


Article

Sustainability Challenges and Innovations in the Value Chain of Flowering Potted Plants for the German Market

Nirit Havardi-Burger ^{1,*}, Heike Mempel ² and Vera Bitsch ¹ 

¹ School of Management and School of Life Sciences Weihenstephan, Technical University of Munich, Chair of Economics of Horticulture and Landscaping, Alte Akademie 16, 85354 Freising, Germany; bitsch@tum.de

² Department of Horticulture and Food Technology, University of Applied Sciences Weihenstephan-Triesdorf, Am Staudengarten 10, 85354 Freising, Germany; heike.mempel@hswt.de

* Correspondence: nirit.havardi-burger@tum.de; Tel.: +49-8161-71-2587

Received: 31 January 2020; Accepted: 28 February 2020; Published: 3 March 2020



Abstract: This study investigated the sustainability challenges and the adoption of sustainability innovations along the value chain of flowering potted plants supplying the German market. Data was collected through eighteen in-depths interviews with chain actors from different stages of the value chain and analyzed through qualitative content analysis. The material flow of the value chain begins at the breeding level followed by the propagation level. Cuttings are produced mostly in African countries, rooted cuttings and potted plants are cultivated in Europe. The main environmental challenges include water scarcity, pesticide use and carbon footprint. Social challenges in Africa include low wages and difficult working conditions. In Germany, social challenges include recruitment and retention of employees and product transparency. Economic challenges include profitability and the need to comply with standards. Sustainability driven innovations can address some sustainability challenges. However, their implementation often leads to increased costs, financial risk and complexity of implementation. Furthermore, the lack of product transparency prevents the transfer of sustainability costs to the consumer by offering a sustainable product for a premium price. Business-to-business standards have generally had a positive influence on the adoption of sustainability innovations. But by setting certification as an entry barrier for suppliers, retailers have become more powerful chain actors.

Keywords: agriculture; certification; cuttings; floriculture; horticulture; NGOs; ornamental plants; private standards; qualitative research

1. Introduction

Floriculture is a global industry, with main markets in Europe, the USA and Japan. Germany is the largest market in Europe for flowers and ornamental plants with a market volume of 8.9 billion euros in retail prices (2019) [1]. Flowering potted plants in Germany hold a market share of 33% of the total value, comprising of outdoor and indoor plants.

The majority of the commercially available flowering plants are propagated either from seeds or cuttings. Some plants such as orchids and Anthurium are propagated in-vitro. Vegetative asexual propagation through cuttings is essential for many commercially significant, herbaceous, ornamental species [2]. Apart from being the only mean of propagation for some plants, vegetative propagation has several advantages. For instance, the breeding process is generally faster than by generative breeding, because the time from spotting new mutations until the cultivar is market-ready is shorter [2]. Because there is no need for seeds development, vegetative breeding offers more possibilities for attractive traits of flowers, which makes them popular among consumers [3]. Furthermore, the unique traits

of the cultivar stay stable from generation to generation [2]. For growers, vegetative cultivars are attractive because of the generally shorter cultivation period and the higher market price [3].

In recent years, there has been a growing criticism on the environmental and social burdens associated with ornamental plant production [4,5]. However, so far sustainability challenges in the value chain of flowering potted plants have not been defined. Investigation on social and environmental sustainability impacts in floricultural value chains focused on the production of cut roses in Africa and Latin America [6–8]. Sustainability assessment of potted plant focused mainly on environmental aspects such as carbon footprint [9]. Furthermore, only production stages taking place in Europe or in the USA, such as young plants and potted plants were assessed in prior studies (Figure 1). Other value chain stages such as breeding and propagation were not considered for the assessment.



Figure 1. Value chain stages of flowering potted plants.

Sustainability challenges can promote innovations and offers new business opportunities [10]. Environmental concerns had led scientist to develop and innovate more environmentally sound materials such as renewable alternatives. Many of these innovations are promising at the trial level, however, few have been adopted by the horticulture industry at a significant scale [11]. Social concerns had led to the emergence of different innovative tools such as standards that seek to regulate the social conditions in the production of floriculture products aimed at the European Union (EU) market [12]. The influence of adopting such standards was investigated for cut-flowers in Africa [13,14]. However, the extent of the adoption of such standards and their influence on the value chain is not known.

Therefore, the aim of this study is to investigate sustainability challenges along the whole value chain of vegetatively propagated flowering potted plants (Figure 1) including social, environmental and economic challenges. In addition, the current study aims to investigate sustainability innovations implemented and the limitations for their adoption.

2. Literature Review

2.1. Sustainability in the Floricultural Sector

The concept of sustainability was first described by the forest scientist von Carlowitz (1713), referring to economically harvesting timber while sustaining the forest for future use [15]. This concept deals with both economic and environmental goals because in this case financial gain is directly dependent on maintaining the natural resources. According to Bitsch (2016), social goals were initially introduced by the Brundtland Report’s definition of sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [16] (p. 41). Nowadays, sustainability is typically framed as the three pillar concept, which distinguishes between environmental, social and economic dimensions [15]. The general goals are defined as reducing environmental degradation, economic instability and social insecurity [17]. In accordance, Krug et al. (2008) defined sustainability goals for sustainable greenhouse production of potted plants as follows, “reduce environmental degradation, maintain agricultural productivity, promote economic viability, conserve resources and energy and maintain stable communities and quality of life” [18] (p. 43).

According to Krug et al. (2008) and Lopez et al. (2008), the main environmental issues associated with greenhouse production of potted plants are (i) pollution from fertilizers and other chemicals, (ii) plastic waste, (iii) carbon footprint due to heating and shipping, (iv) conservation of water and (v) pesticide use. General economic issues are to increase productivity and economic viability as well

as account for consumer concerns regarding the source of the product, such as local and sustainable. Social issues are maintaining a safe working environment and supporting communities by hiring local citizens and purchasing locally [18,19].

A literature review was carried out to identify studies that assessed the sustainability or deal with different sustainability aspects of ornamental plant products to identify the state of the art regarding sustainability challenges. Although the present study focuses on flowering potted plants, assessments of other ornamental plant groups, such as cut flowers, were also included because they can contribute information about relevant sustainability aspects. In addition, studies of the social situation of the horticulture sector were included.

The research identified 36 studies, most of them assessing environmental aspects (26), using Life Cycle Assessment (LCA) or assessing only carbon or water footprint (Table 1). Among them, one study performed both social and environmental LCA [8]; six studies included cost calculation with the environmental assessment. Eight studies evaluated only social aspects, such as work satisfaction, employment relations and workers' safety. Potted plants were investigated mostly for greenhouse gas (GHG) emissions and water consumption. Social aspects were generally investigated in cut-flower farms in Africa. In Europe and the USA, studies of social aspects focused on job satisfaction. Economic aspects investigated in the USA and Europe focused on cost calculations of flowering potted plants. The 36 studies focused on a variety of different sustainability issues, which cannot be discussed in detail here due to space limitations (Table A1 in Appendix A).

Table 1. Publications dealing with sustainability aspects in the value chain of ornamental plants divided according to sustainability dimension—environment, society and economy.

	Publications	Culture/Location	Main Topic(s) Investigated	Env. ¹	So. ²	Ec. ³
[20]	Abeliotis et al. 2016	Cut-carnations/Greece	LCA ⁴	X		
[21]	Anker and Anker 2014	Cut-flowers/Kenya, Lake Naivasha	Living wages		X	X
[22]	Bitsch 1996	Horticulture/Germany	Job satisfaction		X	
[23]	Bitsch 2007	Horticulture/USA	Job satisfaction		X	
[24]	Blonk et al. 2010	Cut-roses /Kenya, The Netherlands, potted Phaelenopsis and potted poinsettia/The Netherlands	CF ⁵ based on LCA ⁴	X		
[25]	Bonaguro et al. 2016	Potted poinsettia, pelargonium and cyclamen/Italy	LCA ⁴ (GHG) ⁶			
[26]	Brumfield et al. 2018	Potted petunia/USA	GHG ⁶ and cost of production	X		X
[27]	De Lucia et al. 2013	Potted bougainvillea/Italy	LCA ⁴ and substrate assessment	X		
[28]	de Vries 2010	Cut roses/Ethiopia, The Netherlands	Qualitative comparison ⁷	X	X	X
[29]	Evers et al. 2014	Cut flowers and cuttings/Uganda	Value chain governance		X	X
[8]	Franze and Ciroth 2011	Cut roses in Ecuador/The Netherlands	LCA ⁴ and Social-LCA	X	X	
[30]	Ingram et al. 2018	Potted wax begonia/USA	LCA ⁴ (GHG) ⁶ water consumption and variable costs	X		X
[31]	Ingram et al. 2018	Potted chrysanthemum/USA	LCA ⁴ (GHG) ⁶ water consumption and variable costs	X		X

Table 1. Cont.

Publications		Culture/Location	Main Topic(s) Investigated	Env. ¹	So. ²	Ec. ³
[32]	Ingram et al. 2019	Potted poinsettia/USA	LCA ⁴ (GHG) ⁶ water consumption and variable costs	X		X
[33]	Ingram et al. 2017	Young foliage plants/USA	LCA ⁴ (GHG) ⁶ water consumption and variable costs	X		X
[34]	Kirigia et al. 2016	Cut flowers and cuttings/Kenya, Tanzania, Uganda, Ethiopia	Local development and food security	X	X	
[35]	Knight et al. 2019	Potted plants/USA	Consumptive water use and water footprint	X		
[26]	Koeser et al. 2014	Potted petunia/USA	LCA ⁴ (GHG) ⁶	X		
[36]	Lazzerini et al. 2015	Woody plants/Italy	LCA ⁴ (GHG) ⁶	X		
[4]	Lazzerini et al. 2018	Potted plants/Italy	Sustainability assessment indicator based	X		
[7]	Mekonnen et al. 2012	Cut roses/Kenya	Water footprint	X		
[37]	Mengistie et al. 2017	Cut flowers/Ethiopia	Pesticide use and private standards	X	X	
[38]	Meyerding 2015	Horticulture/Germany	Job satisfaction		X	
[39]	Nigatu et al. 2015	Cut flowers/Ethiopia	Endotoxin exposure		X	
[5]	Riisgaard and Gibbon 2014	Cut-flower/Kenya	Labor management		X	
[40]	Russo and de Lucia Zeller 2008	Young plants of grafted rose and sowbread seedlings/Italy	LCA ⁴	X		
[41]	Russo, Buttol and Tarantini 2008	Cut roses and potted Cyclamen/Italy	LCA ⁴	X		
[42]	Russo, Scarascia Mugnozza and de Lucia Zeller 2008	Cut roses and potted Cyclamen/Italy	LCA ⁴	X		
[6]	Sahle and Potting 2013	Cut roses/Ethiopia	LCA ⁴	X		
[9]	Soode et al. 2013	Potted poinsettia/Germany	CF ⁵	X		
[43]	Soode et al. 2015	Roses and orchids/Germany	CF ⁵	X		
[44]	Staelens et al. 2018	Cut-flowers/Ethiopia	Job satisfaction		X	
[45]	Thilsing et al. 2015	Potted campanula, lavandula, rhipsalideae and helleborus/Denmark	Exposure to endotoxins, bacteria and fungi		X	
[46]	Torrellas et al. 2012	Cut-roses/Europe	LCA ⁴ and cost-benefit analysis	X		X
[47]	Wandl and Haberl 2017	Cut flowers and potted plants/Austria	LCA ⁴ (GHG) ⁶	X		
[48]	White et al. 2019	Floriculture/USA	Water management	X		
Total: 36				26	13	9

¹ Environment; ² Society; ³ Economy; ⁴ All topics addressed by the standardized life cycle assessment (LCA) method (ISO 14040, ISO 14044); ⁵ Carbon footprint (CF); ⁶ Only greenhouse gas (GHG) emissions were measured based on LCA; ⁷ Different topics related to environmental, social and economic aspects.

2.2. Sustainability Innovations

Innovation is defined by the Organization for Economic Co-operation and Development (OECD) as “the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations” (OECD/Eurostat, 2005, p. 46, cited in Reference [15]). This definition refers to products, processes, organizational and marketing innovations at the firm level, while innovations at the industry level, economy-wide changes and industry reorganization are not part of the above definition [15]. However, according to Porter (1998) innovation is a major source of industries’ structural changes [49].

Innovation is extremely important for achieving sustainability, at the corporate level [10]. New environmental or social regulations and laws increase the pressure for the development of innovations. Sustainability as a concept also inspires ideas that can lead to new business opportunities. However, adopting sustainability innovations poses uncertainty regarding market success and for some innovations, it is not yet clear whether they have a positive or a negative impact on sustainability. Moreover innovations may introduce trade-offs between sustainability dimensions [10]. Due to the uncertainty in the effect of sustainability innovations, Hansen et al. (2009) introduced the concept of sustainability-oriented innovation, referring to “innovations which are individually perceived as adding positive value to sustainable development” [10] (p. 686).

Environmental or eco-innovations are designed to reduce or avoid negative impacts on the environment [50]. Klewitz and Hansen (2013) defined three types of sustainability innovations with regard to the environmental dimension [50]. Process innovations are related to the production of goods and services. Organizational innovations involve new forms of management and reorganization of structures and routines. Product innovations are developments that improve product quality in terms of materials used (e.g., organic or recycled), high durability or low energy consumption.

According to Phills et al. (2008), while many innovations can create benefits for society by economic growth and increased employment, social innovations create social value in situations where the market fails and needs cannot be met otherwise. Furthermore, social innovations are designed to shift the balance towards creating benefits for the public or society as a whole, rather than private value or gain to companies or ordinary (not disadvantaged) consumers. The same authors also claimed that often the involvement of three sectors (private, non-profit and public sectors) is required to innovate and solve social or sustainability challenges. Furthermore, sector interaction serves as a fertile ground for social innovation [51].

Economic sustainability can be defined as activities that “lead to a retention or increase of a company’s overall capital stock” [10] (p. 684). Therefore, sustainable economic innovations can be considered as innovations that contribute to growth or retention of capital stock without compromising social and environmental sustainability goals.

Bloemhof et al. (2015) differentiated between internal and external drivers that motivate firms to adopt sustainability strategies. Internal drivers are factors that help attain sustainable practices within the company. In their study, they included cost efficiency, product quality, process capability, brand reputation, sourcing and operations advantages, transport and logistics advantages, strategic objectives, top management vision and employee safety improvement as internal drivers. External drivers are factors beyond the boundaries of a company and include policy and regulations, stakeholder awareness, market forces, social issues and global warming reduction [17]. Although the above described drivers refer to strategies, such drivers can influence value chain actors to adopt sustainability innovations.

3. Materials and Methods

Qualitative research approaches are well suited to exploring new or not well-researched issues [52]. Sustainability challenges along the value chain of flowering potted plants are not well-researched, therefore, a qualitative approach was chosen. One of the most common qualitative methods for in-depth and extensive understanding of issues is the qualitative research interview [53]. Furthermore,

in-depth interviews allow investigating multiple perspectives of key-actors [54]. Other studies of value chains have used qualitative interviews with different chain actors to explore sustainability hotspots, for example, in pork [55] or to identify critical issues in asparagus [56]. In the current study, interviews were conducted, using a semi-structured interview guide. Semi-structured interviews were chosen, because they allow exploring different issues systematically, without compromising the ability of interviewees to freely express themselves [53,57].

Eighteen in-depth interviews were conducted in two rounds, in the winters of 2016 and 2017. Interviews were conducted with seven propagation nurseries, three potted plant growers, one grower is also part of a growers' cooperative (wholesaler) and another two wholesalers, an agricultural certifier, a business consultant and a horticultural marketing and retail expert (Table 2).

Table 2. List of interviews (type of chain actor, business actions and interviewee's role in the business).

Type of Actor	Business Actions	Interview No.	Interviewee Role
Propagation nursery 1	Breeding, vegetative and rooted cuttings	1	Marketing director
		2	Marketing director
		2	Supply chain manager
Propagation nursery 2	Breeding, vegetative and young plants	3	Marketing manager
Propagation nursery 3	Breeding, vegetative and rooted cuttings	4	Marketing manager and owner
Propagation nursery 4	Breeding, vegetative and young plants	5	Marketing and product manager
Propagation nursery 5	Breeding, mostly vegetative young plants	6, 7	Sales manager Germany (authorized representative)
Propagation nursery 6	Breeding, vegetative, generative, young plants	8	Marketing and product management (EU)
Propagation nursery 7	Breeding, Seeds and cuttings	9	Growing adviser
Grower 1	Breeding generative, seeds, seedlings and potted plants	10	Owner
Grower 2	Rooted cuttings and potted plants	11	Owner, CEO
Grower 3	Breeding generative, seedlings and potted plants	12	CEO
Wholesaler 1	Grower-cooperative, distribution	12	CEO
Wholesaler 2	Growers' organization, distribution and export	13	Sales manager
		13	CEO
Wholesaler 3	Grower-cooperative, distribution and export	14	CEO
		14	Public relation and marketing
		15	Quality management and sustainability (head of department)
Certifier	Certification	16	Commercial manager
Business consultancy	Foot printing	17	Sales Germany
Retail expert	Academic research	18	Scientist horticulture and market research

The semi-structured interview guide covered different stages from breeding, propagation, young plants and logistics to finished product and interviewees were asked to describe the different activities and processes within the value chain. In the second round, questions covered also procedures associated with social and environmental sustainability aspects as well as the adoption of specific sustainability innovations, such as specific technologies or standards. Furthermore, interviewees were questioned regarding the main environmental and social sustainability challenges, as well as economic difficulties within their company and the sector. Findings about the value chain from the first round of interviews as well as the literature review on sustainability impacts of ornamental plant production and agricultural systems were used as a backbone to structure interview questions on sustainability aspects relevant to flowering potted plants.

Topics were presented according to the conversational flow of the interview and adjusted to the profession and function of each interviewee. All interviews were audio-recorded and transcribed verbatim using the f4 transcription software. Transcription was simple transcript, focusing on the content and was conducted in the original language of the interview, either German or English.

All resulting documents were systematically analyzed using the qualitative data analysis software Atlas.ti. The analysis followed a hybrid approach, partly concept-driven (deductive) and partly data-driven (inductive). In concept-driven approach, the coding frame is based on previous knowledge. In the data-driven approach, a coding frame is created inductively based on the data, to capture unanticipated details and describe the material in-depth [58]. In the current study, social and environmental sustainability aspects served as the initial coding framework (deductive). The inductive approach was implemented to explore further sustainability challenges, mostly regarding economic sustainability and identify additional sustainability innovations.

During the coding process, text fragments were marked, and a coding frame was developed to identify processes, sustainability challenges and sustainability innovations. In later stages, related codes were associated in code families. An example of a code family can be seen below for 'water', presenting interviews excerpts related to the value chain stage stock-plants (Table 3). Patterns regarding sustainability issues and innovations were identified by comparing text fragments in an ongoing process of constant contrast and comparison following Boeijs (2002) [59]. The investigated procedures and processes as well as expert opinions allowed identifying sustainability challenges along the value chain. The analysis also focused on the difficulties and drivers for the adoption of sustainability innovations.

Table 3. Codes for the family ‘water’ for the chain stage stock plants, including interview excerpts.

Code	Findings	Interview Excerpt
Water source	Lake or ground water	<p>“The water source-in Ethiopia from a well, in Kenya from the lake” (Propagation nursery 5).</p> <p>“The water level of the lake is always an issue and it is becoming even more important in recent years. However, this big discussion, that we are emptying the lake, that is not the case” (Propagation nursery 5).</p> <p>“In Uganda, water is not limited. Overall, as a country, Kenya has a water shortage and so does Ethiopia. But our production locations are not in the desert areas. We are next to Nairobi, because there is no water shortage there. I do not see any conflict with human needs for water” (Propagation nursery 1).</p> <p>“There are water problems in Kenya due to too much horticulture in one location, in Naivasha. Surely, there are also developments in Ethiopia. It happens so quickly, land use development is fast, there you need large amounts of water. For example, roses” (Propagation nursery 1).</p>
Irrigation system	Advanced water filtration system, drip irrigation Open or closed irrigation systems	<p>“People are investing more and more in how can we use less water” (Certifier).</p> <p>“It has to be pathogen-free. We really have to disinfect the circulating water” (Propagation nursery 5).</p> <p>“In Africa we are talking about bags [referring to plant containers], two-liter bags and we have a drip irrigation that means that there is a pipe with a little hole and water drips into the bag” (Propagation nursery 1).</p>
Waste water	Biological treatment process in artificial wetland to capture fertilizer Pesticides contaminated water go through active coal based filter	<p>“In the wetland there are plants which take out the fertilizer and clean the water” (Propagation nursery 1).</p> <p>“The plants are taking the active ingredients, which make the water again drinkable or they can reuse it” (Certifier).</p> <p>“For example, Kenya, the regulations are very strict. We cannot let unfiltered water back into the lake. We have there a biological wastewater treatment system. Only clarified water after the biological wastewater treatment can return to the lake” (Propagation nursery 5).</p> <p>“When we talk about water that is used for pesticide treatment, there we have a filter system, where we use active coal to filter the pesticides out of the water” (Propagation nursery 1).</p> <p>“There are enormous quantities of roses, there is a lot of water going directly into the ground and chemicals and so forth. I would say there are black spots, not everything is good there” (Propagation nursery 1).</p>

4. Results and Discussion

This section is divided into five parts. The first part presents the specific characteristics of the vegetative value chain of flowering potted plants. The discussion of each sustainability dimension in the following three sections, environmental, social and economic sustainability, builds on understanding the value chain. The environmental section is divided according to the value chain stages, breeding, production and distribution. Although the production stages of propagation material, rooted cuttings and potted plants are separate stages (Table 4), they share similar environmental impacts. The social section differentiates between social sustainability in Africa or Central America and social challenges in Germany. The economic section discusses different challenges relevant to the economic sustainability of different business actors in the value chain. Sustainability innovations are discussed in the context of the different challenges. The last section is dedicated to structuring sustainability challenges and the innovations addressing them along the value chain.

4.1. The Vegetative Value Chain of Flowering Potted Plants Supplied to the German Market

The value chain consists of five stages—breeding for the development of new varieties, production of propagation material, young plant production, potted plant production and distribution to retail (Table 4). All stages take place in Europe, apart from the production of propagation material, which generally takes place in southern countries. Breeders or propagation nurseries generally develop new varieties, produce and sell cuttings and rooted cuttings. Cultivars have to go through an in-vitro cleaning process to achieve pathogen-free plants. The resulting tissue culture plant can then be cultivated in special facilities within Europe under strict hygienic conditions as elite stock plants. Elite stock plants are the source to generate the next generation of stock plants in Africa or Central America.

Table 4. The vegetative value chain of flowering potted plants.

Value Chain Stage	Function	Location
1. Breeding	Development of new cultivars Cultivation of elite stock plants for propagation	Europe
2. Propagation	Cultivation of stock plants Harvest of cuttings for production	Africa and Central America
3. Young plants	Cultivation of rooted cuttings	Europe
4. Potted plants	Cultivation of potted plants	Europe
5. Distribution	Storage and shipment	Germany

Cuttings for the production of plants for the consumer in the German market are produced mostly in African countries namely Kenya, Ethiopia, Uganda and Tanzania. Few breeders also produce cuttings in Central America. The stock plants for producing the cuttings are cultivated in simple greenhouses made of plastic tunnels but under strict hygienic conditions. These include advanced water purification systems, ventilation filters and hygiene protocols to prevent possible transmission of pathogens through employees. Stock plants are cultivated in plastic containers and substrate based on volcanic rock. Harvested cuttings are air-shipped in cardboard boxes to Europe. From the airport, cuttings are transported to the rooting nurseries.

The production of rooted cuttings takes place in Europe, in state-of-the-art greenhouses under controlled temperature and humidity. Production of rooted cuttings takes between three to six weeks, which is the period required for the cuttings to develop roots, depending on the crop.

Cultivation of potted plants is a separate production stage, which takes about three to four months. Plants are potted and cultivated under adjusted conditions of temperature, light, fertilizer, irrigation and humidity. Temperature requirements for potted plants are slightly lower than for the cultivation of rooted cuttings. Potted plants can be distributed directly to retail or through growers' organizations. In some cases, small growers are selling their products directly to the end consumer.

4.2. Environmental Sustainability Challenges and Sustainability-Driven Innovations along the Value Chain

4.2.1. Breeding Stage

The main purpose of breeding is the development of novelties with attractive traits. In some cases, breeders also develop disease-resistant cultivars, plants with temperature tolerance and early bloom. For example, Lütken, Clarke and Müller (2008) reported on efforts to develop cultivars, which are resistant to pest and disease [60]. Cultivars that require less heating or varieties that are more pest-resistant can influence the entire chain by reduced energy consumption and less need for pest control. Therefore, breeding goals have an indirect influence on the environmental impacts in different stages of the value chain. According to interviewees, breeders generally use traditional breeding techniques such as cross-hybridization, selection and mutagenesis. Some companies did not exclude the use of genetically modifying (GM) technologies in the future. GM technologies can possibly expand the gene pool of ornamental crops, which in turn contributes to the development of novelties [61]. Furthermore, development of new varieties using GM techniques has the potential to reduce chemical use such growth retardants and pesticides [60]. Up to now, GM technologies were considered too costly for the floricultural industry [61]. However, the emergence of new and cheaper GM technologies, which was already implemented in different ornamental crops offers new prospects [62,63]. Adopting GM technologies might shorten the breeding process and eventually reduce the overall costs of the development of novelties. Nevertheless, the usage of GM technologies is controversial due to unknown and unpredictable impacts on the environment as well as health and safety concerns regarding agri-food products [60]. Although vegetatively propagated ornamentals are typically not eaten, the limited acceptance of GM technologies by the public and the restrictions on the European market prevent this transition.

4.2.2. Production Stages

Water consumption is an important sustainability aspect especially in arid regions of the world. According to interviewees, the source for irrigation water for the production of cuttings can be either groundwater or a nearby lake, depending on the region. A different study claimed that water is also obtained from rivers and rainwater harvesting [34]. According to interviewees, companies invest in advanced water purification and disinfection systems to prevent pathogen infections in plants. Water purification systems are required for the cultivation of stock plants because harvested cuttings must be free of pests [29]. Interviews with representatives of propagation nurseries producing in Africa confirmed that water shortage is a problem in several horticultural centers in Africa. However, they also argued that there is no water scarcity at their production sites. Although there is no evidence from the literature for water scarcity in cutting production areas, there have been reports on water shortages in cut-rose production regions in Africa. Water overuse for the production of cut-roses was shown in Kenya, which directly influenced the decline of Lake Naivasha's water levels [7]. Water scarcity was experienced also by cut-rose growers irrigating with ground water, during the dry season in the highland cultivation area in Holleta, Ethiopia [6]. De Vries (2010) also emphasized the general risk of water overuse for cut-rose production from lakes and rivers in Ethiopia [28].

According to interviewees, some companies implemented water saving irrigation technologies such as drip irrigation systems or closed irrigation systems. Another nursery reported to have implemented an irrigation system with about 20% drain water. Excess water is captured and treated

as wastewater. The implementation of water-saving techniques had been reported previously for floriculture companies in Uganda and Ethiopia [34].

Interviewed plant growers in Germany expressed concern about the water supply due to longer dry periods that can be attributed to climate change. Some producers reported also to collect rainwater as a measure to guarantee a sufficient water supply. Nursery growers in the USA had also emphasized their concern about water availability [48]. In this recent study, growers referred to the possibility of water source depletion under conditions of long-term drought and uncertainty in accessing additional water resources. Growers also referred to a solution to water shortages by changing irrigation strategies, to be able to re-collect and recycle irrigation water and increases in nursery water storage capacity [48].

Fertilizer runoff is generally dependent on the irrigation system. According to interviewees, stock plants in Africa are grown on substrate in either open or closed irrigation systems. Wastewater is treated in special artificial wetlands. Fertilizer runoff from cut-rose farms was confirmed by Mekonnen et al. (2012) and Sahle and Potting (2013), resulting in pollution of water bodies in Kenya and Ethiopia [6,7]. Production of cut-roses is different from the production of cuttings because the majority of rose plants grow in soil and irrigation water with excess fertilizers drains into the ground [6].

In Germany, growers reported to irrigate using either closed loop recycling systems or open systems. Closed systems have the benefit of saving water and reducing fertilizer use. In these technologies, irrigation water is recycled through filtration and chlorination. Mist irrigation is another form of open irrigation system applied during the first weeks of the production of rooted cuttings, which serves to increase the humidity of the plant environment. According to interviewees, there is generally no fertilizer loss into the environment from neither open nor closed systems. Similarly, no fertilizer losses were reported in a Dutch recycling system for cut-rose production [28].

There is a growing effort to reduce the use of chemicals for plant protection. It is crucial for cuttings to be clean of any pests or diseases ("*zero pest tolerance*"). Therefore, pest control is very important in the cultivation of stock plants. According to interviewees, the producers of cuttings follow an integrated pest management approach. They have scouts regularly controlling the plants and with any sign of pests, plants are treated individually. The approach uses biological pest control first and chemicals only as a last resort. However, the use of beneficial insects is limited, as imported plants (cuttings), have to be free of insects. According to interviewees, a lot of pressure was put on growers to stop using neonicotinoid insecticides, which are suspected to harm the populations of pollinator insects. This requirement from retail was beyond the legal frame because at the time, only the use of some of the neonicotinoid insecticides was restricted by the European Commission [64]. However, some producers reported that in order to avoid neonicotinoids they had to use other more harmful pesticides. Furthermore, this pressure to stop using neonicotinoids has led to the development of a new standard, MPS-ProductProof, to certify neonicotinoid-free plants.

Pathogen-free propagation material (cuttings) is crucial at the rooted cutting stage, because pest control is restricted especially during the first two weeks. In the cultivation of rooted cuttings, fungicides can be applied after the first two weeks, to prevent proliferation of fungus at the conditions of high humidity and temperature. Application of beneficial insects or insecticide is not possible at this stage because of the high humidity and temperature. Other pest control solutions are available such as fungi against flies or bacteria that attack pests. Moreover, according to interviewees, growers avoid application of certain pesticides on rooted cuttings to allow the use of beneficial insects in the next stage of potted plant cultivation.

Potted plants require pest control management due to the longer production period. At this stage, growers reported to implement an integrated pest management approach and try to reduce the application of chemicals for pest control. Growers are also required to keep records of all treatments applied on the plants. Ornamental plants sold by different retailers in the UK, were found to contain a mixture of fungicides and insecticides including neonicotinoid insecticides [65]. As this last study investigated nectar- and pollen-rich ornamental plants, it was claimed that pesticide residues could influence pollinator populations. In Ethiopia, intensive use of pesticides was measured in cut-rose

production. In a LCA, the use of pesticides was shown to contribute to fresh water and terrestrial eco-toxicity [6]. Although cut flower production is different from the cultivation of stock plants, plants are grown in similar greenhouses, therefore, leaching of pesticides into the environment cannot be excluded.

Several aspects have the potential of contributing to the carbon footprint (CF) in the production of potted plants. These can be divided into direct and indirect contributions to greenhouse gas (GHG) emissions. Direct contributions are emissions through energy consumption for heating of greenhouses and artificial light. Indirect contributions are GHG emissions due to non-renewable materials such as peat and plastics. Direct contributions to CF associated with the regulation of storage temperatures and transport will be discussed in the distribution stage.

In Africa, the cultivation of stock plants takes place under optimal climate conditions and there is no need for heating or the use of artificial light. Nevertheless, some plants are grown in high elevations, above 2000 m and heating is required during the night to prevent a temperature drop. Some stock plant growers reported to use geothermal energy for heating; others use coal and electricity. For the production of rooted cuttings and potted plants, greenhouses are heated with different combinations of renewable and non-renewable energy sources, among them wood, coal, gas, oil and geothermal energy. The transition to renewable energy sources, such as woodchips, heating based on geothermal energy or waste heat, can be considered innovative. Cultivars that require less heating have a positive influence on the GHG emission balance, as the reduction of one degree in heating corresponds to considerable energy savings. Some growers in Germany also adopted the Cool Morning–Warm Evening strategy for reducing energy requirements. Several other new technologies have been reported for energy saving in greenhouses, among them energy-efficient heat pumps, better insulating facade materials, innovative pre-heating and cooling ventilation technologies and underground-based heat storage [66]. Furthermore, a concept of low energy greenhouses (ZINEG) was developed that integrates new energy-saving techniques and strategies such as maximal thermal insulation, closed method of operation and using solar energy [67]. A study of the CF of poinsettia plant production in Germany showed that heating would be the highest contributor to GHG emissions, accounting for over 80% of the total emissions, if non-renewable fuels were used. The same study also demonstrated that adoption of the Cool Morning–Warm Evening strategy reduced the CF by 5% on average [9]. In a different study, it was found that emissions from heating of greenhouses in Austria are the major contributor for GHG emissions of most products, accounting for 84 to 90% of the total [47].

In the cultivation of stock plants, artificial light is applied only for certain plants such as poinsettia, to prevent flower induction. Artificial light is generally applied for the production of rooted cuttings and potted plants. The most commonly used technology is high-pressure sodium lamps. Innovative, light emitting diodes (LED) technology, considered more energy-efficient, is available for floricultural purposes. Furthermore, experimental results showed that a dynamic LED lighting system, adjusted to the radiation of solar light, consumes 21% less energy compared to the control LED system [68]. Nevertheless, LED technology is comparably more expensive, though its implementation reduces energy costs. Apart from the higher price, implementing LED technology requires expertise to achieve its full potential. Some growers reported that they experiment with LED technology. Prior studies emphasized that the energy consumption of lighting in the production of floricultural products can be reduced by efficient supplemental lighting sources, such as LED technology [9,69].

Plastic containers contribute to GHG emissions and also result in waste accumulation. Stock plants are cultivated in plastic containers, either bags or pots. In some propagation systems, bags or pots are discarded after every round of stock plants, other nurseries reported that they use bags from durable material, which can be re-used after disinfection by steaming. In this innovative system, bags can be re-used 6 to 7 times. Disinfecting by steaming also consumes energy; however, steaming must also be applied to the substrate and tables and the energy can come from renewable sources.

Rooted cuttings are cultivated in plastic plug trays. Some producers have introduced an innovative, deposit system for the plug trays. In this system, plug trays are collected from growers when shipping

the next round of plants and the trays are re-used after cleaning and disinfecting. Other growers reported that used plug trays are returned to the tray producers where the plastic is recycled.

Potted plants are grown in plastic pots, which are then sold to the end consumer. Alternatives to petroleum based pots are a large diversity of biodegradable, compostable or recycled plastic containers designed to reduce plastic waste [70]. According to interviewees, the adoption of biodegradable or compostable containers in nurseries is still limited. Recycled plastic containers, on the other hand are frequently used. Interviewees referred to dark colored pots generally containing a percentage of recycled plastic. Nambuthiri et al. (2015), differentiated between biocontainers, which are designed for short periods (a few months) before degrading and compostable containers, which are designed for longer cultivation periods of one to three years [70]. Another challenge in implementing different types of containers, such as degradable and compostable containers, are the different irrigation and fertilizer requirements [70]. Recycled containers have the lowest direct costs, compared to the alternatives, which can explain their widespread acceptance among growers [26].

Different studies assessed the contribution of containers to the carbon footprint of potted plants. Results showed that the share of CO₂e emissions of containers depends on the culture and the climatic requirements and can vary between 16% and over 50% of the total CF [30,69]. A few studies compared the CF of degradable containers. Comparing plastic and compostable rice hull pots, it was concluded that both have the highest contribution to CO₂e emissions for poinsettia, zonal geranium and cyclamen; the plastic pots because of the material used for production and the rice pots due to transport from the production site [25]. Therefore, containers may account for a significant part of the CF; however, plastic alternatives do not necessarily offer a lower CF.

According to interviewees, stock plants are generally grown in substrate based on volcanic rock, which can be attained locally and has very good qualities, such as water permeability and a structure that allows sterilization. Some nurseries reported that they re-use the substrate after disinfection by steaming.

Rooted cuttings and potted plants are generally cultivated in peat-based substrate. Peat is the most common growing media in horticulture due to its unique qualities favorable for plant growth. But peat is a limited resource and its extraction is associated with negative environmental impacts, due to habitat destruction. Furthermore, peatlands are serving as carbon sinks and peat extraction contributes to greenhouse gas emissions [71]. Because of the negative impacts of peat use, peat substitutes were developed; however according to Barrett et al. (2016), few have been adopted commercially [11]. These authors further reported that the peat substitutes most commonly adopted by the horticultural industry are coir, pine bark and wood fiber. Indeed, some producers reported experimenting with peat substitutes such as cocos and rice as well as wood-based substrates and reported different levels of success. One producer reported that the use of rice chaff as growing media had failed. According to this grower, rice chaff and other peat substitutes bind nitrogen and therefore reduce the nitrogen availability for the plants grown. Barrett et al. (2016) explained that one of the barriers to adopting peat substitutes is because the growing media has to perform satisfactory across different plant species and under different cultivation conditions. The authors further emphasized the need to assess the sustainability of the different growing media to avoid adopting more environmentally damaging substrates [11]. Wandl and Haberl (2017) analyzed different floricultural products, including potted plants, for GHG emissions in Austria. According to their study, substrate is the second most important contributor to overall emissions and accounts for an average of 13% emissions of potted plants [47].

4.2.3. Distribution Stage

Sustainability challenges in the distribution stage are also related to the direct contributions to CF due to storage and transport. Harvested cuttings are packaged in cardboard boxes and stored in cold rooms until shipment. Cuttings are transported at the harvest day in air-conditioned trucks to a nearby airport. At the airport, cuttings are loaded onto passenger flights, with main destinations Amsterdam or Frankfurt. From the airport, cuttings are transported in climate-controlled vehicles (temperatures

should not drop below freezing) and have to reach the rooting nursery within 3 to 5 days from harvest. To maintain their quality, cuttings require a temperature of 4 to 8 degrees during storage and transport. In general, harvested cuttings require lower temperatures compared to cut-roses to maintain their quality after harvest, which can contribute significantly to GHG emissions [20,29].

According to interviewees, despite air-shipment, producing cuttings in southern countries reduces CO₂e emissions, compared to the alternative of producing in Germany or The Netherlands due to intensive heating and artificial lighting required. These claims are supported by several studies that compared the GHG emissions of cut flower production in The Netherlands to the production of flowers in Africa or Latin America [8,28,72]. Cuttings have relatively low weight, compared to cut flowers and can be packaged in large quantities in cardboard boxes. Moreover, in the current study, interviewees claimed that cuttings produced in Germany or The Netherlands will not reach the same quality as those produced in Africa or Central America in optimal temperature and light conditions.

Rooted cuttings are transported in climate-controlled vehicles for no more than three days until they reach the potted plant nursery. Some propagation nurseries make efforts to produce rooted cuttings locally by working together with sub-contractors. Other propagation nurseries cultivate rooted cuttings centrally, at the company headquarters. Finished plants are transported also in climate-controlled vehicles to a central logistic center. Some growers' organizations have regional logistic centers and try to source plants locally. At the center, they are stored under suitable temperature and lighting conditions. Some logistic centers use LED technology to reduce electricity costs. Other measures to reduce energy consumption include better building materials with better insulation and installation of solar panels. After a short period at the logistic center, plants are distributed to retail shops.

4.3. Social Sustainability Challenges and Sustainability-Driven Innovations along the Value Chain

The cultivation of propagation material (cuttings) is labor-intensive. Therefore, apart from optimal weather conditions, labor costs are an important factor in the choice of production location. Cuttings are produced almost exclusively in southern countries, in low-cost labor markets. Rooted cuttings for the German market are produced by propagation nurseries, collaborating contractors and independent growers in Germany and in The Netherlands. The majority of potted plants are cultivated within Germany. Nursery workers in Germany are subject to the German law in terms of working conditions, such as working hours, minimum wage and safety regulations. In African countries work regulations and standards are different from those in Europe. Moreover, national social security or health care systems that protect citizens from extreme poverty are missing. However, cutting farms are subsidiaries of the propagation nurseries in Europe and therefore the farm workers are direct employees of the European company. This gives the company a sense of responsibility for their employees because it can be directly accused of exploiting the workforce. Moreover, greenhouses of cutting farms are technologically more advanced compared to cut flower farms and partly offer better working conditions. For example, stock plants are grown on tables and not in the ground like roses. Therefore, workers do not need to bend down to the ground [29]. In addition, all propagation nurseries interviewed were socially certified (e.g., MPS Socially Qualified (SQ) or GLOBALG.A.P. GRASP). As most of the research on social conditions in Africa was published on cut-flowers, the social conditions reported by interviewees for cutting farms will be compared to the conditions in cut flower farms.

According to interviewees, stock plant nurseries contribute to the local economy by providing job opportunities and women are often the main workforce. Some interviewees claimed that cutting production is far more profitable than other agricultural products and therefore can support more people. This was supported by a different study, referring to cutting farms as more profitable than flower farms [29]. An average of 68% employment of women was found, among 20 flower and cutting farms in Ethiopia, Uganda, Kenya and Tanzania [34]. In Ethiopia, the floricultural industry employs 70% women [73,74]. Gobie (2019) also emphasized the importance of employment opportunities for women because earning wages allows women economic independence from their husbands and families [74]. In Kenya, jobs in the floriculture sector are considered more attractive than in other

agricultural sectors, because of some benefits and securities offered to employees [21]. Nevertheless, communities in Ethiopia have stressed that changes in land use for floricultural farms have negative consequences. Floricultural farms took over agricultural land and tree plantations, which caused shortages and an increase in market prices of agricultural products and timber for construction and fire-wood [73].

Interviewees from propagation nurseries reported on regional development due to the presence of the cutting farms. They referred to road construction, connection of houses to electricity and community services, such as schools and health services. The owner of a propagation nursery reported that about 5000 people are employed in the floricultural production region close to Addis Abeba, Ethiopia. This region has developed well in the past 10 years, with new villages, schools, bakeries and electricity. A representative of a certification body explained that in many cases nursery employees are migrants, which also contributes to the regional development because of migrants' contributions to the local economy (see also [34]). It was explained that such workers cannot grow their own food because they do not have access to land or the time. Therefore, they must buy food and as a result boost the local markets. Regional development around floricultural farms can also have negative effects. In Lake Naivasha, the largest center of cut flower farms in Kenya, such development led to unplanned building of houses for the large number of migrants, unpaved roads and a lack of water supply and sanitation infrastructure [21]. But also in this example, some positive developments were observed such as connection of houses to electricity and building of shared pit toilets with cement slabs [21].

According to interviewees, nursery workers earn more than the average salaries in the region. Social certification (e.g., MPS Socially Qualified (SQ) or GLOBALG.A.P. GRASP) also increased the salaries at the nurseries. The GLOBALG.A.P. GRASP certification requires payment of at least national minimum wages or according to bargaining agreements (GRASP Guideline for Retailers). According to the MPS SQ standard, wages should at least meet the national or industry (CBA) minimum standards, whichever is higher and be sufficient to meet basic needs (MPS SQ certification scheme, p. 10). Higher wages were paid to flower farm workers compared to the minimum wage paid for agriculture employees in Kenya [21] and also workers in cutting farms in Uganda tend to earn better salaries than in flower farms [29]. According to a sustainability manager of a wholesale company the adoption of social certifications by propagation nurseries has improved the situation compared to four years ago. Kirigia et al. (2016), also confirms that the introduction of such certification standards, contributed to the improvement in working conditions in the floricultural industry in Eastern Africa.

Salaries paid to nursery workers in Germany and The Netherlands are above the minimum wage. Minimum wage was introduced in Germany in January 2015 [75]. Since then it was increased several times and the current hourly rate is 9.35 Euro. According to interviews, the adoption of Fairtrade standards for certain products such as potted poinsettia and pelargonium also meant better payment for nursery workers in Africa and higher prices for growers in Europe.

A representative of a propagation nursery stated that their workers in Africa generally work eight-hour days. During peak seasons, casual workers are recruited, and employees are expected to work overtime, which they are compensated for. In the cut flower industry, workers often have to work long hours due to the perishability of the product [76]. As cuttings have to be transported at the day of harvest, nursery managers are under pressure to harvest sufficient quantities. Therefore, harvest days have to be well planned with sufficient personnel to avoid overtime. In Kenya, flower farm employees work under a collective bargaining agreement stating 46 h per week, with 1.5 times overtime pay [21]. Comparable conditions were reported for cutting farms in Uganda as nursery workers are working six days a week, eight hours a day (Saturday only half-day) and overtime is voluntary [29]. In Germany, working hours can differ slightly between companies within the legal framework, which allows up to 48 h per week. One propagation nursery reported a 38.5-h work week.

According to interviewees, both in African countries and in Europe most of the employees (about 75%) are permanently employed and temporary employees are hired for peak seasons. According to the MPS SQ standards employees must receive a binding, written employment contract (MPS SQ

certification scheme, p. 9). Evers et al. (2014) also reported on 75% permanent employment and 25% temporary contracts for cutting farms in Uganda. The same study also pointed out that in farms that follow a Collective Bargaining Agreement (CBA) workers are employed on temporary contracts for up to six months upon recruitment, followed by yearly renewed contracts. Only workers with one-year contracts are entitled to the full benefits of the CBA [29]. According to the Kenyan CBA, the probation period of new employees is limited to two months followed by permanent work contracts [21]. High levels of workers' absence and turnover was reported on cutting farms, which was reduced with permanent (one-year) contracts and attendance bonuses [29]. However, during the hot rainy season a 10% level of absence remained due to malaria. Interviewees expressed their preference for workforce retention in order to benefit from trained and experienced employees. Security of employment was found a better incentive for workforce retention in Kenya rather than higher wages, under conditions of rising unemployment [5]. Among cut flower workers in Ethiopia, workforce retention was found to be related to job satisfaction. Positive evaluation of extrinsic organizational rewards (wages, job security and healthy environment) contributed to job satisfaction [44].

One of the central difficulties of nurseries in Germany according to interviewees is to recruit and retain employees. Bitsch et al. (2004) already identified the availability of qualified workers as a major challenge to the German horticultural industry [77]. Ludwig-Ohm and Dirksmeyer (2013) also reported a shortage of qualified, skilled workers in the horticultural sector in Germany [78]. According to one of the interviewees, the shortage in employees can be explained partly by the lack of prestige of the floricultural sector. Evidence for this claim came from an earlier study dealing with job satisfaction of apprentices, where Bitsch (1996) concluded that improving the image of the horticultural industry could help to attract qualified workers [22]. Ludwig-Ohm and Dirksmeyer (2013) further explained that the German society has little awareness of the sophisticated plant production systems and the high technical knowledge requirements for professionals in horticulture [78].

Improving different aspects related to job satisfaction offers the potential for attracting new qualified employees [38]. According to Bitsch (2007), job satisfaction is also important for staff retention and motivation. She found that among horticultural workers in the USA, achievement and recognition are the key components of job satisfaction. Other factors contributing to job satisfaction were job security, technical aspects of supervision and interpersonal relationships [23]. In the current study, a nursery manager in Germany spoke of retaining employees through promotions, support and motivation.

In African countries, providing employees with benefits can improve their quality of life and is a common practice to attract and retain the workforce. A manager of an international propagation nursery emphasized how important it is that employees are paid fairly and are happy to work for the company. Propagation nurseries with sites in Africa and Central America reported to provide different benefits for their employees. Among the benefits provided are health services such as clinics at the farm and access to nurses and physicians. Nurseries also generally provided daycare facilities, kindergartens and schools to employees' families. Daycare services allow mothers to go back to work and continue to financially support their families. Some nurseries provide financial services such as bank accounts to employees, small loans and a pension fund. Others provide accommodation at the farm, warm meals and clean drinking water. Some companies reported to also provide services to the community, such as support of schools and health services. This is supported by Kirigia et al. (2016), referring to services provided by the nurseries to the community, such as construction and renovation of schools, clean drinking water, health services and maintenance of roads [34]. Providing such benefits to employees and the community is innovative. On one hand it has a positive influence on attraction and retaining of employees; on the other hand, it contributes to the positive image of the company in the local community and for other stakeholders.

In Kenya, flower farms that signed CBAs offer benefits to their employees, such as cash allowances for housing and travel, paid sick leave, paid public holidays, paid annual leave and paid maternity leave of 3 months [21]. In Uganda, a similar arrangement was achieved, offering benefits to floriculture

farm workers. In the latter CBA, some benefits, such as housing allowance, medical services and daycare are not included. However, most of the farms provided some of these benefits such as medical services, daycare and housing allowance, regardless of the agreement. Moreover, the quality of benefits in cutting farms was better than in flower farms [29]. According to Kirigia et al. (2016), some of the services mentioned above are requirements of certification standards [34]. In Germany, Bitsch et al. (2004), proposed a flexible benefit system as a low cost opportunity for horticultural workplaces to become more attractive [77].

Companies both in African countries and in Europe reported that they train their own employees to acquire new personnel and remain independent. According to Riisgaard and Gibbon (2014), this procedure of on-the-job training is typical for the cut flower sector in Kenya, with the explanation that for this type of job, skills are best acquired by exposure to the work environment [5]. Training on cutting farms is longer and more systematic compared to flower farms and workers with secondary education are preferred [29]. According to interviewees, some companies in Germany strive to retain employees and contribute to job satisfaction by offering special training programs, such as programs for training of nursery managers.

Interviewees reported that occupational health and safety standards in cutting farms are comparable to the European standards. Furthermore, all companies are certified, which obliges propagation nurseries to keep to standard safety measures and document all chemicals used. However, at least in the cut flower farms in Ethiopia, it was concluded that private standards did not improve the sustainability performance in terms of pesticide use [37]. Indeed, reports from flower farm in Ethiopia showed that local communities are concerned about workers' health, due to intensive application of chemicals [73]. Exposure to chemicals was reported as the main complaint of workers and communities around farms [34]. According to Franze and Ciroth (2011), workers' health in flower farms, in Ecuador, is at risk because of insufficient protection gear and the lack of time off after spraying pesticides [8]. In Uganda, workers are still exposed to chemicals, although some improvements have been made due to the CBA. This exposure is mostly during peak periods, when workers are required to enter the greenhouse too soon after spraying due to time pressure. Moreover, in both cutting and flower farms, workers' protective gloves are too short, which exposes them to chemicals. In addition, more chemicals are used in cutting farms because the growing media is fumigated with pesticides, before every new crop [29]. This practice contradicts the findings of the present study, where interviewees reported to steam the substrate for disinfection. In The Netherlands, health and safety is at low risk as workers use suitable protection gear and hazardous substances are applied using machinery [8].

Apart from chemicals, it was found that greenhouse workers on flower farms in Ethiopia are also exposed to high endotoxin levels, carried by organic dust, compared to field workers and suffer more frequently from respiratory symptoms [39]. High temperatures and humidity in greenhouses provide optimal conditions for a wide variety of fungi and bacteria. Moreover, the enclosed space and poor ventilation contributes to the high exposure of workers to dust. Exposure of workers to endotoxins, bacteria and fungi was also measured in Danish potted plant nurseries [45]. They found that the exposure levels depend on the tasks performed and that in 30% of the samples the endotoxin exposure limit was exceeded, which may have health implications for the employees [45].

The majority of potted plants sold in Germany are certified by either GLOBALG.A.P or MPS. Some propagation nurseries also reported that they are performing more controls for pesticides than required by the standards. GLOBALG.A.P and MPS are business-to-business certifications and are designed to meet retailers' requirements. The end consumer is generally not informed about the certification of the products. According to a supply chain manager of a propagation nursery, consumers generally cannot know the origin of the plant and the cultivation conditions. Moreover, the end consumer has no information about traces of chemicals on the plant. On the other hand, positive developments, such as reduction in pesticide use, reduced energy consumption or social benefits for workers in Africa, are also not transparent to the end consumer. Since the interviews were conducted, both GLOBALG.A.P and MPS have developed the consumer labels "GGN" and "follow your plant," offering consumers to

track the origin of the plant by a specific identification number on the label [79,80]. However, currently, the extent of adoption of these labels is not known.

An exception are Fairtrade labeled pelargonium and poinsettia plants marketed by two propagation nurseries. According to interviewees, the Fairtrade label is a way for propagation nurseries to communicate to the consumer what they did anyway, even before the adoption of the Fairtrade certification. Another exception is bee-friendly labeled plants; the label indicates that plants have attractive flowers for pollinators and generally were treated with reduced levels of insecticides. However, as opposed to Fairtrade plants, there is no bee-friendly standard with clear requirements. Bee-friendly is rather a marketing innovation and the consumer has no certainty on what requirements bee-friendly plants must meet.

4.4. Economic Sustainability Challenges and Sustainability-Driven Innovations along the Value Chain

The issues discussed in this section represent the main economic difficulties of companies taking part in the value chain of flowering potted plants. According to interviewees, the price of potted plants in Germany is too low, partly because of price pressure from retailers. Other explanations interviewees offered for decreasing prices are overproduction of some products and high competition. On the other hand, interviewees reported that production costs such as wages and raw materials increase continuously. Moreover, this is a labor-intensive industry, in which labor costs amount to a major part of production costs. The propagation stages of stock plant cultivation and harvest of cuttings are especially labor-demanding. According to interviewees, propagation nurseries have witnessed an increase in salaries in Southern Europe and the Mediterranean region and therefore moved their cutting production sites to Africa and Central America. However, propagation chain actors are concerned that Africa will eventually also become too expensive for the production of cuttings, if prices continue to drop.

Because European legislation prohibits the import of plants of the Solanaceae family, stock plants of the Solanaceae family (e.g., petunia, calibrachoa) cannot be cultivated in Africa but in other regions mostly in Southern Europe and in other Mediterranean countries. This regulation is enforced to protect food crops such as tomatoes and potatoes from pathogen transmission [81]. However, production costs in countries such as Portugal, Tenerife and Israel are generally higher than in Africa.

The German market is perceived by interviewees as stable and not dynamic. Indeed, the German market has not changed much over the past 15 years with an average volume of 8.6 billion euros in retail prices [82]. Chain actors are concerned that generational changes will result in a reduction in the customer base, because young consumers have different preferences. According to interviewees, young consumers are not familiar with plant species, cannot judge plants' quality and invest less time in gardening. A different study predicted an increase in consumption, because the consumer groups spending most on ornamental plants (older than 55 and couples without children), are expected to grow [78].

According to interviewees, due to low margins and the stagnant market, some actors attempt to differentiate their products. In some cases, products are differentiated by means of sustainability labels. An example of marketing innovations of sustainable products for a premium price are Fairtrade potted plants. According to a marketing manager of a propagation nursery, the market price of Fairtrade plants was 30% higher, which also meant a higher profit. Another form of product differentiation are growers' organizations specializing in sustainable production of potted plants. Growers belonging to one of these organizations are committed to keep specific requirements, such as two third of renewable energy sources.

Unpredictable weather conditions affect plant maturation as well as consumer behavior. Although potted plants are mostly grown in protected environments, weather conditions can influence greenhouse production. For example, with above average temperatures in the winter, potted plants will mature too early. Moreover, the demand is also unpredictable and weather-dependent. Consumers are more

likely to purchase outdoor plants when the weather is warm and sunny. Verdouw et al. (2010) also reported demand uncertainties due to weather-dependent sales in the floricultural sector [83].

To sell into retail channels, value chain actors are required to comply with different regulations. Private standards (e.g., MPS or GLOBALG.A.P.) are an innovative tool that has become a requirement from retail chains. According to a sales manager of a propagation nursery without complying with certain standards, they will be excluded from many business opportunities. Some propagation nurseries explained that adopting social and environmental certifications are a form of insurance, to prevent negative media attention typically brought upon them by Non-Governmental Organization (NGOs). According to interviewees, propagation nurseries also require from their contractor growers (of rooted cuttings) to be certified to either MPS or GLOBALG.A.P. Riisgaard (2009) also claimed that standards are a risk management strategy for brand protection of retailers or brand producers [76]. Although social standards were implemented generally as a strategy for risk management, some interviewees pointed out that standards positively influence the well-being of employees in African countries.

Another aspect relevant for economic sustainability of propagation nurseries is the long development of and the large investment in new cultivars. According to interviewees, because the development process takes many years, it is possible that when the new cultivar is finally ready, it is no longer attractive. Indeed, the market of potted plants is driven by consumers' growing demand for novelties and, therefore, research and development departments became increasingly important for competitive companies [60]. Still the development of new cultivars can take up to ten years and the popularity of novelties among consumers sometimes lasts only a few years.

According to some interviewees, there are solutions to many of the environmental and social sustainability challenges in the value chain of potted plants. However, interviewees further claimed that such sustainability solutions involve large investments and the costs cannot be compensated by the price. Nevertheless, some strategies such as increased energy efficiency contribute both to cost reduction as well as reductions in GHG emissions. Moreover, some costs such as the costs of compliance with standards cannot be avoided as non-compliance would be a market entry barrier.

4.5. Addressing the Sustainability Challenges Uncovered

Several environmental sustainability challenges have been identified in the value chain of flowering potted plants. Many of these challenges have available solutions, which include sustainability strategies and innovations. The challenge of water scarcity can be addressed by a combination of independent water sources, such as rainwater harvesting and water saving irrigation systems, such as close loop system. Closed irrigation systems are also a solution for fertilizer runoff and can reduce the amount of fertilizer applied.

Energy consumption due to heating can be reduced by the choice of cultivars that require lower temperatures, implementing energy saving technologies and strategies such as "Cool Morning–Warm Evening." Moreover, heating with renewable energy sources can reduce the GHG emissions due to heating requirements significantly. Electricity consumption can be reduced by the choice of energy-efficient light technology such as LED technology. GHG emissions due to electricity can be reduced by sourcing electricity from renewable sources and own electricity production, for example, by installing solar panels. Energy consumption due to transportation can be reduced by regional production and sourcing of plants and transport with electric vehicles. Air-shipment of cuttings from producing countries is difficult to overcome, as production in closer locations is not economically feasible due to the relatively high cost production in Europe. Pesticide use is still a notable challenge in the industry, as the quality and appearance of the product is important to the end consumer. Application of an integrated pest management approach as well as biological pest control have reduced the use of chemicals. However, eliminating the use of pesticides seems unlikely, at this point.

Substituting peat as a growing medium is difficult. Although a large variety of innovative products are available on the market, the risk of adopting such alternatives is high. Successful cropping will require growers to test different substrates under different growing conditions and on a variety

of plants before they can adopt peat alternatives with satisfactory results. Plastic containers at the early stages in the value chain can be re-used after cleaning, as was shown at the stock plant stage for innovative plastic bags or by the recollecting system of plug-trays. These innovations are already a common practice for some of the propagation nurseries interviewed. However, growers are more reluctant to adopt compostable or biodegradable containers at the potted plants stage. This involves a financial risk, because the costs of such containers are generally higher than plastic containers and successful cultivation is not guaranteed. In addition, the large diversity of products requires growers to test the containers first, in order to minimize the risk. Recycled plastic containers are widely accepted, due to their attractive price and similar qualities to the standard plastic containers. Furthermore, for both peat-free substrates as well as alternative pots, it is not clear whether the alternatives have indeed lower GHG emissions compared to peat or plastics.

Social challenges are different for Europe compared to Africa. Social challenges in Africa are related to low wages and general working conditions. Many of these challenges were addressed by the innovative social standards that have become a market requirement. For example, wages, employment relations and working hours are regulated in these standards. Health and safety issues are regulated further by the Good Agricultural Practice standards such as MPS or GLOBALG.A.P. Propagation nurseries make efforts to improve the lives of employees and their families as well as to contribute to local communities by provision of different benefits. Such benefits are provided to retain and attract workers, improve the image of the company in the local community but also improve the image other stakeholders, such as retailers, consumers and NGOs, perceive. Furthermore, many of the propagation nurseries are family businesses and part of their management vision is the responsibility for the wellbeing of all their employees.

The challenges of recruitment and retention of employees in Germany remain central for the industry. These challenges are related to the unfavorable image of horticulture in Germany and the generally low salaries of nursery workers compared to industrial production. Potted plants sold at large retail chains are generally certified. Adopting consumer labels for the certified products would improve the transparency of the finished product for the end consumer. The main economic challenges are related to the profitability of the product, due to low prices on the German market and relatively high labor costs. Actors deal with these challenges either by cost reduction or by product differentiation. Another economic challenge is the need to comply with standards (e.g., MPS or GLOBALG.A.P.), which serve as barrier to market entry. Adoption of standards also poses financial and administrative burdens. For small nurseries, implementation of such standards is, in some cases, not feasible, which excludes them from supplying to large retailers.

5. Conclusions

Sustainability driven innovations can address many of the sustainability challenges along the value chain. The implementation environmental innovations is generally associated with increased costs, production risk and complexity of implementation. Installation of LED technology, for instance, is associated with a large financial investment compared to the alternatives and effective implementation of LED technology requires knowhow. The adoption of peat-free substrate is associated with production risk and requires expertise as some crops cultivated using alternative substrates had failed. The adoption of social innovations as social standards is also associated with increased costs, however, they have become a market requirement and cannot be avoided. Other social innovations such as Fairtrade potted plants remain a niche product. Furthermore, addressing sustainability challenges may introduce tradeoffs between sustainability dimensions. Increase in salaries, for instance, will have a positive influence on the social dimension but is negative for the economic dimension, as it will affect profitability. However, the lack of transparency of the product prevents the transfer of sustainability costs to the consumer by offering a sustainable product for a premium price. This may change when more certified products are also labeled as such.

Several drivers influence actors to adopt sustainability innovations—(i) cost reduction in the case of reducing energy costs, (ii) barrier to market entry, such as the requirements from retail to adopt private standards, (iii) risk mitigation by adopting standards to prevent media attention, (iv) product differentiation by the adoption of sustainability labels such as Fairtrade, (v) management vision, such as “to become the most sustainable young plant company on the world” or “taking care of our employees” and (vi) company image, for instance by providing benefits to workers and the communities in Africa.

Business-to-business standards have generally had a positive influence on the adoption of specific sustainability innovations such as benefits to nursery workers in Africa. Moreover, by setting certification as an entry barrier for suppliers, retailers are becoming even more powerful chain actors. The involvement of NGOs influenced the adoption of social and environmental standards through pressure on chain actors such as retailers and propagation nurseries. However, pressure to stop using neonicotinoid insecticides also had a negative influence, as growers reported to have used other more harmful substances.

It is difficult to differentiate between social, economic and environmental innovations, as some innovations have impacts on all three dimensions. Private standards, for example, often influence social, environmental, as well as economic aspects. However, environmental innovations are generally technological innovations related to production processes and product qualities. Private companies or academic research institutes responding to market deficiencies generally develop such innovations as a business opportunity. Social and economic innovations, in many cases, are organizational or management tools and their implementation influences not only single actors but also the entire value chain. The development of such tools generally involves cross-sector dynamics and in this case, NGOs, chain actors and private agriculture and labor standards. However, the influence of each of these sectors is different. Some chain actors such as retailers are more powerful and can force other chain actors to comply. In this case, NGOs set the rules by placing particular sustainability challenges on the public agenda and forcing other chain actors and private standard organizations to react.

By investigating sustainability challenges along the value chain of flowering potted plants, the current study set the foundation for the development of sustainability assessment methods including environmental, social and economic dimensions. Indicator-based assessment can provide a reference for actors regarding their sustainability performance and will support them in making better decisions in order to improve their sustainability. Further research on sustainability innovations can help to determine how to better implement such innovations and to assess which innovations can considerably improve sustainability performance in the value chain. Moreover, the knowledge on where changes in the value chain are most urgently needed can promote research and development to contribute to addressing industry needs.

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

Funding: This research was funded by the Bavarian Ministry of Education and Culture, Science and Arts, grant number VIII.2-F1116.WE/26.

Acknowledgments: The authors wish to thank the interviewees for sharing valuable information about the value chain. Special thanks also to T. Schwend for his contribution to data collection.

Conflicts of Interest: The authors declare no conflict of interest in the context of this publication. 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. Main environmental, social and economic issues and the associated publications.

	No. of Publications ¹	References
<i>Environmental aspects</i>		
Water	11	Sahle and Potting (2013), De Vries (2010), Mekonnen et al. (2012), Russo, Scarascia Mugnozza and de Lucia Zeller (2008), Russo and de Lucia Zeller (2008), Lazzerini et al. (2018), [31] Ingram et al. (2018), Ingram et al. (2019), White et al. (2019), Kirigia et al. (2016), Knight et al. (2019)
Fertilizer	6	Russo, Buttol and Tarantini (2008), Sahle and Potting (2013), De Vries (2010), Mekonnen et al. (2012), Lazzerini et al. (2018), Ingram et al. (2019)
Plant protection agents and other Chemicals	3	Sahle and Potting (2013), Lazzerini et al. (2018), Mengistie et al. (2017)
Pots and containers	8	Russo, Buttol and Tarantini (2008), Lazzerini et al. (2015), Lazzerini et al. (2018), Bonaguro et al. (2016), Koeser et al. (2014), [30] Ingram et al. (2018), [31] Ingram et al. (2018), Ingram et al. (2019)
Growing media/substrate	7	Lazzerini et al. (2015), Lazzerini et al. (2018), Koeser et al. (2014), De Lucia et al. (2013) [30] Ingram et al. (2018), Ingram et al. (2019), Wandl and Haberl (2017)
Electricity, light and heating	9	Russo, Buttol and Tarantini (2008), [31] Ingram et al. (2018), Soode et al. (2013), Soode et al. (2015), Torrellas et al. (2012), Franze and Ciroth (2011), Koeser et al. (2014), Wandl and Haberl (2017), Abeliotis et al. (2016)
Transportation	4	Franze and Ciroth (2011), Abeliotis et al. (2016), De Vries (2010), Blonk et al. (2010)
<i>Economic aspects</i>		
Cost benefit analysis	1	Torrellas et al. (2012)
Cost of production	2	Brumfield et al. 2018
Variable costs	4	Ingram et al. (2017), [30] Ingram et al. (2018), [31] Ingram et al. (2018), Ingram et al. (2019)
Value chain Governance	1	Evers et al. (2014)
<i>Social aspects</i>		
Health and safety	6	Nigatu et al. (2015), Thilsing et al. (2015), Franze and Ciroth (2011), Evers et al. (2014), Mengistie et al. (2017), Kirigia et al. (2016)
Working hours (work load)	3	Franze and Ciroth (2011), Evers et al. (2014), Kirigia et al. (2016)
Wages	4	Anker and Anker (2014), Franze and Ciroth (2011), De Vries (2010), Evers et al. (2014)
Employment relations	4	Riisgaard and Gibbon (2014), Franze and Ciroth (2011), Evers et al. (2014), Anker and Anker (2014)
Work satisfaction	4	Bitsch, (1996), Bitsch (2007), Staelens et al. (2018), Meyerding (2015)
Product responsibility	1	Franze and Ciroth (2011)
Community	3	Franze and Ciroth (2011), Anker and Anker (2014), Kirigia et al. (2016),
Local employment	3	Franze and Ciroth (2011), Evers et al. (2014), Kirigia et al. (2016)
Benefits to workers	3	Evers et al. (2014), Anker and Anker (2014), Kirigia et al. (2016)

¹ Publications could qualify for more than one dimension and more than one aspect.

References

1. Zentralverbandes Gartenbau e. V. Jahresbericht 2019. Available online: <https://www.g-net.de/zvg-jahresbericht.html> (accessed on 23 February 2020).
2. Faust, J.E.; Dole, J.M.; Lopez, R.G. The floriculture vegetative cutting industry. In *Horticultural Reviews*; Janick, J., Ed.; Wiley Blackwell: Hoboken, NJ, USA, 2016; Volume 44, pp. 121–172.

3. Havardi-Burger, N.; Mempel, H.; Bitsch, V. Driving forces and characteristics of the value chain of flowering potted plants. *Eur. J. Hortic. Sci.* stage of publication (accepted).
4. Lazzarini, G.; Merante, P.; Lucchetti, S.; Nicese, F.P. Assessing environmental sustainability of ornamental plant production: A nursery level approach in Pistoia district, Italy. *Agroecol. Sustain. Food Syst.* **2018**, *12*, 1–22. [CrossRef]
5. Riisgaard, L.; Gibbon, P. Labour management on contemporary Kenyan cut flower farms: Foundations of an industrial-civic compromise. *J. Agrar. Chang.* **2014**, *14*, 260–285. [CrossRef]
6. Sahle, A.; Potting, J. Environmental life cycle assessment of Ethiopian rose cultivation. *Sci. Total Environ.* **2013**, *443*, 163–172. [CrossRef] [PubMed]
7. Mekonnen, M.M.; Hoekstra, A.Y.; Becht, R. Mitigating the water footprint of export cut flowers from the lake Naivasha basin, Kenya. *Water Resour. Manag.* **2012**, *26*, 3725–3742. [CrossRef]
8. Franze, J.; Ciroth, A. A comparison of cut roses from Ecuador and The Netherlands. *Int. J. Life Cycle Assess.* **2011**, *16*, 366–379. [CrossRef]
9. Soode, E.; Weber-Blaschke, G.; Richter, K. Comparison of product carbon footprint standards with a case study on poinsettia (*Euphorbia pulcherrima*). *Int. J. Life Cycle Assess.* **2013**, *18*, 1280–1290. [CrossRef]
10. Hansen, E.G.; Grosse-Dunker, F.; Reichwald, R. Sustainability innovation cube—A framework to evaluate sustainability-oriented innovations. *Int. J. Innov. Mgt.* **2009**, *13*, 683–713. [CrossRef]
11. Barrett, G.E.; Alexander, P.D.; Robinson, J.S.; Bragg, N.C. Achieving environmentally sustainable growing media for soilless plant cultivation systems—A review. *Sci. Hortic.* **2016**, *212*, 220–234. [CrossRef]
12. Riisgaard, L. *How the Market for Standards Shapes Competition in the Market for Goods. Sustainability Standards in the Cut Flower Industry*; Danish Institute for International Studies (DIIS): Copenhagen, Denmark, 2009.
13. Riisgaard, L.; Hammer, N. Prospects for labour in global value chains: Labour standards in the cut flower and banana industries. *Br. J. Ind. Relat.* **2011**, *49*, 168–190. [CrossRef]
14. Reynolds, L.T. Fair trade flowers: Global certification, environmental sustainability, and labor standards. *Rural Sociol.* **2012**, *77*, 493–519. [CrossRef]
15. Bitsch, V. Sustainability as innovation: Challenges and perspectives in measurement and implementation: Diffusion and transfer of knowledge in agriculture. In *Diffusion and Transfer of Knowledge in Agriculture*; Huyghe, C., Bergeret, P., Svedin, U., Eds.; Quae: Versailles, France, 2016.
16. Brundtland Report. Report of the World Commission on Environment and Development: Our Common Future; UN Documents, A/42/427, February 1987. Available online: <http://www.un-documents.net/wced-ocf.htm> (accessed on 2 March 2020).
17. Bloemhof, J.M.; van der Vorst, J.G.A.J.; Bastl, M.; Allaoui, H. Sustainability assessment of food chain logistics. *Int. J. Logist. Res. Appl.* **2015**, *18*, 101–117. [CrossRef]
18. Krug, B.A.; Burnett, S.E.; Dennis, J.H.; Lopez, R.G. Growers look at operating a sustainable greenhouse. *GMPRO* **2008**, *28*, 43–45.
19. Lopez, R.G.; Burnett, S.E.; Dennis, J.H.; Krug, B.A. 8 steps to take to become sustainable. *GMPRO* **2008**, *28*, 26–29.
20. Abeliotis, K.; Barla, S.-A.; Detsis, V.; Malindretos, G. Life cycle assessment of carnation production in Greece. *J. Clean. Prod.* **2016**, *112*, 32–38. [CrossRef]
21. Anker, R.; Anker, M. Living Wage for Kenya with Focus on Fresh Flower Farm Area Near Lake Naivasha: Executive Summary. Report Prepared for Fairtrade International, Sustainable Agriculture Network/Rainforest Alliance and UTZ Certified. Available online: https://www.isealalliance.org/sites/default/files/LivingWageReport_ExecutiveSummary_Kenya.pdf (accessed on 31 January 2020).
22. Bitsch, V. Job satisfaction during apprenticeship. *Acta Hortic.* **1996**, 97–102. [CrossRef]
23. Bitsch, V. Job satisfaction in horticulture: New insights. *Acta Hortic.* **2007**, 431–438. [CrossRef]
24. Blonk, H.; Kool, A.; Luske, B.; Ponsioen, T.; Scholten, J. *Methodology for Assessing Carbon Footprints of Horticultural Products. A Study of Methodological Issues and Solutions for the Development of the Dutch Carbon Footprint Protocol for Horticultural Products*; Blonk Milieu Advies BV: Gouda, The Netherlands, 2010.
25. Bonaguro, J.E.; Coletto, L.; Samuele, B.; Zanin, G.; Sambo, P. Environmental impact in floriculture: LCA approach at farm level. *Acta Hortic.* **2016**, 419–424. [CrossRef]
26. Brumfield, R.G.; Kenny, L.B.; DeVincentis, A.J.; Koeser, A.K.; Verlinden, S.; Both, A.J.; Bi, G.; Lovell, S.T.; Stewart, J.R. Analysis of economic and social costs of growing petunia ×hybrida in a greenhouse production system using alternative containers. *Hortscience* **2018**, *53*, 1179–1185. [CrossRef]

27. De Lucia, B.; Cristiano, G.; Vecchiotti, L.; Rea, E.; Russo, G. Nursery growing media: Agronomic and environmental quality assessment of sewage sludge-based compost. *Appl. Environ. Soil Sci.* **2013**, *2013*, 1–10. [[CrossRef](#)]
28. De Vries, W. Qualitative Comparison of Dutch and Ethiopian Rose Production Systems: Why Dutch Rose Growers Move to African Nations and What Consequences Does This Migration Have? Master's Thesis, University of Groningen, Groningen, The Netherlands, May 2010.
29. Evers, B.; Amoding, F.; Krishnan, A. Social and Economic Upgrading in Floriculture Global Value Chains. Flowers and Cuttings GVCs in Uganda; Capturing the Gains. Working Paper 42, University of Manchester. 2014. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2456600 (accessed on 2 March 2020).
30. Ingram, D.L.; Hall, C.R.; Knight, J. Global warming potential, variable costs, and water use of a model greenhouse production system for 11.4-cm annual plants using life cycle assessment. *Hortscience* **2018**, *53*, 441–444. [[CrossRef](#)]
31. Ingram, D.L.; Hall, C.R.; Knight, J. Analysis of production system components of container-grown chrysanthemum for their impact on carbon footprint and variable costs using life cycle assessment. *Hortscience* **2018**, *53*, 1139–1142. [[CrossRef](#)]
32. Ingram, D.L.; Hall, C.R.; Knight, J. Modeling container-grown euphorbia pulcherrima production system components: Impacts on carbon footprint and variable costs using a life cycle assessment. *Hortscience* **2019**, *54*, 262–266. [[CrossRef](#)]
33. Ingram, D.L.; Hall, C.R.; Knight, J. Modeling global warming potential, variable costs, and water use of young plant production system components using life cycle assessment. *Hortscience* **2017**, *52*, 1356–1361. [[CrossRef](#)]
34. Kirigia, E.; Betsema, G.; van Westen, G.; Zoomers, A. *Flowers for Food? Scoping Study on Dutch Flower Farms, Land Governance and Local Food Security In Eastern Africa*; LANDac: Utrecht, The Netherlands, 2016.
35. Knight, J.; Ingram, D.L.; Hall, C.R. Understanding irrigation water applied, consumptive water use, and water footprint using case studies for container nursery production and greenhouse crops. *Horttechnology* **2019**, *29*, 693–699. [[CrossRef](#)]
36. 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: A life cycle assessment (LCA) approach in a nursery district in central Italy. *J. Clean. Prod.* **2015**, *112*, 4022–4030. [[CrossRef](#)]
37. Mengistie, B.T.; Mol, A.P.J.; Oosterveer, P. Governance of agro-pesticide through private environmental and social standards in the global cut flower chain from Ethiopia. *Ambio* **2017**, *46*, 797–811. [[CrossRef](#)]
38. Meyerding, S.G.H. Job characteristics and job satisfaction: A test of Warr's vitamin model in German horticulture. *Psychol. Manag. J.* **2015**, *18*, 86–107. [[CrossRef](#)]
39. Nigatu, A.W.; Bråtveit, M.; Deressa, W.; Moen, B.E. Respiratory symptoms, fractional exhaled nitric oxide & endotoxin exposure among female flower farm workers in Ethiopia. *J. Occup. Med. Toxicol.* **2015**, *10*, 8. [[CrossRef](#)]
40. Russo, G.; de Lucia Zeller, B. Environmental evaluation by means of LCA regarding the ornamental nursery production in rose and sowbread greenhouse cultivation. *Acta Hort.* **2008**, 1597–1604. [[CrossRef](#)]
41. Russo, G.; Buttol, P.; Tarantini, M. LCA (Life Cycle Assessment) of roses and cyclamens in greenhouse cultivation. *Acta Hort.* **2008**, 359–366. [[CrossRef](#)]
42. Russo, G.; Scarascia Mugnozza, G.; de Lucia Zeller, B. Environmental improvements of greenhouse flower cultivation by means of LCA methodology. *Acta Hort.* **2008**, 301–308. [[CrossRef](#)]
43. Soode, E.; Lampert, P.; Weber-Blaschke, G.; Richter, K. Carbon footprints of the horticultural products strawberries, asparagus, roses and orchids in Germany. *J. Clean. Prod.* **2015**, *87*, 168–179. [[CrossRef](#)]
44. Staelens, L.; Desiere, S.; Louche, C.; D'Haese, M. Predicting job satisfaction and workers' intentions to leave at the bottom of the high value agricultural chain: Evidence from the Ethiopian cut flower industry. *Int. J. Hum. Resour. Manag.* **2018**, *29*, 1609–1635. [[CrossRef](#)]
45. Thilising, T.; Madsen, A.M.; Basinas, I.; Schlünssen, V.; Tendal, K.; Bælum, J. Dust, endotoxin, fungi, and bacteria exposure as determined by work task, season, and type of plant in a flower greenhouse. *Ann. Occup. Hyg.* **2015**, *59*, 142–157. [[CrossRef](#)] [[PubMed](#)]

46. Torrellas, M.; Assumpció, A.; Ruijs, M.; García Victoria, N.; Stanghellini, C.; Montero, J.I. Environmental and economic assessment of protected crops in four European scenarios. *J. Clean. Prod.* **2012**, *28*, 45–55. [[CrossRef](#)]
47. Wandl, M.-T.; Haberl, H. Greenhouse gas emissions of small scale ornamental plant production in Austria—A case study. *J. Clean. Prod.* **2017**, *141*, 1123–1133. [[CrossRef](#)]
48. White, S.A.; Owen, J.S.; Majsztzik, J.C.; Oki, L.R.; Fisher, P.R.; Hall, C.R.; Lea-Cox, J.D.; Fernandez, R.T. Greenhouse and nursery water management characterization and research priorities in the USA. *Water* **2019**, *11*, 2338. [[CrossRef](#)]
49. Porter, M.E. *Competitive Strategy. Techniques for Analyzing Industries and Competitors: With a New Introduction/Michael E Porter*; Free Press: New York, NY, USA; London, UK, 1998.
50. Klewitz, J.; Hansen, E.G. Sustainability-oriented innovation of SMEs: A systematic review. *J. Clean. Prod.* **2014**, *65*, 57–75. [[CrossRef](#)]
51. Phills, J.A.; Deiglmeier, K.; Miller, D.T. Rediscovering social Innovation. *Stanf. Soc. Innov. Rev.* **2008**, *6*, 34–43.
52. Bitsch, V. Qualitative research: A grounded theory example and evaluation criteria. *J. Agribus.* **2005**, *23*, 75–91.
53. Jamshed, S. Qualitative research method-interviewing and observation. *J. Basic Clin. Pharm.* **2014**, *5*, 87–88. [[CrossRef](#)] [[PubMed](#)]
54. Fusch, P.I.; Ness, L.R. Are we there yet? Data saturation in qualitative research. *Qual. Rep.* **2015**, *9*, 1408–1416.
55. Petit, G.; Sablayrolles, C.; Yannou-Le Bris, G. Combining eco-social and environmental indicators to assess the sustainability performance of a food value chain: A case study. *J. Clean. Prod.* **2018**, *191*, 135–143. [[CrossRef](#)]
56. Schwarz, J.; Schuster, M.; Annaert, B.; Maertens, M.; Mathijs, E. Sustainability of global and local food value chains: An empirical comparison of Peruvian and Belgian asparagus. *Sustainability* **2016**, *8*, 344. [[CrossRef](#)]
57. Rombach, M.; Kang, E.; Bitsch, V. Good deeds revisited: Motivation and boundary spanning in formal volunteering. *Int. Rev. Public Nonprofit Mark.* **2018**, *15*, 105–126. [[CrossRef](#)]
58. Schreier, M. *Qualitative Content Analysis in Practice*; Sage: Los Angeles, CA, USA, 2012.
59. Boeije, H. A purposeful approach to the constant comparative method in the analysis of qualitative interviews. *Qual. Quant.* **2002**, *36*, 391–409. [[CrossRef](#)]
60. Lütken, H.; Clarke, J.L.; Müller, R. Genetic engineering and sustainable production of ornamentals: Current status and future directions. *Plant Cell Rep.* **2012**, *31*, 1141–1157. [[CrossRef](#)]
61. Chandler, S.F.; Tanaka, Y. Transgenic research in floricultural crops. In *Genetic Engineering of Horticultural Crops*; Rout, G.R., Peter, K.V., Eds.; Academic Press: Amsterdam, The Netherlands, 2018; pp. 121–136.
62. Zhang, B.; Yang, X.; Yang, C.; Li, M.; Guo, Y. Exploiting the crispr/cas9 system for targeted genome mutagenesis in petunia. *Nat. Sci. Rep.* **2016**, *6*, 20315. [[CrossRef](#)]
63. Kishi-Kaboshi, M.; Aida, R.; Sasaki, K. Generation of gene-edited chrysanthemum morifolium using multicopy transgenes as targets and markers. *Plant Cell Physiol.* **2017**, *58*, 216–226. [[CrossRef](#)]
64. Auteri, D.; Arena, M.; Barmaz, S.; Ippolito, A.; Linguadoca, A.; Molnar, T.; Sharp, R.; Szentes, C.; Vagenende, B.; Verani, A. Neonicotinoids and bees: The case of the european regulatory risk assessment. *Sci. Total Environ.* **2017**, *579*, 966–971. [[CrossRef](#)]
65. Lentola, A.; David, A.; Abdul-Sada, A.; Tapparo, A.; Goulson, D.; Hill, E.M. Ornamental plants on sale to the public are a significant source of pesticide residues with implications for the health of pollinating insects. *Environ. Pollut.* **2017**, *228*, 297–304. [[CrossRef](#)]
66. Dominguez, G.B.; Mibus-Schoppe, H.; Sparke, K. Evaluation of existing research concerning sustainability in the value chain of ornamental plants. *Eur. J. Sustain. Dev.* **2017**, *6*, 11–19. [[CrossRef](#)]
67. Akyazi, G.; Tantau, H.-J. ZINEG -The low energy greenhouse: An innovative greenhouse with new climate control strategies supported by phytomonitoring data. *Acta Hortic.* **2012**, *927*, 39–42. [[CrossRef](#)]
68. Schwend, T.; Beck, M.; Prucker, D.; Peisl, S.; Mempel, H. Test of a par sensor-based, dynamic regulation of led lighting in greenhouse cultivation of helianthus annuus. *Eur. J. Hortic. Sci.* **2016**, *81*, 152–156. [[CrossRef](#)]
69. Koeser, A.K.; Lovell, S.T.; Petri, A.C.; Brumfield, R.G.; Stewart, J.R. Biocontainer use in a petunia ×HYBRIDA greenhouse production system: A cradle-to-gate carbon footprint assessment of secondary impacts. *Hortscience* **2014**, *49*, 265–271. [[CrossRef](#)]
70. Nambuthiri, S.; Fulcher, A.; Koeser, A.K.; Geneve, R.; Niu, G. Moving toward sustainability with alternative containers for greenhouse and nursery crop production: A review and research update. *Horttechnology* **2015**, *25*, 8–16. [[CrossRef](#)]

71. Gruda, N.S. Increasing sustainability of growing media constituents and stand-alone substrates in soilless culture systems. *Agronomy* **2019**, *9*, 298. [[CrossRef](#)]
72. Williams, A. *Comparative Study of Cut Roses for the British Market Produced in Kenya and The Netherlands*; Precip Report for World Flowers; Cranfield University: Cranfield, UK, 2007.
73. Tizazu, T.Y.; Workie, M.A. Social, economical and environmental issues of floriculture sector development in ethiopia. *Rev. Plant Stud.* **2018**, *5*, 1–10. [[CrossRef](#)]
74. Gobie, W. A seminar review on impact of floriculture industries in Ethiopia. *Int. J. Agric. Econ.* **2019**, *4*, 216. [[CrossRef](#)]
75. Bellmann, L.; Bossler, M.; Gerner, H.-D.; Hübler, O. Collective bargaining coverage, works councils and the new German minimum wage. *Econ. Ind. Democr.* **2018**, *53*. [[CrossRef](#)]
76. Riisgaard, L. Global value chains, labor organization and private social standards: Lessons from east African cut flower industries. *World Dev.* **2009**, *37*, 326–340. [[CrossRef](#)]
77. Bitsch, V.; Bromm, U.; Schalich, C. Improving the horticultural workplace: Fringe benefit options in germany. *Acta Hort.* **2004**, 339–345. [[CrossRef](#)]
78. Ludwig-Ohm, S.; Dirksmeyer, W. Ausgewählte Analysen zu den Rahmenbedingungen und zur Wettbewerbsfähigkeit des Gartenbaus in Deutschland. Thünen Working Paper, No. 6, Thünen-Institut, Braunschweig. Available online: <http://nbn-resolving.de/urn:nbn:de:gbv:253-201308-dn052167-6> (accessed on 2 March 2020).
79. MPS-Milieu Programma Sierteelt. Follow Your Plant. Available online: <https://www.volgjebloemofplant.nl/en/> (accessed on 23 February 2020).
80. Global Gap. Ggn: Certified Floriculture. Available online: <https://floriculture.ggn.org/Flori/Index> (accessed on 31 January 2020).
81. European Commission. Directive 2000/29/EC. Available online: https://ec.europa.eu/food/plant/plant_health_biosecurity/legislation_en (accessed on 31 January 2020).
82. Statista. Umsatz im Gesamtmarkt Blumen und Pflanzen in Deutschland in den Jahren von 2005 bis 2019. Available online: <https://de.statista.com/statistik/daten/studie/206256/umfrage/umsatz-mit-blumen-und-pflanzen/> (accessed on 31 January 2020).
83. Verdouw, C.N.; Beulens, A.J.M.; Trienekens, J.H.; Verwaart, T. Mastering demand and supply uncertainty with combined product and process configuration. *Int. J. Comput. Integr. Manuf.* **2010**, *23*, 515–528. [[CrossRef](#)]



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).