Alias DG | 200 g·hL$^{-1}$ | 2 g | 1 per month |
| | Pindarus 25 WG | 50 g·hL$^{-1}$ | 0.5 g | 1 per month |
| | Triash | 200 mL·hL$^{-1}$ | 2 mL | 1 per month |

**Table 4.** Differences between the two production models: conventional production model (CM) and novel and sustainable production model (NSM), among eight selected ornamental species.

| Type of Variable | Difference | | Importance or Consideration for | | Justification |
|---|---|---|---|---|---|
| | CM | NSM | LCA Analysis | Economic Analysis | |
| Period of the whole production cycle (overall average) | Requires more days 57.5 days for the rooting phase 280 days for the whole production cycle | Requires fewer days 37.5 days for the rooting phase 260 days for the whole production cycle | Least | Highest | See Note (1) |
| Mortality rate during the rooting phase (overall average) | Relatively high (12.5%) | Relatively low (4.4%) | Medium | High | See Note (2) |
| Raw propagation material (i.e., mother plants) | Internal supply The propagation is realized by using propagation materials from mother plants previously produced from the nursery itself that may not guarantee healthy ornamental landscape species | External supply (1rst year only) The mother plants are purchased from external certified/accredited sources (Research National Centre and University of Bari Aldo Moro), fulfilling the requirements of markets and phytosanitary regulations | Low | Medium | See Note (3) |
| Cultivation substrates consumption, mainly related to the mortality rate | Relatively high | Relatively low | High | Low | See Note (4) |
| Water consumption, mainly related to the mortality rate and the period of the cycle of production | Relatively high | Relatively low | High | Least | See Note (5) |
| Energy/fuel, mainly related to the production cycle duration | Relatively high | Relatively low | Highest | High | See Note (6) |
| Consumables/pots, mainly related to the mortality rate | Relatively high | Relatively low | High | Medium | See Note (7) |
| Open-field occupation, mainly related to the mother plants' growth and maintenance | Relatively low | Relatively high | Low | Low | See Note (8) |
| Greenhouse occupation, mainly related to the production cycle duration | Relatively high | Relatively low | High | High | See Note (9) |
| Chemical treatments in terms of the use of auxins | Relatively low | Relatively high | Least | Least | See Note (10) |

**Table 4.** *Cont.*

| Type of Variable | Difference | | Importance or Consideration for | | Justification |
|---|---|---|---|---|---|
| | CM | NSM | LCA Analysis | Economic Analysis | |
| Chemical treatments in terms of the use of phytosanitary products | Relatively high (Massive application) | Relatively low (Low application) | High | High | See Note (11) |
| Labor, mainly related to the production cycle duration | Relatively greater working hours | Relatively fewer working hours | Least | Highest | See Note (12) See Note (9) |
| Labor, mainly related to the mother plants' growth and maintenance | Relatively fewer working hours | Relatively greater working hours | Least | Highest | |

Notes: (1) The overall average period of the whole production cycle is important for the economic analysis because of the duration of costs that are connected to the presence of the plants in the nursery spaces and for the maintenance of the plants. (2) The mortality of the cuttings in the early stages of production implies the use of greater starting plant material and greater cultivation operations. It is important mainly for the economic assessment. (3) The effect of the raw propagation material (i.e., mother plants) on economic analysis is greater than the LCA analysis due to the change mainly in the operating modes of the process. (4) The substrates constitute a big part of the LCA impacts while the relatively low cost determines a lower effect for the economic analysis. (5) Fewer days of irrigation for plant material induce a great effect on LCA. However, the economic aspect is indirectly affected due to the cost of energy consumption for the water withdrawal. (6) Fewer days of watering and greenhouse heating implies here a high impact on both LCA and economic analysis. (7) Plastic pots impact mainly LCA analysis. However, this variable has less impact within the economic analysis due to the fact of the multiple use of pots from the first stage to more cycles of production. (8) The small number of plants affect here shortly the analysis because of the lower use cost of land. (9) The structures and the environmental indirect effect of greenhouse occupation (heating, watering) implies high effects for both analyses. (10) Auxins are used once in the rooting phase of cuttings so even if the amount is doubled in NSM there is no big effect on the analysis reported. (11) Chemicals are used constantly averagely every two weeks. As such, a shortened cycle can affect directly both economic and environmental analysis. (12) Labor affects only the economic analysis in a heavy way because of the relatively high cost of workers.

#### 2.1.2. Inventory of Resources Used and Emissions

To achieve the goals mentioned above, we collected different data categories and modeled them into input (i.e., all emissions extracted from the environment) and output data (i.e., all emissions released into the environment) for each ornamental species in this second phase of LCA, as shown in Figure 2. Hence, the inventory was oriented at acquiring data on characteristics of the species cultivated, pottery and substrates, fuel and energy, chemical inputs for residuals estimation, water, and land occupation. The results of the field survey and interviews addressed to technicians of the plant nursery were then modeled into the Open LCA software using the Eco-invent 3.7.1 database. As such, the input data used in this assessment are shown in Appendix A—Tables A1 and A2 and described as follows:

- Characteristics of the species: the first aspect observed concerns the duration of each phase and the mortality rate calculated in the passage from one phase to the next. The further element of a general nature, characteristic of each species, concerns the type of stationing of the pots in the last phase of the production cycle. While for some species it occurs in the open field, for others it continues in the greenhouse (Tables 1 and 2).
- Pottery: The rooting phase takes place in germination trays of 104 thermoformed polystyrene cells of 14 mL. After the first transplant, the plants grow in extruded and thermoformed polypropylene pots of 0.30 l (d7 cm) and 1.8 l (d16 cm) at the second transplant.
- Fuel and energy: The energy data survey concerned the characteristics of the company structures responsible for heating the greenhouse, the machines for preparing the substrates and for transplanting, and finally the extraction of water from the ground and for irrigation. The data of power and absorption/energy consumption were gathered through the collection of operating technical sheets. Finally, the data for each

species concerned the operating times of the individual machines and equipment as well as the data on the area occupied annually to estimate heating consumption.
- Cultivation substrates: Data relating to the cultivation substrates used in the different stages of production were collected, peat by volume and perlite and pumice by weight.
- Chemical residuals: The data of the treatments were calculated based on the timing of the cultivation of each species, assuming a production of residues introduced into agricultural soil equal to 10% of the quantities administered. In particular, the values in grams of fungicides (Table 3) were calculated.
- Water: The amount of water used for irrigation was entered into the inventory as the amount in liters of ground water taken from wells and used for irrigation as a support activity for agriculture.
- Land occupation: The annual occupation data in square meters of greenhouse and agricultural land per year have been estimated on the time extent and the surface area occupied in each production phase.

#### 2.1.3. Impact Assessment

To translate the results/indicators of environmental interventions into environmental impacts, we used the ReCiPe Midpoint Hierarchist method for this purpose. This technique was initially developed in 2008 through cooperation between RIVM, Radboud University Nijmegen, Leiden University, and PRé Sustainability [43–46]. As such, we transformed the long-life cycle inventory results (Table 3) into a limited number of indicator scores at two hierarchical levels, 18 midpoint indicators and 3 endpoint indicators:

- Agricultural land occupation—ALOP ($m^2$);
- Climate change—GWP100 (kg CO2-Eq);
- Fossil depletion—FDP (kg oil-Eq);
- Freshwater ecotoxicity—FETPinf (kg 1,4-DCB-Eq);
- Freshwater eutrophication—FEP (kg P-Eq);
- Human toxicity—HTPinf (kg 1,4-DCB-Eq);
- Ionizing radiation—IRP_HE (kg U235-Eq);
- Marine ecotoxicity—METPinf (kg 1,4-DCB-Eq);
- Marine eutrophication—MEP (kg N-Eq);
- Metal depletion—MDP (kg Fe-Eq);
- Natural land transformation—NLTP ($m^2$);
- Ozone depletion—ODPinf (kg CFC-11-Eq);
- Particulate matter formation—PMFP (kg PM10-Eq);
- Photochemical oxidant formation—POFP (kg NMVOC);
- Terrestrial acidification—TAP100 (kg $SO_2$-Eq);
- Terrestrial ecotoxicity—TETPinf (kg 1,4-DCB-Eq);
- Urban land occupation—ULOP ($m^2$);
- Water depletion—WDP ($m^3$).

Among these indicators, we prioritized here 4 impact indicators (ALOP, GWP100, FDP, and WDP). In fact, the resonance that the issue of climate change has on public opinion and decision-makers pushes any productive sector such as ornamental to improve the climate impact of its production [47]. Similarly, the assessment of fossil fuel consumption has implications related to climate, but also to the rationalization of business energy costs [48]. In the Mediterranean context, where the water resource is scarce, the evaluation of practices that can make its use more efficient assumes extreme importance [49]. Finally, focusing on land consumption [50], the occupation of land for productive purposes often conflicts with natural spaces and their ability to provide ecosystem services.

### *2.2. Economic Viability Analysis*

The economic suitability of any investment such as the implementation of novel and/or sustainable production practices at nursery plant may be affected by several financial aspects (i.e., cash flows, time value of money, risk, return, and maximization of profits). In this perspective, to quantify the economic performance and viability of the two concerned models, we assessed the CM and NSM from a financial point of view [51,52] through the compilation and calculation of the following financial indices: annual total gross income, annual gross margin (GM), net present value (NPV), and benefit–cost ratio (BCR), as described in Table 5. We used the CBA for this purpose in which it indicates that the change, such as sustainable and novel ornamental practices, will increase, reduce, or not modify these indicators. As such, we collected the gross saleable production data, miscellaneous expenses, wages, and salaries based on the working calendar at the nursery level. We did not include the advance interest and taxes, although they were considered in the calculation of the nursery balance sheet, in the life-cycle cost. We considered the market prices of year 2021 to assess the expenses (i.e., chemical inputs, pots, substrates, energy, and fuel—Appendix A—Tables A3 and A4). We did not consider water as a cost because it was taken directly from the ground. However, the electricity needed for the water extraction has already been included in the financial analysis.

**Table 5.** Financial indicators used to assess the economic viability of the two ornamental production models: conventional production model (CM) and novel and sustainable production model (NSM), among 8 selected ornamental species.

| Indicator | Formula | Comments and/or Interpretation |
|---|---|---|
| Annual total gross income (in EUR) | Number of plants × Plant unit price | Based on market prices. Year: 2021. |
| Annual gross margin (in EUR) | Total gross income—Total variable costs | |
| Net present value (NPV in EUR) | $NPV = \sum_{t=0}^{n} \frac{Rt}{(1+i)^t}$ | $R_t$: net cash flows—outflows during a single period.<br>i: discount rate (here 5%).<br>n: number of periods (here 10 years).<br>NPV determines which production model is the most profitable. |
| Benefit–cost ratio (BCR in EUR) | $BCR = \frac{\sum_{t=0}^{n} CFt\ Benefits/(1+i)^t}{\sum_{t=0}^{n} CFt\ Costs/(1+i)^t}$ | CF: cash flows.<br>i: discount rate (here 5%).<br>n: number of periods (here 10 years).<br>t: period that the cash flow occurs.<br>BCR < 1: the model is destroying value.<br>BCR = 1: the model will neither create nor destroy value.<br>BCR > 1: the model will induce incremental value. |

## 3. Results

### 3.1. Ornemental Species Life Span

The ornamental species life spans (in days) associated with the two production models (CM and NSM) are shown in Table 6, in which we observed an overall average life span of 280 and 260 days for CM and NSM, respectively, with an overall marginal degree of variation (3%) between these models of production among the eight ornamental species.

### 3.2. Environmental Implications

The environmental implications associated with the CM and NSM, to the production of a functional unit of 1000 potted plants, d16, for each of the concerned eight species, are shown in Tables 7 and 8, respectively. While the levels of environmental implications differ slightly between every production practice, the adoption of novel and sustainable practices generates a potential reduction impact for the four environmental categories: ALOP, GWP100, FDP, and WDP, with an overall low degree of variation between these environmental categories across the eight ornamental species (Table 9). Among these plants, *Bougainvillea* cv Don Mario, having a relative high life span cycle (Table 6), showed a relatively high reduction in environmental implications for these indicator categories as shown in Table 9. On the contrary, when considering the climate change indicator, the minimum values of reduction were observed for *Abelia grandiflora* and *Viburnum lucidum*, indicating similar results despite the variation between their production cycle. Furthermore, the implementation of NSM practices achieves a similar reduction in environmental impact with respect to the FDP category for *Jasminum officinalis*, *Lantana camara* cv Bandana rosa, *Loropetalum chinense* cv Black Pearl, and *Trachelospermum jasminoides*. Moreover, the sustainable techniques of cultivation generate a very slight reduction in water depletion among all selected ornamental species (Tables 7–9).

**Table 6.** Ornamental species life span (in days) associated with two production models: conventional production model (CM) and novel and sustainable production model (NSM) among 8 selected ornamental species.

| **Species** | **CM (in Days)** | **NSM (in Days)** |
| --- | --- | --- |
| *Abelia grandiflora* | 190 | 170 |
| *Bougainvillea* cv Don Mario | 370 | 350 |
| *Jasminum officinalis* | 270 | 250 |
| *Lantana camara* cv Bandana rosa | 130 | 110 |
| *Loropetalum chinense* cv Black Pearl | 310 | 290 |
| *Photinia fraseri* cv Red Robin | 300 | 280 |
| *Trachelospermum jasminoides* | 360 | 340 |
| *Viburnum lucidum* | 310 | 290 |
| Overall average | 280 | 260 |
| Standard deviation | 82.3 | 82.3 |
| Coefficient of variation (%) | 29 | 32 |

**Table 7.** Environmental implications associated with conventional production model (CM) among 8 selected ornamental species of 1000 plants.

| **Species** | **ALOP ($m^2$)** | **GWP100 (kg $CO_2$-Eq)** | **FDP (kg oil-Eq)** | **WDP ($m^3$)** |
| --- | --- | --- | --- | --- |
| *Abelia grandiflora* | 34.50 | 411.49 | 89.88 | 12.91 |
| *Bougainvillea* cv Don Mario | 366.45 | 1935.49 | 582.27 | 26.15 |
| *Jasminum officinalis* | 41.29 | 441.62 | 99.67 | 14.47 |
| *Lantana camara* cv Bandana rosa | 86.14 | 731.05 | 193.06 | 8.32 |
| *Loropetalum chinense* cv Black Pearl | 52.29 | 464.44 | 106.08 | 18.11 |
| *Photinia fraseri* cv Red Robin | 50.07 | 446.83 | 101.45 | 17.52 |
| *Trachelospermum jasminoides* | 66.25 | 448.41 | 102.10 | 23.53 |
| *Viburnum lucidum* | 49.74 | 444.08 | 100.54 | 17.50 |

**Table 8.** Environmental implications associated with novel and sustainable production model (NSM) among 8 selected ornamental species of 1000 plants.

| **Species** | **ALOP ($m^2$)** | **GWP100 (kg $CO_2$-Eq)** | **FDP (kg oil-Eq)** | **WDP ($m^3$)** |
| --- | --- | --- | --- | --- |
| *Abelia grandiflora* | 33.88 | 408.87 | 89.03 | 12.88 |
| *Bougainvillea* cv Don Mario | 364.09 | 1922.75 | 578.11 | 26.01 |
| *Jasminum officinalis* | 40.46 | 437.64 | 98.37 | 14.42 |
| *Lantana camara* cv Bandana rosa | 85.42 | 727.51 | 191.91 | 8.28 |
| *Loropetalum chinense* cv Black Pearl | 51.56 | 461.35 | 105.08 | 18.06 |
| *Photinia fraseri* cv Red Robin | 48.89 | 440.64 | 99.43 | 17.45 |
| *Trachelospermum jasminoides* | 65.53 | 445.15 | 101.43 | 23.49 |
| *Viburnum lucidum* | 49.13 | 441.46 | 99.69 | 17.46 |

**Table 9.** Environmental implications variation between two ornamental production models: conventional production model (CM) and novel and sustainable production model (NSM), among 8 selected ornamental species of 1000 plants. Values were derived from Tables 7 and 8.

| Species | ALOP ($m^2$) | GWP100 (kg $CO_2$-Eq) | FDP (kg oil-Eq) | WDP ($m^3$) |
|---|---|---|---|---|
| *Abelia grandiflora* | 0.62 | 2.63 | 0.85 | 0.04 |
| *Bougainvillea* cv Don Mario | 2.36 | 12.74 | 4.16 | 0.14 |
| *Jasminum officinalis* | 0.83 | 3.98 | 1.29 | 0.05 |
| *Lantana camara* cv Bandana rosa | 0.72 | 3.53 | 1.15 | 0.04 |
| *Loropetalum chinense* cv Black Pearl | 0.73 | 3.08 | 1.00 | 0.04 |
| *Photinia fraseri* cv Red Robin | 1.18 | 6.19 | 2.02 | 0.07 |
| *Trachelospermum jasminoides* | 0.71 | 3.26 | 1.06 | 0.04 |
| *Viburnum lucidum* | 0.61 | 2.62 | 0.85 | 0.04 |
| Overall average | 0.97 | 1.55 | 1.55 | 0.06 |
| Standard deviation | 0.59 | 1.12 | 1.12 | 0.03 |
| Coefficient of variation (%) | 60.81 | 72.38 | 72.38 | 60.78 |

Furthermore, Table 10 reveals the extrapolation of the values provided in Table 9, from 1000 plants to the overall nursery plant level of production, considering the total annual number of plants sold by species. As such, the overall averages of the environmental implication variation between the CM and NSM among eight selected ornamental species were 12.85 $m^2$, 49.61 kg $CO_2$-Eq, 16.15 kg oil-Eq, and 0.59 $m^3$ for ALOP, GWP100, FDP, and WDP, respectively, with an overall coefficient of variation for ALOP (54.72%) that is widely different from the rest of the environmental categories across the eight ornamental species. With respect to each category's impact, the main input contributors are diesel (burned in agricultural machinery), peat moss production (for horticultural use), d16 pot production, and pumice quarry operation for ALOP, GWP100, FDP, and WDP, respectively, as illustrated in Table A5.

**Table 10.** Differences of environmental impacts associated with two production models: conventional production model (CM) and novel and sustainable production model (NSM), among 8 selected ornamental species at nursery level, study case.

| Species | Sales per Year (Plants) | ALOP ($m^2$) | GWP100 (kg $CO_2$-Eq) | FDP (kg oil-Eq) | WDP ($m^3$) |
|---|---|---|---|---|---|
| *Abelia grandiflora* | 24,980 | 15.46 | 65.60 | 21.23 | 0.88 |
| *Bougainvillea* cv Don Mario | 6000 | 14.15 | 76.44 | 24.96 | 0.85 |
| *Jasminum officinalis* | 16,400 | 13.57 | 65.19 | 21.19 | 0.79 |
| *Lantana camara* cv Bandana rosa | 9800 | 7.05 | 34.64 | 11.27 | 0.41 |
| *Loropetalum chinense* cv Black Pearl | 4200 | 3.07 | 12.95 | 4.19 | 0.17 |
| *Photinia fraseri* cv Red Robin | 22,950 | 27.04 | 142.01 | 46.33 | 1.60 |
| *Trachelospermum jasminoides* | 16,900 | 12.07 | 0.04 | 0.00 | 0.00 |
| *Viburnum lucidum* | 17,100 | 10.40 | 0.03 | 0.00 | 0.00 |
| Overall average | 17,791.25 | 12.85 | 49.61 | 16.15 | 0.59 |
| Standard deviation | 7.03 | 7.03 | 48.17 | 15.71 | 0.55 |
| Coefficient of variation (%) | 50.92 | 54.72 | 97.08 | 97.31 | 93.60 |

### 3.3. Economic Viability

To capture the economic viability of both models (CM and NSM), gross margin (GM) was elaborated assuming a 10-year production scenario, in which BCR and NPV were generated discounted at 5%. As such, an indicator of profitability, the average annual values of total gross income, vary from a range between EUR 2943 (*Viburnum lucidum*) and near to EUR 6000 (*Lantana camara* cv Bandana rosa) among the different selected species. For the

NSM model, the overall annual average of GM appears to be relatively greater than the overall average of the CM model with overall coefficients of variation of 23.42% and 25.02% for the CM and NSM, respectively (Table 11). An overall annual average gross margin of about EUR 192/1000 plants can be generated using the NSM over the CM model. In fact, the later model may not involve certified mother plants or pressure pest control costs in terms of rigorous monitoring and continuous surveillance labor and use of protected tools from harmful pathogens.

**Table 11.** Annual average total gross income and annual average gross margin (in EUR) associated with two production models: conventional production model (CM) and novel and sustainable production model (NSM), among 8 selected ornamental species.

| Species | CM | | SNM | |
|---|---|---|---|---|
| | **Total Gross Income** | **Gross Margin** | **Total Gross Income** | **Gross Margin** |
| *Abelia grandiflora* | 4994.74 | 3086.27 | 5582.35 | 3431.77 |
| *Bougainvillea* cv Don Mario | 2959.46 | 1752.66 | 3128.57 | 1840.78 |
| *Jasminum officinalis* | 4055.56 | 2653.09 | 4380.00 | 2865.56 |
| *Lantana camara* cv Bandana rosa | 5053.85 | 2279.22 | 5972.73 | 2682.04 |
| *Loropetalum chinense* cv Black Pearl | 4120.97 | 2871.30 | 4405.17 | 3048.93 |
| *Photinia fraseri* cv Red Robin | 3163.33 | 1888.81 | 3389.29 | 2008.44 |
| *Trachelospermum jasminoides* | 3041.67 | 1967.21 | 3220.59 | 2063.48 |
| *Viburnum lucidum* | 2943.55 | 1713.11 | 3146.55 | 1810.74 |
| Overall average | 3791.64 | 2276.46 | 4153.16 | 2468.97 |
| Standard deviation | 893.45 | 533.06 | 1132.92 | 617.64 |
| Coefficient of variation (%) | 23.56 | 23.42 | 27.28 | 25.02 |

Both models have positive NPV (Table 12) and BCR (Table 13) values for all concerned species. As such, the NSM presents higher NPV values (Table 12), indicating that the changes are at an advantage and can induce enough financial flow to recover the variable cost of production. In terms of NPV variation for both models among ornamental species, *Lantana camara* cv Bandana rosa presents the highest value (17.57%), followed by *Abelia grandiflora* (11.08%) and *Jasminum officinalis* (7.16%). The least variation is marked by *Trachelospermum jasminoides* (4.67%).

**Table 12.** Net present value (NPV) variation for two production models: conventional production model (CM) and novel and sustainable production model (NSM), among 8 selected ornamental species. A discount rate of 5% was used for both protocols, even if the production with NSM presumes a reduction in the risk of production of safer phytosanitary ornamental plants. The label values (in %) indicate the variation in NPV between the two models.

| Species | CM (in EUR) | NSM (in EUR) | Variation (in %) |
|---|---|---|---|
| *Abelia grandiflora* | 25,022.94 | 27,794.50 | 11.08 |
| *Bougainvillea* cv Don Mario | 14,210.25 | 14,886.55 | 4.76 |
| *Jasminum officinalis* | 21,510.75 | 23,051.56 | 7.16 |
| *Lantana camara* cv Bandana rosa | 18,479.47 | 21,727.12 | 17.57 |
| *Loropetalum chinense* cv Black Pearl | 23,279.97 | 24,687.47 | 6.05 |
| *Photinia fraseri* cv Red Robin | 15,314.16 | 16,251.54 | 6.12 |
| *Trachelospermum jasminoides* | 15,949.77 | 16,695.25 | 4.67 |
| *Viburnum lucidum* | 13,889.56 | 14,648.56 | 5.46 |
| Overall average | 18,457.11 | 19,967.82 | 7.86 |
| Standard deviation | 4322.01 | 4996.73 | 4.42 |
| Coefficient of variation (%) | 23.42 | 25.02 | 56.29 |

**Table 13.** Benefit–Cost Ratio (BCR) variation for two production models: conventional production model (CM) and novel and sustainable production model (NSM), among 8 selected ornamental species. A discount rate of 5% was used for both protocols, even if the production with NSM presumes a reduction in the risk of production of safer phytosanitary ornamental plants. The label values (in %) indicate the variation in BCR between the two models.

| Species | CM (in EUR) | NSM (in EUR) | Variation (in %) |
|---|---|---|---|
| *Abelia grandiflora* | 2.62 | 2.60 | −0.82 |
| *Bougainvillea* cv Don Mario | 2.45 | 2.43 | −0.93 |
| *Jasminum officinalis* | 2.89 | 2.86 | −1.21 |
| *Lantana camara* cv Bandana rosa | 1.82 | 1.81 | −0.35 |
| *Loropetalum chinense* cv Black Pearl | 3.30 | 3.25 | −1.50 |
| *Photinia fraseri* cv Red Robin | 2.48 | 2.45 | −1.11 |
| *Trachelospermum jasminoides* | 2.83 | 2.78 | −1.68 |
| *Viburnum lucidum* | 2.39 | 2.36 | −1.54 |
| Overall average | 2.60 | 2.57 | −1.14 |
| Standard deviation | 0.43 | 0.42 | 0.44 |
| Coefficient of variation (%) | 16.69 | 16.33 | −38.54 |

However, the BCR analysis values are greater than 1, indicating that both models were profitable (Table 13). With respect to this ratio, the efficiency of the changes is slightly less efficient for an overall average of around −1%. This is particularly due to the pressure costs of the certified propagation material plants (see Tables 14 and 15 on *Abelia grandiflora* as an example) for planting delivered by external accredited research organism and to the costs of maintenance during their life cycle of production.

**Table 14.** Economic analysis (in EUR) associated with the conventional production model (CM) for *Abelia grandiflora*.

| In (EUR) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gross income | 4994.74 | 4994.74 | 4994.74 | 4994.74 | 4994.74 | 4994.74 | 4994.74 | 4994.74 | 4994.74 | 4994.74 |
| Production cost | 1892.20 | 1892.20 | 1892.20 | 1892.20 | 1892.20 | 1892.20 | 1892.20 | 1892.20 | 1892.20 | 1892.20 |
| Propagation plant material (i.e., mother plants) | 16.27 | 16.27 | 16.27 | 16.27 | 16.27 | 16.27 | 16.27 | 16.27 | 16.27 | 16.27 |
| Cash flow (CF) | 3086.27 | 3086.27 | 3086.27 | 3086.27 | 3086.27 | 3086.27 | 3086.27 | 3086.27 | 3086.27 | 3086.27 |
| Discounted CF (DCF) | 3086.27 | 2939.30 | 2799.34 | 2666.03 | 2539.08 | 2418.17 | 2303.02 | 2193.35 | 2088.91 | 1989.44 |
| Accumulated DCF | 3086.27 | 6172 | 9259 | 12,345 | 15,431 | 18,518 | 21,604 | 24,690 | 27,776 | 30,863 |

**Table 15.** Economic analysis (in EUR) associated with the novel and sustainable production model (NSM) for *Abelia grandiflora*.

| In (EUR) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gross income | 5582.35 | 5582.35 | 5582.35 | 5582.35 | 5582.35 | 5582.35 | 5582.35 | 5582.35 | 5582.35 | 5582.35 |
| Production cost | 2107.56 | 2107.56 | 2107.56 | 2107.56 | 2107.56 | 2107.56 | 2107.56 | 2107.56 | 2107.56 | 2107.56 |
| Propagation plant material (i.e., mother plants) | 209.31 | 16.27 | 17.90 | 19.69 | 21.65 | 23.82 | 26.20 | 28.82 | 31.70 | 34.88 |
| Cash flow (CF) | 3265.48 | 3458.52 | 3456.90 | 3455.11 | 3453.14 | 3450.97 | 3448.59 | 3445.97 | 3443.09 | 3439.92 |
| Discounted CF (DCF) | 3265.48 | 3293.93 | 3135.51 | 2984.65 | 2840.91 | 2703.93 | 2573.39 | 2448.99 | 2330.42 | 2217.40 |
| Accumulated DCF | 3265.48 | 6724.00 | 10,180.90 | 13,636.01 | 17,089.15 | 20,540.12 | 23,988.71 | 27,434.68 | 30,877.77 | 34,317.69 |

With respect to the structure of variable input production costs by cycle of 1000 plants (Table 16), the consumable categories in terms of pots (mainly d16 polyethylene pots) represent the largest portion of inputs costs, followed by labor expenses. The cultivation substrates costs account for around 24% for both production models. Chemical spray costs in general are relatively very low and account for around 1%. As such, the NSM induces over the CM an overall additional average cost of around EUR 3 by cycle of 1000 plants among the eight selected ornamental species. Regardless of the ornamental production model, *Bougainvillea* cv Don Mario has by far the highest total variation cost of production (with an average value of around EUR 1208 for both models) and *Lantana camera* cv Banadana rosa has the lowest production costs (with an average value of around EUR 973 for both models) among the eight ornamental plants.

**Table 16.** Average variable input production costs (EUR/by cycle of 1000 plants)) variation associated with two production models: conventional production model (CM) and novel and sustainable production model (NSM), among 8 selected ornamental species. (Average is based on market prices. Year: 2021).

| Variable Input | CM | NSM |
|---|---|---|
| Mother plants | 15.21 | 39.69 |
| Pots | 442.55 | 441.46 |
| Energy | 38.51 | 38.02 |
| Substrates | 255.55 | 255.21 |
| Chemicals | 11.54 | 10.20 |
| Labor | 298.73 | 296.33 |
| Total | 1062.09 | 1080.91 |
| Overall average | 177.01 | 180.15 |
| Standard deviation | 181.24 | 176.76 |
| Coefficient of variation (%) | 102.4 | 98.12 |

## 4. Discussion

Plant nurseries constitute a potential risk driver for quarantine pests to be introduced, established, and spread in non-infected or restricted areas. Bacterial diseases, particularly those caused by Xf such as Pierce's disease of grapes in California [6], variegated chlorosis of citrus in Brazil [53], leaf scorch of oak in Florida [54], leaf scorch of oleander [55], leaf scorch of coffee [56], Alfalfa Dwarf disease [57], and olive quick decline syndrome in Italy [58], are among the most quarantined disease outbreaks limiting production, profitability, and trade activities, imposing regulatory obligations, and affecting the reputation of the plant nurseries in the national, regional, and international markets of ornamental and landscape species. Consequently, nursery growers, in the infected areas, are encouraged to improve their conventional cultivation techniques through the implementation of novel and sustainable practices [59], to prevent the introduction of new pests and the spreading of already established pests, considering the environmental implication and economic viability of such best practices. As the NSM requires fewer days of production compared to the CM (Table 6), this protocol represents a source of lower potential risk for the ecosystem. Consequently, it is clear how useful it can be to associate this model of production (NSM) with sustainability. In fact, the purchase of raw propagation material (i.e., mother plants) from certified organisms (i.e., the National Research Centre and University of Bari Aldo Moro) provides healthy and high-quality commercial ornamental landscape species and, consequently, fulfills the requirements of the markets and phytosanitary regulations. In addition, the NSM requires (i) less consumption of ground water that is not easily replaced/renewed, (ii) less use of plastic containers (i.e., plastic pots related to mortality rate in which their disposal leads to relevant environmental pollution), and (iii) less consumption of diesel oil essential to agricultural machinery and to ensure thermal regime for the growth period. It also attenuates the potential direct toxicity to nursery workers and to consumers (i.e., decrease the massive application of chemical control treatments that may also pollute the surface and underground water).

In this study, despite a moderate reduction of 20 days associated with the cycle of production (Table 6), NSM was found to induce relatively less environmental impact at nursery level towards the four most relevant indicator categories: ALOP, GWP100, FDP, and WDP (Table 9). As such, there are good opportunities to reduce environmental burden by adopting the NSM model. In other words, the LCA results per functional unit showed that the NSM production of ornamental species resulted in slightly greater environmental impact (Table 8) than the CM model (Table 7). In this context, diesel was the main contributor to these considered environmental impact categories, followed by peat moss production, plastic production in terms of d16 pot production, and pumice quarry operation. With respect to ALOP, fuel was responsible for approximatively 84% of the cumulative categories' impacts for *Bougainvillea* cv Don Mario and *Lantana camara* cv Bandana rosa and around 23% for the rest of the ornamental species across the two production models due to diesel burned in agricultural machinery. Here, the stage of the commercial maturity, the final stage of the cultivation models, influenced the consumption of diesel, in which *Bougainvillea* cv Don Mario and *Lantana camara* cv Bandana rosa continued their life span inside the greenhouses, while the rest of the species were in the open-field areas.

Regarding GW100, $CO_2$ emissions with the NSM production model (an overall average of 660.67 kg $CO_2$/1000 plants/year) were slightly low compared with CM production (an overall average of 665.42 kg $CO_2$/1000 plants/year), in line with Lazerni et al. [2], who measured $CO_2$ emissions, applying the LCA technique, of various Italian nursery ornamental productions. Here, two categories were the main sources for GHG emissions: (i) the peat moss production (for *Abelia grandiflora*, *Jasminum officinalis*, *Photinia fraseri* cv Red Robin, *Loropetalum chinense* cv Black Pearl, *Viburnum lucidum*, *Trachelospermum jasminoides*) in line with the impactful results of plastic, highlighted as a crucial $CO_2$ emitting source [60,61], and (ii) diesel, burned in agricultural machinery (for *Bougainvillea* cv Don Mario and *Lantana camara* cv Bandana rosa) in agreement with Kendall and McPherson [42], who demonstrated that energy made a notable contribution to GHG emissions. Our results match also with those founded by Hawera et al. [62] and Lan et al. [63], in which GW100, as an indicator of global warming, appeared to be primarily influenced by the energy, the main source of $CO_2$ emissions.

Concerning WDP, irrigation made here the lowest impact, which was less than 10% of the cumulative impacts for WDP among the selected landscape species, except for *Lantana camara* cv Bandana rosa, which reached around 13.4%, mainly due to the relative low water consumption of around 17.3 $m^3$/1000 plants/year for both cultivation models. However, the results of other LCA studies, mainly on vegetables cultivation, show that the irrigation system was qualified as an important energy driver due to pumping ground water and reached the highest impact contribution due to the high-water consumption [64]. This is obvious, considering that ornamental species require less water in greenhouse production, due to lower planting density [40]. The impact on FDP was very limited. The FDP results for the CM and NSM models were 171.88 and 170.33 kg oil-Eq, respectively. Here, the main contributors for FDP for FDP are as follows: (i) the d16 pot production (for *Abelia grandiflora*, *Jasminum officinalis*, *Photinia fraseri* cv Red Robin, *Loropetalum chinense* cv Black Pearl, *Viburnum lucidum*, *Trachelospermum jasminoides*) and (ii) diesel, burned in agricultural machinery (for *Bougainvillea* cv Don Mario and *Lantana camara* cv Bandana rosa). As such, the plastic pot production is here widely alleged to be linked to fossil depletion during the two cultivation systems, in which the contribution ranges from 60 to 70% of the total impact on FDP. These results are relatively high when compared to other agricultural products such strawberries due to their cultivation system [65].

Furthermore, auxin is known for its physiological effects in root development [66]. As such, using this plant regulator and considering other cultural practices (i.e., certified planting material and continuous monitoring and surveillance) in the NSM model, we found a moderate increase in nursery business profitability in an economically sustainable way, and it appeared to be the most profitable production model for the eight economically relevant ornamental species and relatively economically advantageous to the Apulia horticulture sector under the threat of an Xf invasion. In contrast, the CM model allowed for a relatively lower level of profitability in terms of BCR. Certainly, the adoption of best plant nursery practices to manage potential quarantine pests would reduce production costs for nursery growers. Subsequently, we recommended the implementation of novel and sustainable practices considering a nursery ability production cycle within a range that varies from 110 days (*Lantana camara* cv Bandana rosa) to 350 days (*Bougainvillea* cv Don Mario). Our results are in line with Rossa et al. [14], who assessed the impact of the use of auxins on the production cost of two ornamental species (*Euphorba phosperea* mart and *Euphorba entrophora* dark) and concluded that this kind of treatment reduced cutting mortality, thus inducing positive NPV and high BCR. Similarly, another study underlined that the intensive monitoring and surveillance and the early detection of ornamental plant diseases induced a 68% chance of nursery net benefit than the implementation of curative control strategies or standard chemical treatments [67]. Both NPV and BCR provide the same preferred positive outcomes for the two concerned models of production (CM and NSM). Using NPV suggests that the NSM model provides the better outcome as the NPV of the NSM is greater than the NPV of the CM alternative. However, using the BCR, the CM option appear to be slightly advantageous as its ratio is greater than the BCR of the NSM among the eight ornamental species. As such, the overall CBA result is determined by considering the costs and benefits involved in NSM, which are relatively greater. Therefore, we found it more appropriate to include both NPV and BCR results without ignoring one or focusing on the other to let the concerned nursery growers, under the pressure of the threat of quarantine pests such as Xf, to get a fuller understanding of the economic viability, when deciding about what to invest in or to adopt, such as NSM nursery practices. The latter could be useful to produce ornamental and landscape plants with high sanitary quality. The moderate difference in the cultivation period between the CM and NSM does not induce a significant variation of variable costs. Overall, the level of the latter saving differs to a small extent between CM and NSM among the eight selected ornamental species. As such, an overall annual average gross margin of about EUR 192/1000 plants (Table 16) can be generated by using the following: (i) certified propagation planting material, (ii) an optimal concentration of plant stimulator, and (iii) continuous monitoring and surveillance of insects, such as vector of quarantine pests such as Xf. However, this research does not assess the economic viability in terms of per surface unit function (i.e., hectare yield), overall cost estimates per multiple ornamental planting system in the study area. Moreover, consumers' perceptions of sustainable and eco-friendly ornamental practices to be adopted by nursery growers [68–71] should be addressed in the future to fully explore the assessment.

## 5. Conclusions

This research focused simultaneously on the environmental implications and economic viability concerning the implementation of novel and sustainable practices to produce eight ornamental species, representing the most economically important landscape species of the Apulian horticultural sector, mainly in the demarcated area of Xf invasion. The environmental sustainability of the production of ornamental plants was analyzed through LCA, which provides for the detection of inputs and outputs in terms of matter, energy, and emissions, retracing the entire production process. The economic sustainability of the innovation proposed by the project was analyzed by investigating the technical and economic implications on production processes and comparing them in terms of costs and benefits. By providing financial data such as ornamental production costs and gross revenue, this study explains the economic viability of the ornamental production models and serves as a complementary tool for indicating the sustainability of this kind of production in the short- and midterm. Moreover, our study may help nursery growers to adopt sustainable practices toward the improvement of the sustainability performance of the Apulian horticultural sector. Over the CM model, the NSM induces dissimilar implications at different levels of the environmental sustainability dimension. Even if the NSM model would not be highly or significantly economically sustainable for the plant nursery, this study showed that this alternative solution could be a way to contribute to the attenuation of the climate impact of ornamental species production and to decrease the nursery plant energy costs and fossil fuels, thus reducing the environmental burden. Furthermore, the NSM permits the more efficient use of water for the irrigation of ornamental species, where, in the context of Apulia as well as the Mediterranean basin, water resources are scarce, and drought and the risk of desertification are well-established themes. In addition, focusing on land consumption, the NSM assumes an extreme importance of the occupation of land to produce ornamental species, inducing less conflicts with natural spaces and their faculty to dispense ecosystem services. Moreover, the nursery growers may diminish the use of plastic pots within the NSM if compared to ornamental plants produced conventionally. In addition, despite the small differences of the ecological and economic benefits between the CM and NSM, this research can be considered as a real representative case study in the Apulia region, especially giving consideration that the Apulian nursery growers can be targeted for environmentally friendly management, organization improvements, and the rational use of resources at their nursery plants to produce healthy ornamental and landscape species. Lastly, this study is limited to just one case. However, further challenges should not be neglected in future research on the environmental implications for post-harvest handling and the consumer behavior stages of the life cycle analysis of ornamental plants. As such, this analysis could be enlarged to cover a few more cases that certainly provide much more insightful results about the whole Apulia region ornamental sector and would allow more general conclusions and the obtainment of a complete overview assessment of this region in terms of sustainability.

## 6. Patents

There are no patents resulting from the work reported in this manuscript.

**Author Contributions:** Conceptualization, M.F. and A.P.; methodology, M.F.; A.P. and F.B.; software, A.P.; validation, V.F.; formal analysis, V.F. and F.B.; investigation, A.P. and M.F.; resources, F.B.; data curation, V.F.; writing—original draft preparation, M.F.; writing—review and editing, A.P.; visualization, A.P.; supervision, C.A. and R.B.; project administration, F.B.; funding acquisition, A.P. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the Rural Development Programme (Regional)—Puglia—2014IT06RDRP020: Italy, Measure 16.2, Project name: "ProDiQuaVi"—Transfer of protocols for quarantine and harmful organisms and for the selection of sanitary materials improved for the Apulian nursery. The APC was funded by UNIBA (University of Bari Aldo Moro).

**Data Availability Statement:** Not applicable.

**Acknowledgments:** Thanks are due to Daniela Cuppone and Enza Campanella for their administrative support.

**Conflicts of Interest:** The authors declare no conflict of interest The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

## Appendix A

**Table A1.** Types of inputs used under CM ornamental production model.

| Input (Unit) | | Ornamental Species | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Abelia grandiflora** | **Bougainvillea cv Don Mario** | **Jasminum officinalis** | **Lantana camara cv Bandana rosa** | **Loropetalum chinense cv Black Pearl** | **Photinia fraseri cv Red Robin** | **Trachelospermum jasminoides** | **Viburnum lucidum** |
| Labor per cycle (hours) | | 26.6 | 28.40 | 29.36 | 22.07 | 30.11 | 30.00 | 31.29 | 30.11 |
| Cultivation substrates | Peat (mc) | 2.04 | 2.08 | 2.04 | 2.04 | 2.09 | 2.04 | 2.04 | 2.04 |
| | Pumice(kg) | 373.07 | 378.69 | 373.07 | 373.07 | 381.99 | 373.07 | 373.07 | 373.07 |
| | Perlite (kg) | 0.11 | 0.25 | 0.12 | 0.12 | 0.13 | 0.15 | 0.12 | 0.11 |
| Water Irrigation | Rooting (l) | 62.80 | 244.22 | 104.67 | 52.33 | 129.29 | 125.60 | 99.16 | 109.90 |
| | Growth (l) | 1470 | 3266.67 | 2940.00 | 1470.00 | 3458.82 | 2940.00 | 2940.00 | 2940.00 |
| | Maturity (l) | 9045 | 18,090 | 9045 | 4020 | 12,060 | 12,060 | 18,090 | 12,060 |
| Energy Fuel | Diesel for heating and machinery (l) | 5.78 | 294.44 | 11.23 | 67.82 | 13.31 | 11.56 | 11.14 | 11.31 |
| | Electricity for water pumping and irrigation (Kwh) | 18.89 | 38.57 | 21.59 | 9.90 | 27.94 | 27.01 | 37.73 | 26.98 |
| Consumables Pots | Number of dashes (life span: 3 cycles) | 9.62 | 21.37 | 10.68 | 10.68 | 11.31 | 12.82 | 10.12 | 9.62 |
| | Number of 7 pots | | | | | | | | |
| | Number of Ø7 pots (life span: 3 cycles) | 1000 | 1111 | 1000 | 1000 | 1176 | 1000 | 1000 | 1000 |
| | Number of Ø16 pots (life span: 1 cycle) | 1000 000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Land occupation | Agricultural land ($m^2$*$year^{-1}$) | 24.66 | - | 24.66 | - | 32.88 | 32.88 | 49.32 | 32.88 |
| | Greenhouse ($m^2$*$year^{-1}$) | 1.02 | 51.87 | 1.98 | 11.95 | 2.35 | 2.04 | 1.96 | 1.99 |
| Chemical treatments | Rhizopon (mL) | 20.00 | 44.44 | 22.22 | 22.22 | 23.53 | 26.67 | 21.05 | 20.00 |
| | Omix (mL) | 67.86 | 167.46 | 98.81 | 47.62 | 122.69 | 114.29 | 129.70 | 110.71 |
| | Radicifo (mL) | 67.86 | 167.46 | 98.81 | 47.62 | 122.69 | 114.29 | 129.70 | 110.71 |
| | Azaka (mL) | 4.83 | 12.63 | 7.72 | 3.78 | 9.45 | 8.67 | 9.11 | 8.33 |
| | Alias (mL) | 9.67 | 25.26 | 15.44 | 7.56 | 18.90 | 17.33 | 18.21 | 16.67 |
| | Pindarus 25 WG (mL) | 2.42 | 6.31 | 3.86 | 1.89 | 4.73 | 4.33 | 4.55 | 4.17 |
| | Triash (mL) | 9.67 | 25.26 | 15.44 | 7.56 | 18.90 | 17.33 | 18.21 | 16.67 |

**Table A2.** Types of inputs used under NSM ornamental production model.

| Input (Unit) | | Abelia grandiflora | Bougainvillea cv Don Mario | Jasminum officinalis | Lantana camara cv Bandana rosa | Loropetalum chinense cv Black Pearl | Photinia fraseri cv Red Robin | Trachelospermum jasminoides | Viburnum lucidum |
|---|---|---|---|---|---|---|---|---|---|
| | | **Ornamental Species** | | | | | | | |
| Labor per cycle (hours) | | 26.03 | 28.17 | 29.13 | 21.84 | 29.89 | 29.77 | 31.06 | 29.89 |
| Cultivation substrates | Peat (mc) | 2.04 | 2.07 | 2.04 | 2.04 | 2.09 | 2.04 | 2.04 | 2.04 |
| | Pumice(kg) | 373.07 | 378.69 | 373.07 | 373.07 | 381.99 | 373.07 | 373.07 | 373.07 |
| | Perlite (kg) | 0.11 | 0.18 | 0.11 | 0.11 | 0.13 | 0.12 | 0.11 | 0.11 |
| Water Irrigation | Rooting (l) | 31.40 | 124.60 | 62.80 | 15.70 | 92.35 | 66.11 | 62.80 | 78.50 |
| | Growth (l) | 1470.00 | 3266.67 | 2940.00 | 1470.00 | 3458.82 | 2940.00 | 2940.00 | 2940.00 |
| | Maturity (l) | 9045 | 18,090 | 9045 | 4020 | 12,060 | 12,060 | 18,090 | 12,060 |
| Energy Fuel | Diesel for heating and machinery (l) | 5.28 | 292.54 | 10.57 | 67.24 | 12.72 | 10.62 | 10.57 | 10.82 |
| | Electricity for water pumping and irrigation (Kwh) | 18.83 | 38.36 | 21.51 | 9.83 | 27.88 | 26.90 | 37.67 | 26.93 |
| Consumables Pots | Number of dashes (life span: 3 cycles) | 9.62 | 15.26 | 9.62 | 9.62 | 11.31 | 10.12 | 9.62 | 9.62 |
| | Number of 7 pots | | | | | | | | |
| | Number of Ø7 pots (life span: 3 cycles) | 1000 | 1111 | 1000 | 1000 | 1176 | 1000 | 1000 | 1000 |
| | Number of Ø16 pots (life span: 1 cycle) | 1000 000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Land occupation | Agricultural land ($m^2$*$year^{-1}$) | 24.66 | - | 24.66 | - | 32.88 | 32.88 | 49.32 | 32.88 |
| | Greenhouse ($m^2$*$year^{-1}$) | 0.93 | 51.54 | 1.86 | 11.85 | 2.24 | 1.87 | 1.86 | 1.91 |
| Chemical treatments | Rhizopon (ml) | 20.00 | 31.75 | 20.00 | 20.00 | 23.53 | 21.05 | 20.00 | 20.00 |
| | Omix (mL) | 60.71 | 140.25 | 89.29 | 39.29 | 114.29 | 100.75 | 121.43 | 103.57 |
| | Radicifo (mL) | 60.71 | 140.25 | 89.29 | 39.29 | 114.29 | 100.75 | 121.43 | 103.57 |
| | Azaka (mL) | 4.17 | 10.09 | 6.83 | 3.00 | 8.67 | 7.40 | 8.33 | 7.67 |
| | Alias (mL) | 8.33 | 20.18 | 13.67 | 6.00 | 17.33 | 14.81 | 16.67 | 15.33 |
| | Pindarus 25 WG (mL) | 2.08 | 5.04 | 3.42 | 1.50 | 4.33 | 3.70 | 4.17 | 3.83 |
| | Triash (mL) | 8.33 | 20.18 | 13.67 | 6.00 | 12.33 | 14.81 | 16.67 | 15.33 |

**Table A3.** Input categories' costs associated with CM ornamental production model of 1000 plants (based on market prices. Year: 2021).

| **Input Category** | | **Ornamental Species** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ***Abelia grandiflora*** | ***Bougainvillea* cv Don Mario** | ***Lantana camara* cv Bandana rosa** | ***Jasminum officinalis*** | ***Photinia fraseri* cv Red Robin** | ***Loropetalum chinense* cv Black Pearl** | ***Viburnum lucidum*** | ***Trachelospermum jasminoides*** | **Average** |
| Pots | Dashes | 6.41 | 14.25 | 7.12 | 7.12 | 8.55 | 7.54 | 6.41 | 6.75 | |
| | Ø7 pots | 33.33 | 37.04 | 33.33 | 33.33 | 33.33 | 33.33 | 33.33 | 33.33 | |
| | Ø16 pots | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 442.55 |
| | Total | 439.74 | 451.28 | 440.46 | 440.46 | 441.88 | 446.76 | 439.74 | 440.08 | |
| | % | 44.42 | 32.32 | 43.29 | 42.60 | 42.23 | 42.11 | 42.14 | 41.48 | 41.32 |
| Energy | Diesel | 3.47 | 176.66 | 40.69 | 6.74 | 6.94 | 7.99 | 6.79 | 6.69 | |
| | Electricity | 4.72 | 9.64 | 2.47 | 5.40 | 6.75 | 6.99 | 6.75 | 9.43 | 38.51 |
| | Total | 8.19 | 186.30 | 43.17 | 12.14 | 13.69 | 14.97 | 13.53 | 16.12 | |
| | % | 0.83 | 13.34 | 4.24 | 1.17 | 1.31 | 1.41 | 1.30 | 1.52 | 3.14 |
| Substrates | Peat | 162.96 | 166.63 | 163.07 | 163.07 | 163.30 | 167.01 | 162.96 | 163.01 | |
| | Pumice | 89.54 | 90.88 | 89.54 | 89.54 | 89.54 | 91.68 | 89.54 | 89.54 | |
| | Perlite | 1.26 | 2.80 | 1.40 | 1.40 | 1.68 | 1.48 | 1.26 | 1.33 | |
| | Total | 253.76 | 260.32 | 254.01 | 254.01 | 254.51 | 260.17 | 253.76 | 253.88 | 255.55 |
| | % | 25.63 | 18.64 | 24.96 | 24.57 | 24.32 | 24.52 | 24.32 | 23.93 | 23.86 |
| Chemicals | Chemicals | 7.59 | 18.56 | 6.32 | 10.68 | 12.32 | 12.79 | 11.33 | 12.72 | 11.54 |
| | % | 0.77 | 1.33 | 0.62 | 1.03 | 1.18 | 1.21 | 1.09 | 1.20 | 1.05 |
| Land Occupation | Greenhouse | 3.57 | 181.55 | 41.82 | 6.93 | 7.13 | 8.21 | 6.98 | 6.87 | |
| | Agricultural land | 1.40 | 0.00 | 0.00 | 1.40 | 1.87 | 1.87 | 1.87 | 2.81 | |
| | Total | 4.97 | 181.55 | 41.82 | 8.33 | 9.00 | 10.08 | 8.85 | 9.68 | 34.28 |
| | % | 0.50 | 13.00 | 4.11 | 0.81 | 0.86 | 0.95 | 0.85 | 0.91 | 2.75 |
| Labor | Labor | 275.70 | 298.20 | 231.75 | 308.25 | 315.00 | 316.20 | 316.20 | 328.50 | 298.73 |
| | % | 27.85 | 21.36 | 22.78 | 29.82 | 30.10 | 29.80 | 30.30 | 30.96 | 27.87 |
| | Total costs | 989.95 | 1396.21 | 1017.52 | 1033.86 | 1046.41 | 1060.97 | 1043.41 | 1060.98 | 1081.16 |
| | % | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

**Table A4.** Input categories' costs associated with NSM ornamental production model of 1000 plants (based on market prices. Year: 2021).

| **Input Category** | | **Ornamental Species** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ***Abelia grandiflora*** | ***Bougainvillea* cv Don Mario** | ***Lantana camara* cv Bandana rosa** | ***Jasminum officinalis*** | ***Photinia fraseri* cv Red Robin** | ***Loropetalum chinense* cv Black Pearl** | ***Viburnum lucidum*** | ***Trachelospermum jasminoides*** | **Average** |
| Pots | Dashes | 6.41 | 10.18 | 6.41 | 6.41 | 6.75 | 7.54 | 6.41 | 6.41 | |
| | Ø7 pots | 33.33 | 37.04 | 33.33 | 33,33 | 33.33 | 39.22 | 33.33 | 33.33 | |
| | Ø16 pots | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | |
| | Total | 439.74 | 447.21 | 439.74 | 439.74 | 440.08 | 446.76 | 439.4 | 439.74 | 441.60 |
| | % | 44.59 | 32.36 | 43.43 | 42.75 | 42.37 | 42.26 | 42.29 | 41.62 | 41.46 |
| Energy | Diesel | 3.17 | 175.52 | 40.34 | 6.34 | 6.37 | 7.63 | 6.49 | 6.34 | |
| | Electricity | 4.71 | 9.59 | 2.46 | 5.38 | 6.73 | 6.97 | 6.73 | 9.42 | |
| | Total | 7.88 | 185.11 | 42.80 | 11.72 | 13.10 | 14.60 | 13.22 | 15.76 | 38.02 |
| | % | 0.80 | 13.39 | 4.23 | 1.14 | 1.26 | 1.38 | 1.27 | 1.49 | 3.12 |
| Substrates | Peat | 162.96 | 165.99 | 162.96 | 162.96 | 163.01 | 167.01 | 162.96 | 162.96 | |
| | Pumice | 89.54 | 90.88 | 89.54 | 89.54 | 89.54 | 91.68 | 89.54 | 89.54 | |
| | Perlite | 1.26 | 2.00 | 1.26 | 1.26 | 1.33 | 1.48 | 1.26 | 1.26 | |
| | Total | 253.76 | 258.88 | 253.76 | 253.76 | 253.88 | 260.17 | 253.76 | 253.76 | 255.21 |
| | % | 25.73 | 18.73 | 25.06 | 24.67 | 24.44 | 24.61 | 24.41 | 24.02 | 23.96 |
| Chemicals | Chemicals | 6.93 | 14.77 | 5.33 | 9.57 | 10.51 | 12.01 | 10.66 | 11.85 | 10.20 |
| | % | 0.70 | 1.07 | 0.53 | 0.93 | 1.01 | 1.14 | 1.03 | 1.12 | 0.94 |
| Land Occupation | Greenhouse | 3.26 | 180.38 | 41.46 | 6.52 | 6.55 | 7.85 | 6.67 | 6.52 | |
| | Agricultural land | 1.40 | 0.00 | 0.00 | 1.40 | 1.87 | 1.87 | 1.87 | 2.81 | |
| | Total | 4.66 | 180.38 | 41.46 | 7.92 | 8.42 | 9.72 | 8.54 | 9.32 | 33.80 |
| | % | 0.47 | 13.05 | 4.10 | 0.77 | 0.81 | 0.92 | 0.82 | 0.88 | 2.73 |
| Labor | Labor | 273.30 | 295.80 | 229.35 | 305.85 | 312.60 | 313.80 | 313.80 | 326.10 | 296.33 |
| | % | 27.71 | 21.40 | 22.65 | 29.74 | 30.10 | 29.69 | 30.18 | 30.87 | 27.79 |
| | Total costs | 986.26 | 1382.15 | 1012.44 | 1028.56 | 1038.58 | 1057.06 | 1039.72 | 1056.53 | 1075.16 |
| | % | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

**Table A5.** Inputs' contribution to input categories associated with CM and NSM ornamental production models of 1000 plants.

| **Impact** | **ALOP** | | | |
|---|---|---|---|---|
| Protocol | CM | | NSM | |
| Species | Main input contributor | % | Main input contributor | % |
| *Abelia grandiflora* | Diesel, burned in agricultural machinery | 17.72% | Diesel, burned in agricultural machinery | 16.49% |
| *Bougainvillea* cv Don Mario | Diesel, burned in agricultural machinery | 84.95% | Diesel, burned in agricultural machinery | 84.95% |
| ***Lantana camara*cv Bandana rosa** | Diesel, burned in agricultural machinery | 83.25% | Diesel, burned in agricultural machinery | 83.23% |
| *Jasminum officinalis* | Diesel, burned in agricultural machinery | 28.76% | Diesel, burned in agricultural machinery | 27.61% |
| ***Photinia fraseri*cv Red Robin** | Diesel, burned in agricultural machinery | 24.42% | Diesel, burned in agricultural machinery | 22.97% |

**Table A5.** *Cont.*

| Impact | ALOP | | | |
|---|---|---|---|---|
| *Loropetalum chinense* cv Black Pearl | Diesel, burned in agricultural machinery | 26.91% | Diesel, burned in agricultural machinery | 26.09% |
| *Viburnum lucidum* | Diesel, burned in agricultural machinery | 24.05% | Diesel, burned in agricultural machinery | 23.28% |
| *Trachelospermum jasminoides* | Diesel, burned in agricultural machinery | 17.79% | Diesel, burned in agricultural machinery | 17.05% |
| Impact | GWP100 | | | |
| Protocol | CM | | NSM | |
| Species | Main input contributor | % | Main input contributor | % |
| *Abelia grandiflora* | Peat moss production, horticultural use | 65.03% | Peat moss production, horticultural use | 65.45% |
| *Bougainvillea* cv Don Mario | Diesel, burned in agricultural machinery | 79.27% | Diesel, burned in agricultural machinery | 79.28% |
| ***Lantana camara*cv Bandana rosa** | Diesel, burned in agricultural machinery | 48.34% | Diesel, burned in agricultural machinery | 48.16% |
| *Jasminum officinalis* | Peat moss production, horticultural use | 60.64% | Peat moss production, horticultural use | 61.15% |
| ***Photinia fraseri*cv Red Robin** | Peat moss production, horticultural use | 60.01% | Peat moss production, horticultural use | 60.75% |
| *Loropetalum chinense* cv Black Pearl | Peat moss production, horticultural use | 59.05% | Peat moss production, horticultural use | 59.44% |
| *Viburnum lucidum* | Peat moss production, horticultural use | 60.26% | Peat moss production, horticultural use | 60.62% |
| *Trachelospermum jasminoides* | Peat moss production, horticultural use | 59.70% | Peat moss production, horticultural use | 60.11% |
| Impact | FDP | | | |
| Protocol | CM | | NSM | |
| Species | Main input contributor | % | Main input contributor | % |
| *Abelia grandiflora* | d16 pot production | 69.24% | d16 pot production | 69.90% |
| *Bougainvillea* cv Don Mario | Diesel, burned in agricultural machinery | 85.18% | Diesel, burned in agricultural machinery | 85.24% |
| ***Lantana camara*cv Bandana rosa** | Diesel, burned in agricultural machinery | 59.18% | Diesel, burned in agricultural machinery | 59.02% |
| *Jasminum officinalis* | d16 pot production | 62.45% | d16 pot production | 63.27% |
| ***Photinia fraseri*cv Red Robin** | d16 pot production | 61.35% | d16 pot production | 62.60% |
| *Loropetalum chinense* cv Black Pearl | d16 pot production | 58.67% | d16 pot production | 59.23% |
| *Viburnum lucidum* | d16 pot production | 61.90% | d16 pot production | 62.43% |
| *Trachelospermum jasminoides* | d16 pot production | 60.96% | d16 pot production | 61.60% |
| Impact | WDP | | | |
| Protocol | CM | | NSM | |
| Species | Main input contributor | % | Main input contributor | % |
| *Abelia grandiflora* | Pumice quarry operation | 8.65% | Pumice quarry operation | 8.67% |
| *Bougainvillea* cv Don Mario | Diesel, burned in agricultural machinery | 8.35% | Diesel, burned in agricultural machinery | 8.34% |
| ***Lantana camara*cv Bandana rosa** | Pumice quarry operation | 13.41% | Pumice quarry operation | 13.48% |
| *Jasminum officinalis* | Pumice quarry operation | 7.72% | Pumice quarry operation | 7.74% |
| ***Photinia fraseri*cv Red Robin** | Pumice quarry operation | 6.37% | Pumice quarry operation | 6.40% |
| *Loropetalum chinense* cv Black Pearl | Pumice quarry operation | 6.31% | Pumice quarry operation | 6.33% |
| *Viburnum lucidum* | Pumice quarry operation | 6.38% | Pumice quarry operation | 6.39% |
| *Trachelospermum jasminoides* | Pumice quarry operation | 4.74% | Pumice quarry operation | 4.75% |

## References


1. Lazzerini, G.; Lucchetti, S.S.; Nicese, F.P. Analysis of greenhouse gas emissions from ornamental plant production: A nursery level approach. *Urban For. Urban Green.* **2014**, *13*, 517–525. [CrossRef]
2. Lazzerini, G.; Lucchetti, S.; Nicese, F.P. Green House Gases (GHG) emissions from the ornamental plant nursery industry: A Life Cycle Assessment (LCA) approach in a nursery district in central Italy. *J. Clean. Prod.* **2016**, *112*, 4022–4030. [CrossRef]

3. Bonaguro, J.E.; Coletto, L.; Samuele, B.; Zanin, G.; Sambo, P. Environmental impact in floriculture: LCA approach at farm level. *Acta Hortic.* **2016**, *1112*, 419–424. [CrossRef]
4. NationMaster. Ornamental Plant and Flowers Production. Top Countries for Ornamental Plants and Flowers Production. Available online: https://www.nationmaster.com/nmx/ranking/ornamental-plants-and-flowers-production (accessed on 5 September 2022).
5. Rani, A.; Donovan, N.J.; Mantri, N. The future of plant pathology diagnostics in a nursery production system. *Biosens. Bioelectron.* **2019**, *145*, 111631. [CrossRef] [PubMed]
6. Wells, J.M.; Raju, B.C.; Hung, H.Y.; Weisburg, W.G.; Mandelco-Paul, L.; Brenner, D.J. *Xylella fastidiosa* gen. nov., sp. nov: Gram-negative, xylem-limited, fastidious plant bacteria related to *Xanthomonas* spp. *Int. J. Syst. Bacteriol.* **1987**, *37*, 136–143. [CrossRef]
7. European Food Safety Authority Panel on Plant Health. Update of the *Xylella* spp. host plant database-systemic literature search up to 30 June 2021. *EFSA J.* **2022**, *20*, e07356. [CrossRef]
8. Bonaguro, J.E.; Coletto, L.; Sambo, P.; Nicoletto, C.; Zanin, G. Environmental analysis of sustainable production practices applied to Cyclamen and Zonal Geranium. *Horticulturae* **2021**, *7*, 8. [CrossRef]
9. Morelli, M.; García-Madero, J.M.; Jos, Á.; Saldarelli, P.; Dongiovanni, C.; Kovacova, M.; Saponari, M.; Baños Arjona, A.; Hackl, E.; Webb, S.; et al. *Xylella fastidiosa* in Olive: A aeview of control attempts and current management. *Microorganisms* **2021**, *9*, 1771. [CrossRef]
10. Frem, M.; Fucilli, V.; Nigro, F.; El Moujabber, M.; Abou Kubaa, R.; La Notte, P.; Bozzo, F.; Choueiri, E. The potential direct economic impact and private management costs of an invasive alien species: *Xylella fastidiosa* on Lebanese wine grapes. *NeoBiota* **2021**, *70*, 43–67. [CrossRef]
11. Bozzo, F.; Frem, M.; Fucilli, V.; Cardone, G.; Garofoli, P.F.; Geronimo, S.; Petrontino, A. Landscape and vegetation patterns zoning is a methodological tool for management costs implications due to *Xylella fastidiosa* invasion. *Land* **2022**, *11*, 1105. [CrossRef]
12. European Food Safety Authority Panel on Plant Health. Scientific Opinion on the risks to plant health posed by *Xylella fastidiosa* in the EU territory, with the identification and evaluation of risk reduction options. *EFSA J.* **2015**, *13*, 3989. [CrossRef]
13. Frem, M.; Chapman, D.; Fucilli, V.; Choueiri, E.; Moujabber, M.E.; Notte, P.L.; Nigro, F. *Xylella fastidiosa* invasion of new countries in Europe, the Middle East, and North Africa: Ranking the potential exposure scenarios. *NeoBiota* **2020**, *59*, 77–97. [CrossRef]
14. Rossa, Ü.B.; Winckler, P.R.; Winckler, P.R.F. Cuttings of *Euphorbia phosphorea* Mart and *Euphorbia enterophora* Drake at different concentrations of indole-butyric acid and analysis of economic viability. *Ornam. Hortic.* **2018**, *25*, 314–323. [CrossRef]
15. Russo, G.; Buttol, P.; Tarantini, M. LCA (Life Cycle Assessment) of roses and cyclamens in greenhouse cultivation. *Acta Hortic.* **2008**, *801*, 359–366. [CrossRef]
16. Blonk, H.; Kool, A.; Luske, B.; Ponsioen, T.; Scholten, J. *Methodology for Assessing Carbon Footprints of Horticultural Products*; Blonk Milieu Advies: Gouda, The Netherlands, 2010.
17. Ingram, D.L. Life cycle assessment of a field-grown red maple tree to estimate its carbon footprint components. *Int. J. Life Cycle Assess.* **2012**, *17*, 453–462. [CrossRef]
18. Beccaro, G.L.; Cerutti, A.K.; Vandecasteele, I.; Bonvegna, L.; Donno, D.; Bounous, G. Assessing environmental impacts of nursery production: Methodological issues and results from a case study in Italy. *J. Clean. Prod.* **2014**, *80*, 159–169. [CrossRef]
19. Bisaglia, C.; Cutini, M.; Romano, E.; Fedrizzi, M.; Menesatti, P.; Santoro, G.; Frangi, P.; Minuto, G.; Tinivella, F.; Miccolis, V.; et al. Trends and perspectives for the optimal use of energy in ornamental plant production and distribution in Italy. *Acta Hortic.* **2008**, *801*, 795–802. [CrossRef]
20. Vadiee, A.; Martin, V. Energy management in horticultural applications through the closed greenhouse concept, state of the art. *Renew. Sustain. Energy Rev.* **2012**, *16*, 5087–5100. [CrossRef]
21. Takhur, A.; Singh, R.; Gahlot, A.; Kaviti, A.; Aseer, R. Advancements in solar technologies for sustainable development of agricultural sector in India: A comprehensive review on challenges and opportunities. *Environ. Sci. Pollut. Res.* **2022**, *29*, 43607–43634. [CrossRef]
22. Mugnozza, G.S.; Russo, G.; De Lucia, B. LCA methodology application in flower protected cultivation. *Acta Hortic.* **2007**, *761*, 625–632. [CrossRef]
23. Grigatti, M.; Giorgioni, M.E.; Ciavatta, C. Compost-based growing media: Influence on growth and nutrient use of bedding plants. *Biores. Technol.* **2007**, *98*, 3526–3534. [CrossRef] [PubMed]
24. Papafotiou, M.; Physhalou, M.; Kargas, G.; Chatzipavlidis, I.J.; Chronopoulos, J. Olive-mill wastes compost as growing medium component for the production of poinsettia. *Sci. Hortic.* **2004**, *102*, 167–175. [CrossRef]
25. Tzavara, S.; Darras, A.; Assimakopoulou, A. Tobacco dust waste as an alternative medium to grow geranium (Pelargonium x hortorum) plants. *Adv. Hortic. Sci.* **2019**, *33*, 295–298. [CrossRef]
26. De Lucia, B.; Cristiano, G.; Vecchietti, L.; Rea, E.; Russo, G. Nursery growing media: Agronomic and environmental quality assessment of sewage sludge-based compost. *Appl. Environ.* **2013**, *10*, 565139. [CrossRef]
27. Darras, A. Overview of the dynamic role of specialty cut flowers in the international cut flower market. *Horticulturae* **2021**, *7*, 51. [CrossRef]
28. Weiss, D. Introduction of new cut flowers: Domestication of new species and introduction of new traits not found in commercial varieties. In *Breeding for Ornamentals: Classical and Molecular Approaches*; Springer: Dordrecht, The Netherlands, 2002; pp. 129–137.
29. De Pascale, S.; Romano, D. Potential use of wild plants in floriculture. *Acta Hortic.* **2019**, *1240*, 87–98. [CrossRef]

30. Ingram, D.L.; Fernandez, R.T. Life cycle assessment: A tool for determining the environmental impact of horticultural crop production. *HortTechnology* **2012**, *22*, 275–279. [CrossRef]
31. Ingram, D.L.; Hall, C.R. Carbon footprint and related production costs of system components of a field grown *Cercis canadensis L.* 'Forest Pansy' using life cycle assessment. *J. Environ. Hort.* **2013**, *31*, 169–176. [CrossRef]
32. Oguzcan, S.; Dvarioniene, J.; Tugnoli, A.; Kruopiene, K. Environmental impact assessment model for substitution of hazardous substances by using life cycle approach. *Environ. Pollut.* **2019**, *254*, 112945. [CrossRef]
33. Salehpour, T.; Khanali, M.; Rajabipour, A. Environmental impact assessment for ornamental plant greenhouse: Life cycle assessment approach for primrose production. *Environ. Pollut.* **2020**, *266*, 3. [CrossRef]
34. Bonilla-Gámez, N.; Toboso-Chavero, S.; Parada, F.; Civit, B.; Arena, A.P.; Rieradevall, J.; Durany, X.G. Environmental impact assessment of agro-services symbiosis in semiarid urban frontier territories. Case study of Mendoza (Argentina). *Sci. Total Environ.* **2021**, *774*, 145682. [CrossRef]
35. Maesano, G.; Chinnici, G.; Falcone, G.; Bellia, C.; Raimondo, M.; D'Amico, M. Economic and environmental sustainability of olive production: A case study. *Agronomy* **2021**, *11*, 1753. [CrossRef]
36. *ISO 14044*; International Standard Environmental Management—Life Cycle Assessment: Requirements and Guidelines. ISO: Geneva, Switzerland, 2006.
37. Hall, C.; Ingram, D. Production costs of field grown *Cercis canadensis* L. 'Forest Pansy' identified during life cycle assessment analysis. *HortScience* **2014**, *49*, 6. [CrossRef]
38. Valatin, G.; Price, C.; Green, S. Reducing disease risks to British forests: An exploration of costs and benefits of nursery best practices. *Int. J. For. Res.* **2022**, *95*, 477–491. [CrossRef]
39. Baldo, G.L.; Mariono, M.; Rossi, S. *Analisi del Ciclo di Vita LCA. Manuali di Progettazione Sostenibile*; Edizioni Ambiente: Milan, Italy, 2008.
40. Sahle, A.; Potting, J. Environmental life cycle assessment of Ethiopian rose cultivation. *Sci. Total Environ.* **2013**, *443*, 163–172. [CrossRef] [PubMed]
41. Vivai Capitanio Stefano. Eco-Sustainable Production. Available online: www.vivaicapitanio.it (accessed on 22 September 2022).
42. Kendall, A.; McPherson, E.G. A life cycle greenhouse gas inventory of a tree production system. *Int. J. Life Cycle Assess.* **2012**, *17*, 444–452. [CrossRef]
43. Basset-Mens, C.; Vannière, H.; Grasselly, D.; Heitz, H.; Braun, A.; Payen, S.; Biard, Y. Environmental impacts of imported and locally grown fruits for the French market: A cradle-to-farm-gate LCA study. *Fruits* **2016**, *71*, 93–104. [CrossRef]
44. Bessou, C.; Basset-Mens, C.; Latunussa, C.; Vélu, A.; Heitz, H.; Vannière, H.; Caliman, J.P. Partial modelling of the perennial crop cycle misleads LCA results in two contrasted case studies. *Int. J. Life Cycle Assess.* **2016**, *21*, 297–310. [CrossRef]
45. Chatzisymeon, E.; Foteinis, S.; Borthwick, A.G. Life cycle assessment of the environmental performance of conventional and organic methods of open field pepper cultivation system. *Int. J. Life Cycle Assess.* **2017**, *22*, 896–908. [CrossRef]
46. Wimmerova, L.; Keken, Z.; Solcova, O.; Bartos, L.; Spacilova, M. A comparative LCA of ceroponic, hydroponic, and soil cultivations of bioactive substance producing plants. *Sustainability* **2022**, *14*, 2421. [CrossRef]
47. Oliva, R.D.P.; Huaman, J.; Vásquez-Lavin, F.; Barrientos, M.; Gelcich, S. Firms adaptation to climate change through product innovation. *J. Clean. Prod.* **2022**, *350*, 131436. [CrossRef]
48. Chen, C.; Qu, L.; Tseng, M.L.; Li, L.; Chen, C.C.; Lim, M.K. Reducing fuel cost and enhancing the resource utilization rate in energy economic load dispatch problem. *J. Clean. Prod.* **2022**, *364*, 132709. [CrossRef]
49. Yang, X.; Pu, Y.; Weng, S.; Hou, M.; Wang, Z. Review of agricultural water-saving policies and measures in recent years–a case study of Jiangsu province, China. *Water Supply* **2022**, *22*, 3951–3967. [CrossRef]
50. Sistema Nazionale per la Protezione dell'Ambiente. Consumo di Suolo, Dinamiche Territoriali e Servizi Ecosistemici. Edizione 2022. Report SNPA 2022, *32*. Available online: https://www.snpambiente.it/2022/07/06/consumo-di-suolo-dinamiche-territoriali-e-servizi-ecosistemici-edizione-2022/ (accessed on 9 September 2022).
51. Banaeian, N.; Omid, M.; Ahmadi, H. Energy and economic analysis of greenhouse strawberry production in Tehran province of Iran. *Energy Convers. Manag.* **2001**, *52*, 1020–1025. [CrossRef]
52. Khoshnevisan, B.; Rafiee, S.; Mousazadeh, H. Environmental impact assessment of open field and greenhouse strawberry production. *Eur. J. Agron.* **2013**, *50*, 9–37. [CrossRef]
53. Lopes, S.A. Scion substitution: A new strategy to control citrus variegated chlorosis disease. *Plant Dis.* **2020**, *104*, 239–245. [CrossRef]
54. Barnard, E.L.; Ash, E.C.; Hopkins, D.L.; McGovern, R.J. Distribution of *Xylella fastidiosa* in Oaks in Florida and its association with growth decline in *Quercus laevis*. *Plant Dis.* **1998**, *82*, 569–572. [CrossRef] [PubMed]
55. Singh, R.; Ferrin, D.M.; Huang, Q. First Report of *Xylella fastidiosa* associated with Oleander Leaf Scorch in Louisiana. *Plant Dis.* **2010**, *94*, 274. [CrossRef] [PubMed]
56. Li, W.B.; Pria, W.D., Jr.; Teixeira, D.C.; Miranda, V.S.; Ayres, A.J.; Franco, C.F.; Costa, M.G.; He, C.X.; Costa, P.I.; Hartung, J.S. Coffee Leaf Scorch caused by a strain of *Xylella fastidiosa* from citrus. *Plant Dis.* **2001**, *85*, 501–505. [CrossRef] [PubMed]
57. Abou Kubaa, R.; Giampetruzzi, A.; Altamura, G.; Saponari, M.; Saldarelli, P. Infections of the *Xylella fastidiosa* subsp. pauca strain "De Donno" in Alfalfa (Medicago sativa) Elicits an Overactive Immune Response. *Plants* **2019**, *8*, 335. [CrossRef]

58. Surano, A.; Abou Kubaa, R.; Nigro, F.; Altamura, G.; Losciale, P.; Saponari, M.; Saldarelli, P. Susceptible and resistant olive cultivars show differential physiological response to *Xylella fastidiosa* infections. *Front. Plant Sci.* **2022**, *13*, 968934. [CrossRef] [PubMed]
59. El Handi, K.; Hafidi, M.; Sabri, M.; Frem, M.; El Moujabber, M.; Habbadi, K.; Haddad, N.; Benbouazza, A.; Abou Kubaa, R.; Achbani, E.H. Continuous pest surveillance and monitoring constitute a tool for sustainable agriculture: Case of *Xylella fastidiosa* in Morocco. *Sustainability* **2022**, *14*, 1485. [CrossRef]
60. Cambria, D.; Pierangeli, D. A life cycle assessment case study for walnut tree (*Juglans regia* L.) seedlings production. *Int. J. Life Cycle Assess.* **2011**, *16*, 859. [CrossRef]
61. Girgenti, V.; Peano, C.; Bounous, M.; Baudino, C. A life cycle assessment of non-renewable energy use and greenhouse gas emissions associated with blueberry and raspberry production in northern Italy. *Sci. Total Environ.* **2013**, *458–460*, 414–418. [CrossRef] [PubMed]
62. Hawera, T.; Tefera, B.; Sahu, O. Flower farms environmental performance evaluation in Ethiopia. *J. Environ. Earth Sci.* **2021**, *3*, 48–58. [CrossRef]
63. Lan, Y.-C.; Tam, V.W.; Xing, W.; Datt, R.; Chan, Z. Life cycle environmental impacts of cut flowers: A review. *J. Clean. Prod.* **2014**, *369*, 133415. [CrossRef]
64. Bartzas, G.; Zaharaki, D.; Komnitsas, K. Life cycle assessment of open field and greenhouse cultivation of lettuce and barley. *Inf. Process. Agric.* **2015**, *2*, 191–207. [CrossRef]
65. Legua, P.; Hernández, F.; Tozzi, F.; Martínez-Font, R.; Jorquera, D.; Jiménez, C.R.; Giordani, E.; Martínez-Nicolás, J.J.; Melgarejo, P. Application of LCA methodology to the production of strawberry on substrates with peat and sediments from ports. *Sustainability* **2021**, *13*, 6323. [CrossRef]
66. Roychoudhry, S.; Kepinski, S. Auxin in root development. *CSH Perspect Biol.* **2022**, *14*, a039933. [CrossRef]
67. Ruett, M.; Whitney, C.; Luedeling, E. Model-based evaluation of management options in ornamental plant nurseries. *J. Clean. Prod.* **2020**, *12*, 26–53. [CrossRef]
68. Dennis, J.H.; Lopez, R.G.; Behe, B.K.; Hall, C.R.; Yue, C.; Campbell, B.L. Sustainable production practices adopted by greenhouse and nursery plant growers. *HortScience* **2010**, *45*, 1232–1237. [CrossRef]
69. Behe, B.K.; Campbell, B.L.; Hall, C.R.; Khachatryan, H.; Dennis, J.H.; Yue, C. Consumer preferences for local and sustainable plant production characteristics. *HortScience* **2013**, *48*, 200–208. [CrossRef]
70. Campbell, B.; Khachatryan, H.; Behe, B.; Dennis, J.; Hall, C. Consumer perceptions of eco-friendly and sustainable terms. *Agric. Res. Econ. Rev.* **2015**, *44*, 21–34. [CrossRef]
71. Berki-Kiss, D.; Menrad, K. Consumer preferences of sustainability labelled cut roses in Germany. *Sustainability* **2019**, *11*, 3358. [CrossRef]