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1. Introduction, Knowledge, Objectives

Sustainability assessments typically employ sustainability indicators as a source of information for stakeholders (Niemeijer and Groot, 2008). However, there is no general systematic approach to indicator-based methods. Moreover, many methods were developed for analysis at the farm level, and thus, are not suitable for assessing entire supply chains. Demand for sustainable ornamental crops is growing (Getter et al., 2016). Methods that have been applied to assess the sustainability of floriculture include life cycle assessment (LCA) (Sahle and Potting, 2013), carbon footprint (Soode et al., 2015) and water footprint (Mekonnen et al., 2012). These studies focused on single products, often cut roses. Sustainability assessment has also been attempted for pot plants, such as cyclamen (Russo et al., 2008), poinsettia and Phalaenopsis (Soode et al., 2015). These assessments have been used to address only environmental aspects or to examine a single aspect, such as carbon footprint. Social and economic aspects have been largely neglected.

Assessing the sustainability of ornamental plants should take into account a large variety of products, conditions, and processes in each phase of the (often global) supply chain. Though the number and type of actors involved in the supply chains for different products varies, most include plant breeders and propagation nurseries, growers and plant production nurseries, and wholesale suppliers (Hulme et al., 2018). Developing a sustainability assessment method requires thorough knowledge of the system to be evaluated (van Cauwenbergh et al., 2007). So far, research into the supply chain in the floriculture sector has focused mainly on management and logistics issues (de Keizer et al., 2015) rather than on analyzing supply chain processes. Accordingly, the aim of this study is to identify processes in supply chains shared by bedding and pot plants. Uniform processes in the supply chain will enable sustainability assessments of a wide variety of ornamental products.

2. Material and Methods

To characterize a supply chain for ornamental plants, seven in-depth interviews were conducted in February 2016 - six at the IPM Essen (five breeders and one wholesaler) and an additional interview with a producer of rooted cuttings and pot plants in southern

Germany. All interviews were carried out in person using a semi-structured interview guide, and were audio-recorded. Each interview lasted 21-47 minutes. Interviews were transcribed using the software package F4. All resulting documents were coded and categorized using the qualitative data analysis software package Atlas.ti, employing a constant contrast and comparison process.

3. Results

The majority of bedding plants and some pot plants go through similar steps in the supply chain (figure 1). There are two distinct supply chains for plants propagated from seeds and those grown from cuttings. Young plants, whether raised from seed or from cuttings, are further cultivated by potted plant producers and are subsequently either distributed by wholesalers or sold directly to retailers. Small nurseries may also sell directly to consumers. Of the ten top-selling bedding plants in Germany (AMI, 2015), chrysanthemum, Argyranthemum frutescens, Fuchsia and Impatiens New Guinea are typically propagated from cuttings, while viola and primula are propagated from seeds. Others, such as pelargonium, petunia, Sanvitalia procumbens and begonia can be propagated from either seeds or cuttings. Some pot plants, such as cyclamen, are propagated from seed; while others, such as poinsettia and kalanchoe, are propagated from cuttings.

Breeders and propagation nurseries develop new cultivars of vegetatively propagated plants, and supply propagation material in the form of cuttings or rooted cuttings. Some companies also sell seedlings, most of which are propagated from purchased seeds. In a few cases, when market availability is limited, these companies also produce their own seeds. Company assortments are maintained either as seeds or in vegetative form. In-vitro technology or tissue culture is also used for vegetative propagation by some specialized growers. However, as these methods are time-consuming and expensive, they are implemented mostly for Phalaenopsis orchids and plants of the Araceae family (Anthurium, Spathiphphyllum). Although none of the breeders and propagation nurseries interviewed for this study use in-vitro technology for propagation purposes, in-vitro technology is implemented for the maintenance of disease-free stock plants.

3.1 Vegetative pathway

When cuttings are used as propagation material, the mother plants originate from stock plants. Each year, new mother plants are propagated from these stock plants. The stock material is then shipped by air to Africa (mostly to Kenya, Ethiopia, and Uganda) and grown in accordance with strict hygiene protocols. Interviewees claimed that the production of cuttings in Germany is not financially feasible, because it is not possible to achieve the same quality and quantity. Harvested cuttings are assembled in frost-protected cardboard boxes, and cooling pads are placed inside to maintain an average temperature of 4-8°C degrees. The cuttings are then transported to the nearest international airport in climate-controlled trucks. At the airport, boxes are loaded onto passenger flights, and arrive in Europe the next day (primarily in Amsterdam or Frankfurt). Mother plants of the Solanaceae family (e.g., petunia, calibrachoa) are cultivated mostly in Mediterranean countries due to European legislation that prohibits the import of Solanaceae cuttings from Africa, because of the risk for pathogen transmission. Cultivation locations include Portugal, Israel, Turkey and Tenerife. Cuttings grown within Europe are transported with climate-controlled vehicles;

cuttings grown elsewhere are shipped by air. From the airport, cuttings are transported in trucks with controlled temperature to rooting stations within 2-3 days after harvest to insure the cuttings remain in good condition. These cuttings are then further cultivated in rooting stations in Europe by specialized growers. Some breeders and propagation nurseries have their own rooting stations; others work with specialized growers. The development of young plants from cuttings can take from 3 to 12 weeks, depending on the crop. Root development is achieved by maintaining high humidity and temperature levels, and by adjusting light conditions.

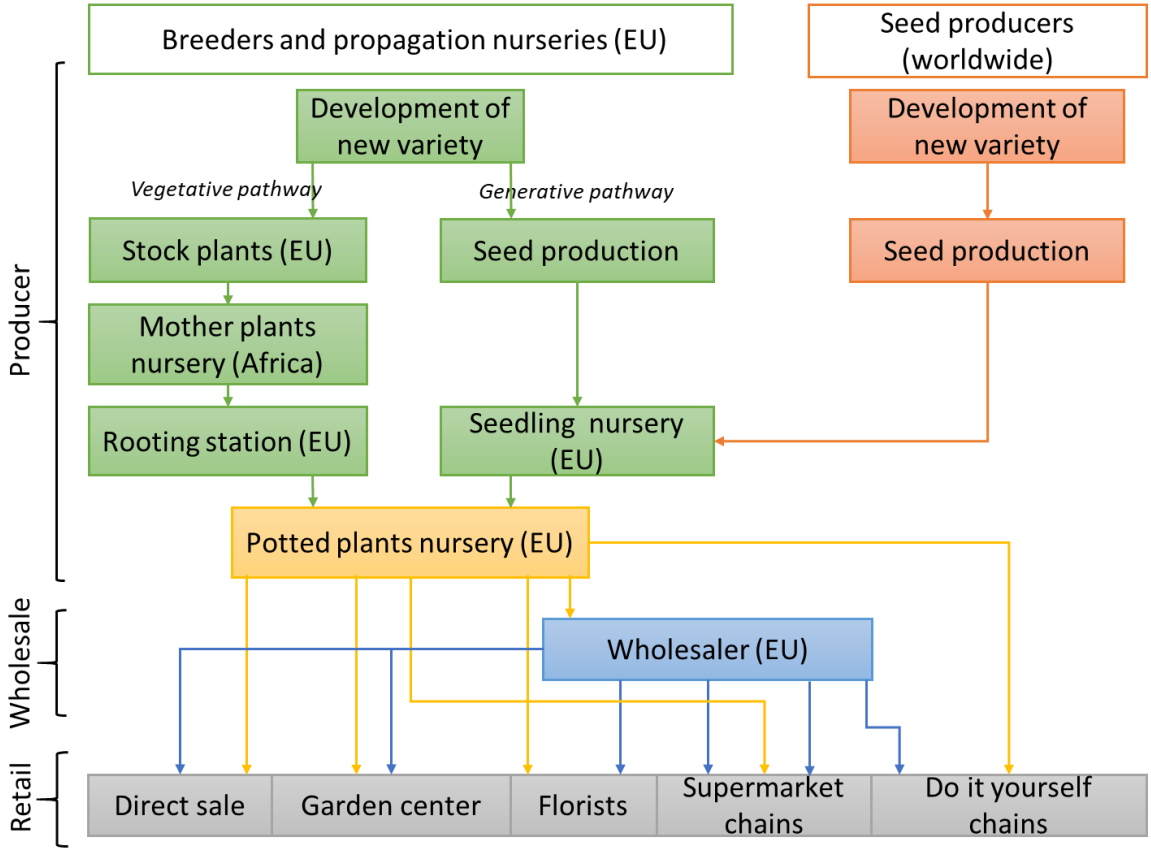

Figure 1: Supply chain network for ornamental plants in Germany
(green: breeders and propagation nurseries**;** orange: seed producers; yellow: potted plants nursery;
blue: wholesaler; gray: retailers)

3.2 Generative pathway

Production of seeds takes place in various locations around the world; including China, the United States, Chile and Europe. Seed producers also develop new cultivars. Production of seeds is carried out mostly by cross-breeding to produce the F1 hybrid generation. Plants are grown in greenhouses under controlled conditions. Seeds are cleaned and germination rate is tested to determine seed quality. Some seeds are pretreated to help ensure consistent time to germination and accelerate it. Seeds produced outside of Europe are shipped by air. Sowing is an automated process in which single seeds are planted. Some plants germinate better in the dark (e.g., viola and cyclamen), and therefore are placed first

in a germination chamber with controlled humidity and temperature. After germination, seedlings are placed in greenhouses for several weeks until they are ready to be delivered. Duration of cultivation depends on the crop and the size of the product.

3.3 Potted plants producers, wholesale and retail

Seedlings and rooted cuttings are delivered to potted plant producers, to be cultivated to the phase of finished goods. Rooted cuttings and seedlings are transported in temperature-regulated trucks within 3 days to ensure they retain high quality. The phase from young plants to finished good usually takes from 3 to 4 months. Plants are potted up, pinching may be performed for branching, and in some cases, staking and tying may be required for support. Finally, the products reach the consumer through wholesalers or other channels. The main retailers in Germany, according to Gabriel and Menrad (2013) are supermarket chains, specialist garden centers, florists and do-it-yourself shops..

4. Discussion

Many commercially important ornamental plants in Germany can be clustered into two main supply chains according to the propagation method used - seeds or cuttings. The phase from young plants to finished good is common to both supply chains, with variation occurring in the length of time it takes to complete this phase. In the supply chain for poinsettia described by Soode et al. (2013), cutting production is considered the material acquisition phase, and cuttings are transported from producers within Germany. According to the results of the present study, cuttings are not produced in Germany, but rather, mostly in Africa. Solanaceae cuttings are usually produced in Mediterranean countries. The cultivation phase of mother plants was not described by Soode et al. (2013). Furthermore, the authors assumed only one production phase of poinsettia, from cutting to mature plant. The difference between the findings in the present study and those for the supply chain described by Soode et al. (2013) regarding location of cutting production and number of production phases (one vs. two distinct phases) could be due to simplification for the purpose of the assessment of product carbon footprint. Furthermore, Soode et al. (2013) used data from a research greenhouse, not commercial growers.

According to Russo et al. (2008), cyclamen, an example of seed-propagated plants, are cultivated in southern Italy. Seedlings are bought from national farms, and are further cultivated in greenhouses from May to September. Again, the young plant phase is not taken into consideration in the assessment. Due to different climate conditions in southern Italy, ventilation and heating demand might be different from Germany. However, cyclamen can be grown in rather low temperatures, and since the main cultivation season is spring and summer, conditions still might be comparable.

5. Conclusions

The characterization of two supply chains, for both vegetatively and generatively propagated plants, is the first step toward the development of an assessment method for sustainability across the supply chain. Due to the similarities in the production of many commercially important ornamental plants, a general sustainability assessment with suitable indicators, specifically for floriculture, is likely possible. However, variation in

cultivation times between the different plants, and different energy and light requirements must be taken into consideration. General assessments can be performed separately for each phase in the supply chain. These assessments can then be adjusted to a specific plant according to the length of cultivation time and energy requirements. For example, an assessment for the rooting station phase can be calculated per day, and then multiplied according to the number of days required for the specific plant to develop roots. Energy consumption for heating and light can be also adjusted according to the requirements of a specific plant.

6. Literature

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