European Journal of Sustainable Development (2017), **6**, 3, 11-19 ISSN: 2239-5938
Doi: 10.14207/ejsd.2017.v6n3p11

Evaluation of Existing Research Concerning Sustainability in the Value Chain of Ornamental Plants

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Abstract
In recent years the concept of "Sustainable Development" has become increasingly relevant in society as well as for the economy. Like in other consumer spending areas, sustainability is getting an increasing role in the ornamental plant production, marketing and consumption. Research in the production area has been focused on achieving a better quality and longevity of ornamentals at point of sale and also on environmental aspects as part of sustainability. The maintenance of the quality and longevity of the plants until the point of sale have been the objectives of post-harvest handling and distribution. At consumer level studies show that the well-being and the indoor quality improvement are the main reasons for having ornamentals. However the concept of sustainability has not been investigated throughout the entire ornamental plant value chain. Economic and interdisciplinary factors play a role in this lack of studies. By analysing the existing literature, the paper evaluates in which areas of the value chain the concept of sustainability have not been considered and identifies potential future steps to reach a more sustainable complete lifecycle of ornamentals.

Keywords: Sustainability, ornamental plants, horticulture, value chain

1. Introduction

In the last decades, the production of ornamental plants has been changed by factors such as the globalization of markets and the economic development of societies. Globalization has led to increased competition due to the entry of new competitors into the market for ornamental plants, especially among developing countries, which enjoy apparent competitive advantages related to favourable environmental conditions, the abundance of natural resources, the availability of low-cost labour (Schimmenti et al. 2010). These conditions in global markets lead to lower consumer prices, an increase in consumer demand and therefore in a growing market (United Nations 2013).

In the past, most of the ornamental products were sold in local markets. Nowadays growers are producing for the local market but also on global scale. This has led to an increasing competition also between producers from different countries. The globalization of markets continues to increase due to faster and cheaper transportation, better communication between commercial agents, and the predominance of supermarkets owned by multinational corporations leading to the purchase of the products from where they are available at the best price (Monteiro 2007). The market for ornamental plants is not only determined by producer choices and distributor needs, but also by consumer desire and driven by a continuously increasing demand for novelties and high quality (Lütken et al. 2012). The economic development of society, the higher

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level of available per capita income, and a growing sensitivity to environmental aspects have led to profound changes in purchasing behaviour. Flowers and ornamental plants, initially considered as products bought in important occasions, now tend to satisfy the broader needs and therefore the consumption is more distributed during the year (Schimmenti et al. 2010).

However, the increase in demand and the shift of global production into countries with less developed infrastructure have led to an increase in the scarcity of the raw material sources and to the lack of sufficient "sinks" to absorb waste from industrial pollution causing damages to the environment (Meadows 1974).

The Rio Declaration on Environment and Development and Agenda 21 have taken a central role in shaping the idea of sustainable development. Whereas the Rio Declaration provided a vision of sustainable development, Agenda 21 provided a comprehensive plan of action that was created to guide and coordinate the work of the United Nations, governments, and other major groups in their efforts to transition society toward sustainable development. The two documents are based on the principle that core economic objectives have to be harmonized with social and environmental objectives in the medium and long term (Gudmundsson et al. 2016) in order to minimize the inevitable negative interventions to maintain vital resources and compensate through sufficient positive interventions (Brinkjans and Scholz 2003). This policy for the first time has provided a detailed definition of sustainable production and its different elements. Since then, environmentally and health-friendly production methods and conscientious use of resources have become crucial for reaching the goal of a more sustainable plant production (Lütken et al. 2012). This paper evaluates the interpretation of the sustainability concept along the value chain of ornamentals and also analyses which aspects have not yet been investigated. Furthermore the paper identifies potential future steps to reach a more sustainable complete lifecycle of ornamentals.

The value chain of ornamental plants is separated into Production, Transport, Retailing and Consumption (Fig. 1).

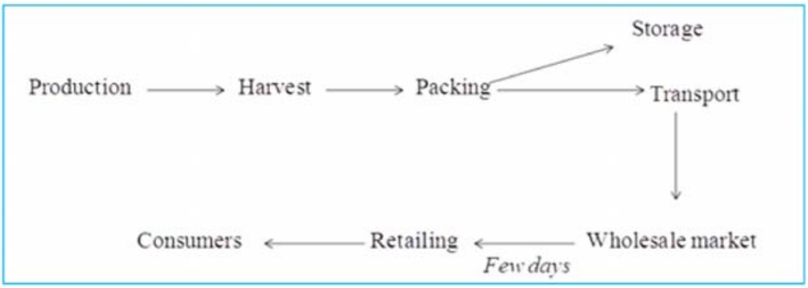

Figure 1: Flow diagram showing the serial steps of post-harvest handling of ornamental plants (Islam and Joyce 2015).

2. Sustainability Potential of the Production

In the production sector a clear differentiation between economic and environmental objectives can be observed by analysing the literature. Few researches related to the third element of the Triple Bottom line, the social one, have been found.

In the Floricultural sector, the production focus has been moving since the 90´s from the markets in the Northern hemisphere towards countries where climatic conditions are more favourable and production and labour costs are lower. As a result, the new centers of production are typically developing countries such as Colombia, Kenya, Ecuador and Ethiopia. The character of flower production (use of chemicals, labour, water…) has made the sector susceptible to criticism about working conditions and its environmental impact. As a response, a large number of social and environmental standards has emerged, both the result of initiatives in the market and in producing countries. Standards have been broadened in line with demands for guarantees in social and ethical practices in the supply chain (Rikken 2010).

One of the main economic objective in the ornamental plant sector has been to minimize energy consumption per unit of output. To achieve this, different strategies have been implemented. In the 90´s several authors proposed that technology should be developed to improve the environmental parameters in greenhouses (Serra 1994; Bot 2001). Also few production strategies like the improvement of space utilization, reducing pot size and reducing crop losses have been implemented to reduce the energy use per crop unit (Serra 1994). In the last years improvements related to renewable and sustainable based technologies which can save up to 80% of energy have been reported. These new technologies include photovoltaic modules, solar thermal collectors, hybrid collectors and systems, phase change material and underground based heat storage techniques, energy-efficient heat pumps, alternative facade materials for better thermal insulation and power generation, innovative ventilation technologies using pre-heating and cooling and efficient lighting systems to achieve potential utilization in greenhouses (Cuce et al. 2016; Dannehl et al. 2013; Akyazi and Tantau 2012).

On the other side, the environmental sustainability has become an important objective in the production of ornamentals in the last decades. For many producers, environmentally friendly production methods and conscientious use of resources have become crucial in attempting to achieve the goal of more sustainable plant production (Lütken et al. 2012). Sustainable plant production practices have been carried out to reduce the levels of synthetic fertilizers, pesticides and other agro-chemicals. The use of an integrated pest management system to deal with insects, diseases and weeds and the focus on building the soil to promote plant health have been the main focus to avoid environmental pollution (Diver and Greer 2008). Chemical growth retardants have been extensively used to control plant growth and morphology in order to improve the visual and physiological quality of ornamentals at point of sale. Due to their potentially negative impacts on human health and the environment (Islam et al. 2014; Lütken et al. 2012) they have been partially replaced by other approaches to regulate plant growth and morphology. Some efforts have concentrated on temperature control (Moe and Heins 1990; Myster and Moe 1995) or on responses to light quality (Bailey and Miller 1991; Joiner J.N. and Harrison 1967; Rajapakse and Kelly 1994, Myster and Moe 1995; Mata and Botto 2009; Torre et al. 2012; Islam et al. 2014). Other strategies to improve the quality of ornamentals through genetic engineering have been reported by using biotechnological alternatives to growth retardants and chemical ethylene inhibitors (Lütken et al. 2012; Bailey and Miller 1991; Mibus et al. 2011).

3. Sustainability Potential of an Improved Post-Harvest Quality

The production process also needs to look at the handling of ornamentals in the sectors of the value chain following production. For the handling process studies are focused on reaching an excellent external quality (morphology, plant architecture, color and shape (Bakker et al. 1995)), an outstanding post-harvest performance and long life-stress tolerant ornamentals. These are essential criteria in a competitive floriculture market (Lütken et al. 2012) and therefore an economic driver. Strategies to improve the post production quality and longevity have been studied in the last 30 years. The main factors to improve the post-production quality and longevity identified in the reviewed literature are irradiation, temperature, fertilization and irrigation.

With the introduction of supplemental lighting the outer quality and longevity of different ornamental plants have been improved. Several investigators "played" with the irradiance during the production and postproduction phase to achieve different goals. The external quality of many ornamentals have been considerable enhanced by the increase of number of shoots and flowers with increasing light supply (Hendriks 2001). Apart from the external quality the plant longevity has also been improved by increasing the light supply (Moe et al. 1992; Serek and Trolle 2000; Hendriks 2001; Bulle 2005; Karunananda and Peiris 2011). These phenomena have been associated with a large carbohydrate reserves in the plants (Moe et al. 1992; Serek and Trolle 2000; Hendriks 2001). Additionally, a reduction of light supply at the end of production, to simulate the indoor conditions to acclimatize the ornamental plants have been reported (Nell and Barret 1986; Conover et al. 1993; Karunananda and Peiris 2011). The reduction of light supply at the end of production induce the plant to achieve some physiological (reduction of the light compensation point and dark assimilation), morphological and anatomical adaptations (Reyes et al. 1996; Hendriks 2001; Bulle 2005). However, different light levels during cultivation also can have different effects depending on the crop (Bulle 2005). There have been for example investigation, which indicate that acclimation practices in flowering plants have a negative impact on longevity (Nell and Barret 1990).

A reduction of the temperature at the end of the production phase increases the color intensity of flowers and bracts of some species (Hendriks 2001; Bulle 2005). However, some authors also reported a decrease in longevity in some cultivars (Moe et al. 1992; Evensen and Olsonand 1992; Hendriks 2001; Moe and Heins 1990). Temperature has not been found to be an important factor in the post-harvest live of foliage plants (Nell and Barret 1990) and flowering plants (Bulle 2005).

Fertilization practices during production influence the post-harvest quality of ornamentals. High fertilization levels reduce longevity of organs (Nell 1990; Serek and Trolle 2000; ter Hell and Hendriks 1995; Drüge 2000; Hendriks 2001). The optimal fertilization rate supply to reach a higher longevity is determined by plant species, N-Form, buffering capacity of the substrate, and the climatic conditions during the production and the conditions at the consumer environment (Nell and Barret 1990). Physiological Calcium deficiency have been recognized as a cause for a number of plant defects at the consumer level (Hendriks 2001). Increasing Calcium and Ammonium in the nutrient solution leads to a better postharvest quality (Starkey and Pedersen 1997; Nielsen and Starkey 1999).

Water supply and air humidity affect the morphological and physiological conditions of ornamentals, including their post-harvest life. Generally, it is being assumed that water stress or water deficiency both interfere with the longevity of organs. This assumption is derived from the fact that the effects of the water supply on the longevity of ornamental plants have hardly been scientifically examined (Hendriks 2001; Islam and Joyce 2015). A correlation has been observed between the amount of water given and the plant growth and quality (de Graaf-van der Zande 1990; Röber and Horn 1993). Miniature Rose potted plants grown with water deficit treatment tolerated subsequent water stress better than plants produced with a constant supply of water. When the plants receive adequate water during the post-production phase the effect of reduced production water availability on post-production plant quality is cultivar-dependent (Williams et al. 2000). Water supply and air humidity have correlative influences on plant transpiration (Islam and Joyce 2015). Mortensen 2000, found that water consumption per leaf area unit during growth was decreased in chrysanthemum, *Kalanchoe* and poinsettia when the relative air humidity decreased.

Long distance transportation is commonly used in the delivery of ornamental plants to retailed markets in the United States and Europe therefore the transport and retailing sector of the value chain focuses on maintaining the quality and longevity of the ornamentals to the point of sale. These are essential requirements for the acceptability of the product by consumers. In addition, reduction of the quality and longevity at point of sale means economic and time losses on the side of producers and retailers. With the help of simulated transports and simulated indoor environment many studies investigate the optimal conditions in which the ornamental plants maintain best their quality. Maintenance of proper temperature, light, relative humidity conditions, growing medium moisture levels and the control of ethylene during transit is important during transport and storage (Nell and Vonk Noordegraaf 1992; Nell et al. 1995; Borch et al. 1996; Hendriks 2001; Islam and Joyce 2015).

4. Sustainability Potential of Consumer Use

At the consumer side, most of the literature concentrates on the human benefits like well-being and health related to ornamental plants in households, at work-places, and public or private space. Studies have discovered many positive effects on emotional states, cognitive functioning, physiological activity and health (Doxon 1991; Brethour et al. 2007; Bringslimark et al. 2007; Buta et al. 2013; Hall and Hodges 2014). Also the improvement of indoor environment caused by ornamentals have been investigated. Investigations found that there are high number of ornamentals that can purify the air in living and working spaces (Yang et al. 2009; Buta et al. 2013; Torpy et al. 2014).

Other approaches in relation to the consumer area have also been observed in the literature. Woodhead and Einert 1973 pointed out the importance to investigate the environmental factors at household level. Nell and Hoyer 1995 remarked that plants should be evaluated using standard interior conditions: Nell and Hoyer mentioned in

1995 that plants should be evaluated using standard interior conditions "a constant temperature of 20°C, relative humidity of 40-60% and an irradiance level of 8 µmol m^{-2} s^{-1} should be provided for 12 hours daily". Several of the already mentioned authors assume that the environmental conditions in households are at a minimum of 10 µmol $m^{-2}s^{-1}$ for irradiation and at 20°C for temperature. These conditions are often used in the indoor environmental simulations and are quite close to the ones reported in offices (BGR 2008; Hartung and Blume 2004) and at point of sale. However in the current literature no investigations can be found that focus on monitoring the real interior conditions at households to confirm the indoor environmental simulations. High external quality at point of sale does not always imply a high longevity and ornamental value at the household level (Bakker et al. 1995). This premise in combination with the acquisition of information related to the indoor environmental conditions, could be the keys to complete a sustainable life cycle of ornamentals. Clarifying this aspect at the consumer level, will give the chance to produce ornamentals in a more sustainable way.

5. Conclusion and Outlook

The innovations carried out in the area of production of ornamental plants are improving the efficiency in the use of natural resources and the reduction of environmental charge. Also standards have been expanded in line with demands for guarantees in social and ethical practices in the floricultural supply chain in developing countries. During the postproduction the scientific community has concentrated on investigating strategies to improve the quality and longevity of plants until the point of sale. This has been clearly motivated by economic drivers. At the consumer level, aspects related to the well-being and the improvement of the environment are well known. However, there is still a lack of information on certain aspects that play a decisive role in understanding the value chain of ornamental plants as a whole:

- The actual environmental conditions in households. The knowledge of the real environmental conditions such as water supply and light in households serve as basic information for the producers to improve the plant resistance.
- The amount of applied fertilizer or other products in households. Sustainable plant production practices have been carried out to reduce the levels of synthetic fertilizers and other agro-chemicals. Having an idea of the use of these products could help to understand the real situation at the consumer side.
- The number of ornamental plants which are thrown away per year and disposal ways.
- The carbon footprint throughout the whole value chain
- The interactions of the consumers with the plants, the motivations to obtain ornamental plants and the durability desired by the consumer.

This missing information and the fact that three out of four households in Germany buy an ornamental plant for the interior, balcony or garden (AMI 2012) at least once a year, led the Department of Urban Horticulture & Ornamental Plant Research, the Department of Horticultural Economics at the Hochschule Geisenheim University and the Chair of Marketing and Management of Biogenic Resources at the Hochschule Weihenstephan-Triesdorf University in Germany, to create the Project "ProKonZier".

This interdisciplinary project develops evaluation models based on the Product Carbon Footprint (PCF) for sustainability in the value chain of ornamental plants, investigates the consumption context (with the help of Ethnographic studies) and environmental conditions at a household level. Also, new production methods for stress-adapted ornamental plants are tested in cultivation trials. In collaboration with partners from production and retail sectors, sustainable product concepts are planned to be developed and their acceptance in a consumer study is going to be investigated. The information obtained from this study and the collaboration with partners from production and retail is fundamental in order establish a bridge of communication between the different segments of the value chain which will help to develop a more end to end sustainable value chain of ornamental plants. To achieve this goal, a higher flexibility to adapt the products to the needs of the consumer and environment and at the same time achieve the greatest possible profitability are the challenges which need to be overcome.

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