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Physiological mechanisms for delaying the leaf yellowing of potted geranium plants

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ABSTRACT

The ornamental quality of flowering pot plants mainly depends from flower health and the colour of the leaves. During the post-production stages, potted plants undergo severe stress and the quality is often compromised. Therefore, the present study was aimed to evaluate the effect of 10 μM thidiazuron (TDZ), 200 μM gibberellic acid 3 (GA), 300 μM 5-aminolevulinic acid (AA) or 300 μM glutamic acid (GLU) in the reduction of leaf yellowing of potted geranium plants during transport and permanence to retail shelves. In control plants F0 values increased after 6 d of permanence in the simulated retail environment (SRE), while the Fv/Fm ratio declined. The net photosynthesis showed the highest values in the plants treated with TDZ and GA. The relative water content (RWC) values were lower in the control plants. The leaf TBARS content was higher in control and GLU treated plants. TDZ and GA treatments delayed the reduction of chlorophyll *a* and *b* contents in leaves, by improving the precursors of chlorophyll biosynthesis and reducing the catabolites. Plants sprayed with GA and TDZ significantly inhibited leaf yellowing and showed lower ABA contents in SRE conditions. Exogenously application of TDZ and GA are able to prevent leaf senescence by preserving the leaf pigments, membrane integrity and antioxidant activity keeping ABA at the basal level.

1. Introduction

The market of ornamentals is global and has been continuously undergoing re-organization in order to lower the production costs. The gradual delocalization to new production areas have been expanding, due to the opportunity to take advantage of favourable climatic conditions and lower production costs. Often, however, these production sites are far from consumer markets, so potted plants need to be transported over long distances. This could damage the qualitative characteristics of potted plants and above all the aesthetic appearance, features of primary importance in the ornamental industry (Ferrante et al., 2015).

Ornamental plants during the cultivation, often carried out in the greenhouse, benefit from optimum environmental conditions, which enable them to reach the commercial stage in a short time. During the post-production stages, however, potted plants may undergo severe stresses and the quality is often compromised. Critical stages in post-production of ornamental potted plants process mainly concern the transport and storage in warehouses and then the recovery in retailer's shops and end-users. These post-production stages are usually characterized by sub-optimal environmental conditions (temperature, humidity, water and light). The most common post-production disorders are represented by leaf yellowing (in both flowering and potted plants), colour loss of bracts, flowers or leaves, flower wilting or abscission and fungi development (Tromp et al., 2017).

The possibility to preserve the quality of potted plants after the cultivation stage is linked to understanding the physiological alterations, which occur during the post-production phase. Understand the causes of physiological disorders can allow the identification of suitable technical and technological strategies to extend the ornamental quality of this commodities for consumers' needs (Ferrante et al., 2015). In addition to the ornamental value concerns, the leaf yellowing is

Abbreviations: AA, aminolevulinic acid; ABA, abscisic acid; CKs, kinetin; DW, dry weight; GA, gibberellic acid; GLU, glutamic acid; TBARS, thiobarbituric acid reactive substances; PGR, plant growth regulator; RWC, relative water content; SRE, simulated retail environment; TDZ, thidiazuron

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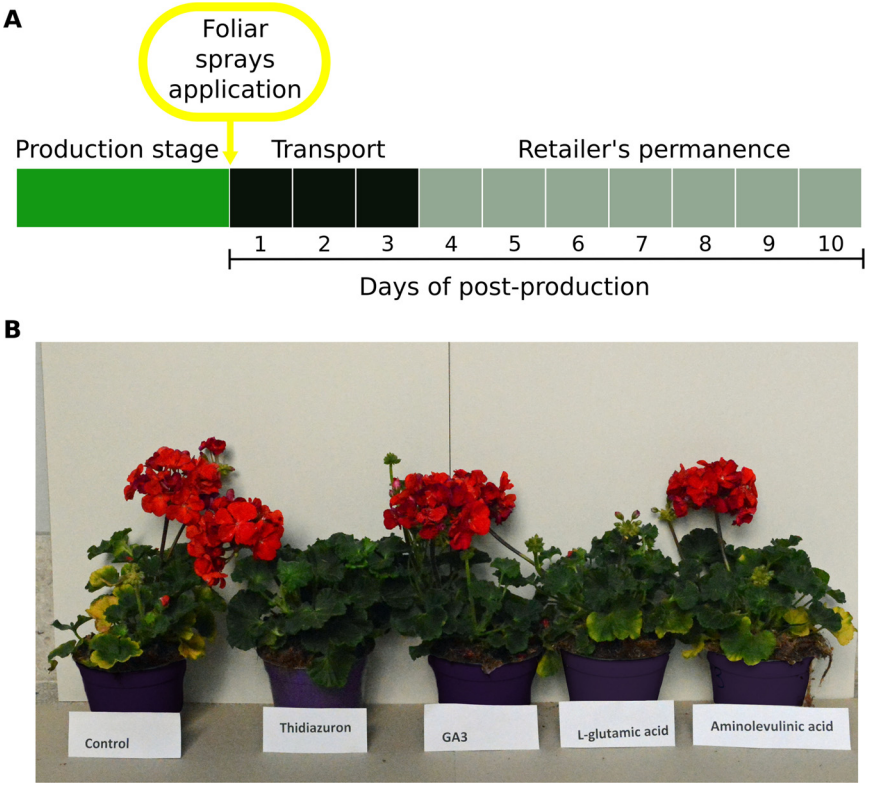

Fig. 1. Post production of geranium potted plants. (A) Experimental design and (B) effects of foliar sprayed treatments at the end of the trial.

intimately associated with a reduction of photosynthetic performances, which in turn are crucial for normal flower development and longevity (Reid et al., 2002). The sub-optimal environmental conditions impaired the photosynthetic machinery and consequently, even if the substrate is rich in nutrients, the plants are not able to properly absorb these elements (Starman et al., 2007).

During the post-production phases the anabolic processes, as the light photosynthetic reactions, carbon fixation, the biosynthesis of chlorophyll, flavonoids and amino acids, are strongly inhibited, while those catabolic, as the metabolism of lipids and carbohydrates, are accelerated (Lin and Wu, 2004).

Leaf yellowing is a form of leaf senescence that is both highly programmed and genetically regulated (Buchanan-Wollaston et al., 2005; Jibran et al., 2013). However, leaf yellowing is not only an age dependent process, but also it can be induced by many factors including pathogens, mechanical damage, harvesting or environmental stresses (Ferrante et al., 2009; Trivellini et al., 2016). For example, leaf yellowing has been associated with dark storage at low temperatures and is aggravated by high-temperature shipping stress (Prince et al., 1987; Prince and Cunnighan, 1989; Klopotek et al., 2016).

Geranium is a very widespread potted ornamental plants in the world (Àlvarez et al., 2013). *Pelargonium* × *hortorum* L.H. Bailey has remained very popular for many years, mainly for its flowers and drought tolerance (Lang and Trellinger, 2001).

The commercial value and quality of *Pelargonium* potted plants can be adversely affected during transport by high temperatures, exposure to ethylene, or darkness, promoting petal abscission and leaf yellowing and leading to considerable product losses (Ferrante et al., 2004; Hatami and Ghorbanpour, 2013). Several plant growth regulators (PGRs) are involved in the regulation of leaf senescence and yellowing. Abscisic acid and ethylene accelerate or promote leaf senescence, while gibberellins and cytokinins delay leaf senescence progression (Lim et al., 2007). It has been shown that foliar application of cytokinins delays the degradation of chlorophylls and photosynthetic proteins (Fletcher et al., 2010; Jaleel et al., 2007; Mutlu and Agan, 2015). The synthetic analogous of cytokinins, thidiazuron (TDZ), and gibberellic acid (GA) were also reported to delay the onset of leaf senescence in *Pelargonium* (Currey and Lopez, 2013; Mutui et al., 2005, 2012) and to reduce flower abscission and the senescence of leaves and flowers in cut inflorescences of phlox and lupins (Sankhla et al., 2003, 2005). The use of chlorophyll biosynthesis precursor, such as 5-aminolevulinic acid (AA) and glutamic acid (GLU) may have a positive impact on the post-production longevity, since they increase leaf photosynthesis under environmental stresses (Hotta et al., 1997). The 5-aminolevulinic acid (AA) is the biosynthetic precursor of all biological tetrapyrroles, such as chlorophyll and heme.

A crucial step, which strongly affects the potted plants selling, is the recovery phase of these products after transportation at supermarkets and other medium-large retailers characterized by sub-optimal conditions of temperature and light. However, so far very few studies dealing with this specific issue (Ferrante et al., 2015). Therefore, the aim of this work was to understand the mechanism of action involved in the reduction of quality in geranium potted plants during their transport and permanence to supermarket shelves. Using different spray-applied chemicals before transportation (TDZ, GA, AA and GLU), known to be a promoters of photosynthesis, we evaluated the display quality of potted plants during postproduction. The novelty reported in this work is represented by the investigation of AA and GLU in the chlorophyll biosynthesis and catabolism. GA and TDZ, instead have been also considered as positive controls.

2. Materials and methods

2.1. Experimental conditions

The experiment was conducted at the Department of Agriculture, Food and Environment (Di3 A) of Catania, at the Department of Agricultural and Environmental Sciences of Milan and at Institute of Life Science (Pisa), from June and July 2016. Potted plants of geranium (*Pelargonium* × *hortorum* L.H. Bailey 'ML Cembalo') were obtained from