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Growing floricultural crops with brackish water

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ABSTRACT

In the current review we focus on the opportunity to use brackish water in the cultivation of floricultural plants, plants for which, due to their high economic value, growers have traditionally used good quality water for irrigation. Now, even for these crops the use of alternative water sources for irrigating nursery plants is needed because of the limited supplies of fresh water in many countries; understanding how saline water can be used will also enhance sustainable development in floriculture. While salt stress usually reduces plant growth, any such reduction might not be negative for ornamentals, where shoot vigour is sometime undesirable, although on flower crops salt stress can delay flowering or decrease flower quality characteristics. However, a decrease in growth rate is not enough to characterize the salt tolerance of ornamental plants, but traits like tip and marginal leaf burn, as consequence of sodium and chlorine accumulation, have to be considered for their effects on aesthetical value. With this in mind, some halophytes should be considered for floriculture because of their ability to cope with saline environments; their potential to tolerate salt is an important factor in reducing production costs. Consequently, the identification of ornamental halophytes is important for producing a commercially acceptable crop when irrigated with brackish waters. Many aspects of a plant's reaction to salt are genetically determined, so selection of suitable genotypes or breeding for salt tolerance in ornamentals are interesting options. Developing salt-tolerant floricultural crops, together with typical management practices that avoid excessive salinity stress in the root media, will provide the grower with economically and environmentally sound wastewater reuse options.

1. Introduction

The commercial floricultural industry includes bedding and garden plants, potted flowering and foliage plants, propagation material, cut flowers, and cut cultivated foliage (USDA, 2008). Throughout the world, floricultural crops are produced on a surface of 1.3 million of hectares, divided between cut flowers and potted plants (530,000 hectares), nursery plants (over 700,000 hectares) and bulbs (70,000 hectares). Floriculture contributes significantly, in economic terms, to the horticultural sector, with a worldwide production value of about € 37,000 million and involves around 170,000 farms (MIPAAF, 2011).

A dramatic aspect of floriculture is water consumption: it has been estimated that 100–350 kg of water are needed to produce 1 kg of plant dry matter, but it can vary with species and variety, cultivation system and plant growing season (Fornes et al., 2007). About half of the fresh water available to support a growing world population is already used for human consumption (Rozema and Flowers, 2008). However, the majority of water on Earth is seawater (98%), with only about 1% being fresh-water and an equivalent supply of brackish water (1%). Rising demands for good quality water for domestic and industrial uses in countries with highly developed economies have already created the necessity to re-use wastewater. Many developing countries are now facing this situation, especially in arid and semi-arid regions where limited water availability is already a severe constraint to development.

Integrated water management involves consideration of the social, environmental and technical aspects of water use and promotes the coordinated development and management of water. This holistic approach, coupled with competition from environmental, urban and industrial water users, has and will continue to impact significantly on the availability of water for horticulture (Boland, 2008). This not only influences the quantity of water available but also its quality – with the best quality water being used for drinking and poorer quality water (from a human health perspective) used for irrigation in agriculture and horticulture (Table 1).

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Table 1
Classification of irrigation water (modified from Paranychianakis and Chartzoulakis, 2005).

Water classification	TDS[a] (ppm)	EC[b] (dS m^{-1})
Freshwater	<500	<0.6
Slightly brackish	500–1000	0.6–1.5
Brackish	1000–2000	1.5–3.0
Moderately saline	2000–5000	3.0–8.0
Saline	5000–10,000	8.0–15.0
Highly saline	10,000–35,000	15.0–45.0

[a] TDS, total dissolved solids.
[b] EC, electrical conductivity.

'Poor quality' waters may be derived from recycling of domestic or industrial wastewaters or from seawater, either being used diluted or undiluted with waste or good quality water.

Some benefits of using recycled water to grow plants are water conservation, nutrient savings, organic matter savings, energy conservation, a favorable public image, protection of the environment and conservation of resource (see Skimina, 1992). Benefits apart, reclaimed wastewater is, however, usually of poor quality for plant growth, with higher concentration of salts than fresh water and especially so if derived from seawater. Several studies have shown the environmental and agronomical interest of using low-quality water for irrigation in different crops (Parsons et al., 2001) and water requirements of food crops are relatively well quantified in the agronomic literature. There has, however, been little quantification of the irrigation requirement in order to maintain healthy growth and acceptable quality of ornamental plants (Grant et al., 2009; Bãnón et al., 2011) where the salt concentration of the water is enhanced. Growers have, over decades, used high quality water to irrigate floricultural crops because of their high economic value. Nowadays the increase in population and agricultural production together with the diminishing sources of fresh water continue to intensify competition for good water (Carter and Grieve, 2010). Therefore wastewater, which has an electrical conductivity between 0.6 and 45.0 dS m^{-1} (Table 1) is increasingly being proposed for irrigation as the availability of high quality water decreases.

Many countries have started to use treated, reclaimed municipal wastewater as a source of irrigation water for agricultural crops to reduce the need for high quality water (Parsons, 2000). In Florida 92,345 ha were irrigated with reclaimed municipal water in 2005; 6144 ha was agricultural land and the rest was used for irrigating golf courses and landscapes (Morgan et al., 2008; Villarino and Mattson, 2011). Recently Cassaniti et al. (2012) have analyzed the potential use of brackish water for growing ornamentals. Another trial conducted on about 100 ornamental species grown in 2.8 L containers showed the feasibility of growing plants with recycled water without loss of yield (Skimina, 1992). Plants that were cultivated with recycled water (a blend of 50% processed runoff and 50% of fresh water) exhibited a mean relative growth of 103% of the fresh water control even with an EC of 6 dS m^{-1}. Experiments conducted in Israel (Shillo et al., 2002) and in California (Carter et al., 2005; Grieve et al., 2008) testify to the possibility of growing ornamentals and cut flowers even where the EC of the irrigation water is not optimal for plant growth. In the Negev desert the salt levels of the irrigation water for flower crops were monitored constantly thus enabling growers to keep salinity at relatively low levels in fields and to ensure high yields and good quality flowers (Shillo et al., 2002). *Limonium*, *Dianthus*, *Celosia*, *Gypsophila*, *Matthiola*, *Chrysanthemum*, *Antirrhinum* are, for example, crops that have been identified as suitable for water reuse systems (Shillo et al., 2002; Carter et al., 2005; Grieve et al., 2006; Friedman et al., 2007; Carter and Grieve, 2008). Sometimes salt stress can also become an environmental friendly alternative to chemical growth regulators for controlling any excessive stem height (Shillo et al., 2002; Carter et al., 2005; Carter and Grieve, 2006).

An advantage of growing floricultural crops with low quality water is that as they are not used as food, risks for human health from contamination with toxic elements are low (Carter and Grieve, 2008). However, the reuse of water with possible toxic compounds or heavy metals can impact on soil and water, that may become less suitable for future crops.

In this review we draw the attention to the possibilities of utilizing brackish water for growing cut flowers and potted/bedding plants, as these species are often sensitive to salinity and the ways in which they are normally grown involve aspects such as soilless culture and use of small volumes of substrates that enhance salt stress. Currently advances in methods of cultivation, in breeding and in selection techniques give growers the possibility to produce cut flowers with low quality water without sacrificing plant quality (Grieve and Poss, 2010), even though most cut flowers, are glycophytes and so highly sensitive to salinity (Grattan and Grieve, 1999; Valdez-Aguilar et al., 2009b). A further exciting possibility stems from the fact that several plant families contain halophytic species that are potentially useful as cut flowers (e.g. Asteraceae, *Inula* spp.; Gentianaceae, *Eustoma* spp.; Plumbaginaceae, *Armeria* spp., *Limonium* spp.) or as pot plants (Portulacaceae, *Portulaca* spp.) (Carter and Grieve, 2006). Using halophytic species together with cultivation practices that avoid or limit the accumulation of salt in the substrate will have economical and environmental benefits.

2. The effects of salt stress on floricultural crops

2.1. Growth (biomass, leaf area and number)

Salinity stress is a common environmental problem and an important factor limiting crop production: it is a combined result of the complex interactions among different morphological, physiological and biochemical processes (Munns and Tester, 2008). Plants respond to salt stress by decreased growth rate, with corresponding formation of smaller and fewer leaves and reduced plant height (Shannon and Grieve, 1999). This reduction in growth has been observed whether for glycophytes (e.g. François and Clark, 1978; Risse and Shenk, 1990; Greenway and Munns, 1980; Ibrahim et al., 1991; Zurayk et al., 1993; Kuehny and Blanca, 1998; Wang, 1998; Küçükahmetler, 2002) or halophytes (Flowers and Colmer, 2008). As an example of the effects on a floricultural plant, high accumulation of Na^+ and Cl^- led to strong shoot reduction in plants of *Angelonia angustifolia* 'Black Pearl' (Niu et al., 2010). The reduction in leaf area is a consequence of changes in cell wall properties, cell water relations and a reduction in photosynthetic rate (Franco et al., 1997; Lee and van Iersel, 2008).

The effect of saline irrigation on floricultural crops has been investigated to a much lesser extent than other crops (for examples see Table 2) because ornamentals are normally irrigated with high quality water. Having information available on the sensitivity of floricultural crops will allow growers to choose appropriate species for cultivation with low quality water. Aendekerk (2000) listed several genera of shrubs and herbaceous perennials as being very sensitive to salt. Prominent are the members of the Ericaceae (*Calluna*, *Daboecia*, *Erica*, *Kalmia*, *Leucothoe*, *Pieris*, *Vaccinium*), Hamamelidaceae (*Corylopsis*, *Fothergilla*, *Hamamelis*) and ornamental ferns (*Adiantum*, *Asplenium*, *Pellaea*, *Polypodium*). Other genera mentioned are *Allium*, *Andromeda*, *Aucuba*, *Cautleya*, *Geum*, *Hebe*, *Pygmaea*, *Rosmarinus*, *Sarracenia*, *Selaginella* and *Thymus*. However, this list is very short considering the high number of floricultural species (Dole and Wilkins, 1999). Furthermore, where data is available, since the response varies with the conditions in which the experiment was carried out (e.g. temperature, nutrient status