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Review

Post-production physiology and handling of ornamental potted plants

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ABSTRACT

Flowering or foliage potted plants are ornamental items usually grown in greenhouses under optimal growing conditions. Cultivation in protected environments allows for rapid growth and high quality characteristics. When plants reach the desired commercial size they can be transferred to hardening greenhouses or directly sent to the distribution chain. The growing and post-production conditions such as storage and transportation can have very deleterious effects on the ornamental quality of plants. The major post-production disorders are bud and flower abscission in flowering potted plants or leaf abscission or yellowing in foliage potted plants. On the other hand, the ornamental quality of potted plants is extremely important and depends on the number and colour of flowers or leaves, flower, leaf and plant longevity. The presence of flowers on flowering potted plants depends on flower longevity and turnover. The colour and size of leaves of foliage potted plants is linked to pre- and post-production environmental conditions. The post-production quality losses of flowering potted plants can be mainly ascribed to natural flower senescence. This phenomenon is highly regulated by plant hormones such as ethylene and abscisic acid, but the post-production environment can dramatically influence plant hormone equilibrium. Quality losses of foliage potted plants are mainly due to leaf senescence usually associated with inadequate acclimatization from the production area to the post-production chain.

1. Introduction

The ornamental industry over the last 25 years has had to deal with a very competitive worldwide trade and face an increase in international competitiveness. The market of ornamentals is already global and is currently undergoing transformation. New production areas have been expanding, leading to a gradual delocalization towards countries with favourable climatic conditions, plenty of natural resources and with lower production costs. Gradually, the major producers in the USA and in Europe have transferred part of the production of these commodities into areas characterized by lower labour cost and more favourable climatic conditions in order to reduce the energy requirements for cultivation (mainly heating costs). It means that growing areas and markets are often very separated and potted plants have to be shipped over long distances. Therefore, these products must be suitably handled to maintain high quality and longevity, features of primary importance in the ornamental industry. Understanding of the physiological responses of ornamental plants during the post-production stage becomes very important to preserve their quality. In the past, economic successes of the ornamental potted plants were based on maximizing the plant growth rate using extensive cultivation systems, in relation to relatively low costs of most inputs (Majsztrik et al., 2011). Currently, commercial benefits are estimated on the basis of critical steps during post-production such as storage and transport. Moreover, highly and detailed logistic plans allow for reaching of different parts of the world in a few hours. During storage and transport, potted plants are often damaged and quality can be compromised. In fact, these post-production stages are usually characterized by sub-optimal environmental conditions (temperature, humidity, water and light) for plants and consequently the photosynthetic machinery is impaired (Starman et al., 2007). Thus, the maintenance of ornamental quality of these commodities is the main goal for their commercial success. Unlike what happens for cut flowers, for which the problems connected with postharvest quality are sufficiently delineated, in potted plants, knowledge associated with the intense vegetative activity of plants is lacking. Indeed, flowers and leaves have a relationship that is more complex than that established in a cut stem. This review focuses on the description and discussion of how post-production

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environmental conditions and treatments can affect the quality of potted plants.

2. Post-production of potted plants

2.1. Quality of potted plants

The quality of flowering and foliage potted plants is essentially defined by visual appearance, which depends on shape, size, colour, turn-over of flowers and leaves. Plotted plants include a wide number of species with many peculiar ornamental characteristics that make them very attractive. For flowering potted plants the main quality parameters are represented by colour, and flower number (Noordergraaf, 1994), while for foliage plants by leaf shape, sizes and greenness (Wang et al., 2005).

The variation of quality parameters during post-production depends on the species. For example in miniature roses, loss of quality during post-production is still an important problem and is mainly associated with leaf, flower and bud drop (Buanong et al., 2005). However, other authors have linked the quality losses of miniature roses with leaf yellowing, and flower, bud and leaf abscission (Serek, 1993; Williams et al., 2000). Hence, it is important to define when flowers can be considered "healthy". In general, flowers can be considered in good health when they are half-open or fully open without any senescence symptoms (Müller et al., 1998). Flower drop does not only affect the visual appearance of the potted plant but can also increase the incidence of *Botrytis* and other saprophytic pathogens (Burana et al., 2013). In other species such as potted lilies the quality losses are associated with leaf yellowing or browning, leaf abscission, bud abortion, and reduced flower and inflorescence longevity (Ranwala and Miller, 2005). Gago and Monteiro (2012) found that the quality of *Bougainvillea spectabilis* 'Killie Campbell' is essentially defined by bract longevity. In some species the quality can be also defined on the basis of flower senescence percentage on the plant. In particular, the quality of potted carnations can be considered compromised when at least 50% of the flowers per pot are senesced (Karimi et al., 2012).

Horticulturists are faced with the problem of defining the quality of plants in terms of aesthetic criteria, stress resistance, longevity and after-sales development. One of the main criteria for the visual quality of an ornamental potted plant is its shape, which should be compact and well branched (Morel et al., 2012). However, each species can have peculiar features which contribute to define the quality. For instance, the growth and visual quality of weeping fig (*Ficus benjamina* L.) 'Danielle' was evaluated in relation to different shading conditions (reductions of 50, 58, 66, 80 and 86% of the incident irradiation outside of the greenhouse). The highest shading level positively influenced parameters such as plant shape (lower height/width ratio) and leaf characteristics (greater unit area, flat stereometry and dark green colour), all important parameters in determining the visual quality of ornamental foliage plants (Scuderi et al., 2013).

The use of image analysis could be an efficient way for helping to determine indicators that characterize plant quality. An analysis of the morphology of plant features could be particularly useful through the use of a quality index. However, these indices vary in relation to plant characteristics and cannot be generalized. Ban˜òn et al. (2011) applied a visual index to evaluate aesthetic quality of *Lantana camara* and *Polygala myrtifolia* at the end of an experiment with wastewater treatments. In this case, the index ranged from 1 (non-commercial) to 5 (very good quality) based on the amount of leaf discoloration, leaf necrosis, defoliation and flowering. As a reference value, healthy control plants were used and the parameters were expressed as a percentage. Leaf yellowing and petal, bud and flower abscission were scored using hedonic scales: 0–5 (dark green to completely yellow) and 0–3 (no abscission to complete abscission). Plant quality grade in poinsettia was evaluated after 30 days in an interior environment using a classification ranging from 1 = poor to 5 = excellent (Wang and Blessington, 1990). An analogous system has been adopted by different authors (Sawwan and Ghunem, 1999; Chen et al., 2001) for indoor evaluation of different species of foliage plants (*F. benjamina*, *Dieffenbachia*, *Anthurium*, *Aglaonema*, *Schefflera arboricola*).

In some bedding plants the evaluation grade considered the plant wilt status with a classification from 1 to 5, where 5 = completely turgid, 4 = soft to the touch, 3 = starting to wilt, 2 = wilted with complete loss of turgor, 1 = wilted to the point that leaves were dry and brittle (Waterland et al., 2010a). In the same experiment, leaf chlorosis was also evaluated with a score ranging from 11 (leaves completely green with no sign of chlorosis) to 1 (leaves with a chlorosis ranging from 91 to 100%) (Waterland et al., 2010a). However, the use of SPAD readings can be coupled with visual estimations in order to objectively estimate the overall quality of green-leaved foliage plants (Wang et al., 2005). Indeed, visual quality grading of the green-leaved plants was closely related to the SPAD reading, which was highly correlated with the chlorophyll content. Five foliage species were graded visually based on a scale of 1–5, where 1 = leaves are chlorotic, poor quality and 5 = leaves are dark green, excellent quality (Wang et al., 2005). The SPAD-502 has been also used in *Aglaonema* potted plants for evaluating the quality after 1-MCP treatment (Fan et al., 2009).

In Table 1 the main parameters considered to evaluate the performance of flowering and foliage plants during the post-production stage are shown. Of course, in a single paper, several parameters may have been considered. In 36.8% of the papers listed, the authors considered the visual quality of plants while 33.3% of them based their studies on leaf drop. This latter parameter is mainly linked to the limited light conditions during the production and post-production stages. The other parameters considered were plant longevity (17.5%), quality index (15.8%), leaf wilting (19.3%), leaf chlorosis (17.5%), flower number (19.3%), wilted flowers (24.6%), flower or inflorescence longevity (21.1%).

2.2. Physiological disorders

Ornamental potted plants are usually grown in greenhouses under optimal environmental conditions for each species in order to have fast growth and to reach the commercial stage as soon as possible. When the plants are transferred to storage rooms or track containers, they undergo severe stress and quality can be compromised. The most common post-production disorders are represented by leaf yellowing (in both flowering and foliage potted plants), colour loss of bracts, flowers or leaves, flower wilting or abscission and fungi development (Fig. 1).

The drop of flowers and leaves is the major post-production disorder of potted plants. Although it is a natural aspect of plant life, it leads to a loss of quality and, consequently, a reduction in profit for both the producer and the seller (Embry and Northnagel, 1994; Ascough et al., 2008). Interest in the plantscape has recently increased the development of international markets for tropical foliage plants. Indoor plants have many benefits: physically, they contribute to a cleaner, healthier air, thus improving well-being and comfort (Lohr, 2010). However, the positive effect on human health is linked with the quality and health status of the plant itself. Therefore, the prime goal for shippers and wholesalers is to deliver plants with minimal quality deterioration (Fan et al., 2009).

Leaf yellowing can rapidly occur in sensitive plants that are held for several days in dark or dim light conditions. Dark incubation has been extensively used to induce leaf senescence artificially in order to understand the molecular mechanisms involved (Zhang and Zhou, 2013). Leaf yellowing is mainly due to chlorophyll