The Influence of Deficit Irrigation on Growth, Ornamental Quality, and Water Use Efficiency of Three Potted Bougainvillea Genotypes Grown in Two Shapes

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Additional index words. Bougainvillea, flower index, leaf water potential, mineral composition, water productivity, water stress

Abstract. Bougainvillea is widely used as flowering shrub in gardening and landscaping in the Mediterranean region characterized by limited water supply. The evaluation of deficit irrigation as a possible technique to improve water productivity and selection of genotypes that can better withstand soil water deficits is essential for sustainable production. A greenhouse experiment was conducted to determine the effects of deficit irrigation on three potted Bougainvillea genotypes [B. glabra var. Sanderiana, B. ×buttiana ‘Rosenka’, B. ‘Lindleyana’ (= B. ‘Aurantiaca’)] grown in two shapes, globe and pyramid, on agronomical and physiological parameters. Irrigation treatments were based on the daily water use (100%, 50%, or 25%). The shoot, total dry biomass, leaf number, leaf area, and macronutrient [nitrogen (N), phosphorus (P), and potassium (K)] concentration decreased in response to an increase in water stress with the lowest values recorded in the severe deficit irrigation (SDI) treatment. At 160 days after transplanting (DAT), the percentage of total dry biomass reduction caused by irrigation level was lower in B. ×buttiana ‘Rosenka’ compared with B. glabra var. Sanderiana and B. ‘Lindleyana’ (= B. ‘Aurantiaca’). At 160 DAT, the flower index increased in response to an increase in water stress with the highest values recorded under both moderate deficit irrigation (MDI) and SDI for B. ×buttiana ‘Rosenka’. The biomass water use efficiency (WUE) increased under water stress conditions with the highest values recorded in B. glabra var. Sanderiana and B. ×buttiana ‘Rosenka’ grown under MDI (average 1.43 and 1.25 g L⁻¹, respectively) and especially with SDI (average 1.68 and 1.36 g L⁻¹, respectively). A number of tolerance mechanisms such as increase in stomatal resistance, decrease in leaf water potential, and decrease in leaf osmotic potential have been observed, especially under SDI. The MDI treatment can be used successfully in Bougainvillea to reduce water consumption while improving the overall quality and WUE, whereas the genotypes B. glabra var. Sanderiana and B. ×buttiana ‘Rosenka’ could be considered suitable for pot plant production.

Water is fast becoming a scarce resource in arid and semiarid regions such as the Mediterranean basin (Gregory, 1984). There is high pressure on the ornamental floriculture industry to reduce water regimes and to produce plants more efficiently in the face of government regulations on water use (Sánchez-Blanco et al., 2009; Sweatt and Davies, 1984). The irrigation scheduling, in particular the water amount and frequency in most ornamental nurseries, is based on arbitrary personal experience, which is rarely modified to match the crop water requirements (Alvarez and Sánchez-Blanco, 2013; Grant et al., 2012). Possible consequences of exposing plants to drought stress is the decrease in internode length, leaf size, flower number, and size with a possible negative effect on the their ornamental values (Alvarez et al., 2009, 2013; Cameron et al., 1999; Sánchez-Blanco et al., 2002). From a physiological point of view, it is well established that under severe water stress, plants reduce photosynthesis, mainly because of stomata closure (Chaves et al., 2003). With closing the stomata, plants reduce not only water loss by transpiration, but also carbon dioxide supply to the leaves (Cornic and Massacci, 1996). Consequently, plant biomass and growth are reduced, resulting in the loss of plant quality. However, the sensitivity to water stress may vary considerably between different species and/or cultivars (Clary et al., 2004; Sánchez-Blanco et al., 2002; Zollinger et al., 2006). For all these reasons, understanding agronomical and physiological responses of flowering plants to water management is critical for optimizing the production in pots of high-quality ornamentals.

Water-saving irrigation management strategies are among the options available to horticultural growers to reduce water consumption and improve WUE. Possible strategies include deficit irrigation (DI), regulated deficit irrigation, and partial root-zone drying. DI involves the application of water at a rate and volume lower than the evapotranspiration rate (ET) throughout the whole growth period and may be used in potted ornamental plants to improve plant quality by reducing excessive vigor and increasing WUE. However, the level and the duration of water stress imposed in each species and/or cultivars are also critical to reach this purpose (Alvarez et al., 2009; Alvarez and Sánchez-Blanco, 2013). In the last three decades, interest in DI has primarily centered on its potential to save water and/or to control excessive vegetative growth in fruit trees and vegetables (Costa et al., 2007, and references cited therein; Goldhamer and Beede, 2004; Mao et al., 2003; Rouphael et al., 2008a). Its application to ornamental crops has received limited interest so far, because flowering ornamental plants are generally grown in pots, which provide a small water storage capacity in the root zone compared with open-field conditions. This small water-holding capacity makes it technically more difficult to apply DI without causing stress damage to the plants (Cameron et al., 2006).

Bougainvillea is a genus of flowering plants that belongs to the family Nyctaginaceae native in South America originated from west Brazil to southern Argentina. Different authors accept between four and 18 species in the genus (Kent et al., 2007); it is widely used in the arid landscapes for horticulture, agriculture, and environmental industries as a result of its high adaptability in different agroclimatic regions around the world (Saifuddin et al., 2010; Suxia et al., 2009). Potted Bougainvillea plants are a significant part of the Italian ornamental plant industry as a result of the high demand for this product on national and international markets (ISMEA, 2013). Despite the importance of the Bougainvillea in floriculture production, no published data are available concerning the effects of different levels of deficit irrigation on agronomical and physiological parameters of three Bougainvillea genotypes grown in two different shapes. For these reasons, the evaluation of DI as a possible technique to improve water productivity and the selection of genotypes that can better withstand soil water deficits are essential for sustainable production.

The aim of this study was to determine the effects of three irrigation treatments (full or
deficit irrigation) on the agronomical and physiological responses of three potted Bougainvillea
geotypes (B. glabra var. Sanderiana, B. ×buttiana ‘Rosenka’, B. ‘Lindleyana’ (=B. ‘Aurantiaca’)) trained to two canopy shapes (globe and pyramid). For this, plant growth, ornamental quality, WUE, mineral composition, stomatal resistance, and water relations were measured during the growing cycle. These results can play an important role for the ornamental industry, which is very interested in selecting tolerant genotypes and suitable shapes under water stress conditions and to evaluate the DI as a useful technique to save water without affecting the economic value of the plant.

Materials and Methods

Plant material and growth conditions. The experiment was conducted from Mar. to Oct. 2011 in a 265-m² glass zinc-coated steel greenhouse situated at the Experimental Station of the University of Naples Federico II, South Italy (lat. 43°31’ N, long. 14°58’ E; alt. 60 m above sea level). Plants were grown under a 50% black shading net. The greenhouse was maintained at daily temperature between 16 and 26 °C and day/night relative humidity of 50/88%.

Rooted cuttings of three flowering potted Bougainvillea genotypes (B. glabra var. Sanderiana, B. ×buttiana ‘Rosenka’, B. ‘Lindleyana’ (=B. ‘Aurantiaca’)) were obtained from a commercial grower (Vivai Torsanlorenzo, Ardea, Rome, Italy) and transplanted on Mar. 1 into pots (depth 17 cm, height 15 cm) containing 3 L of peat-moss. The pots were placed on three 180 cm wide and 7-m-long troughs with a plant density of 6 plants/m². Bougainvillea plants were grown in two canopy shapes: globe and pyramid. The Bougainvillea globe shape was obtained by regular pruning based on the new shoot thinning and cut back, whereas the pyramid Bougainvillea plants were grown as a vine on a tutor and pruned by trimming exceeding shoots.

Treatments were arranged in a randomized complete block design with three replicates. The treatments were defined by a factorial combination of three irrigation levels based on the daily water use (100%, 50%, or 25%), three Bougainvillea genotypes (B. glabra var. Sanderiana, B. ×buttiana ‘Rosenka’, B. ‘Lindleyana’ (=B. ‘Aurantiaca’)), and two canopy shapes (globe or pyramid). Each experimental unit consisted of 15 plants.

Irrigation treatments. The irrigation treatments consisted of a control; when substrate moisture was maintained close to container capacity, it was watered so that 20% of the applied water was leached; and two DI treatments obtained applying 50% (MDI) or 25% (SDI) of the amount of water supplied in the control treatment. The electrical conductivity of the water applied was 0.6 dS m⁻¹. The three levels of water recovery (100%, 50%, and 25%) were obtained using four, two, and one emitter(s) per plant, respectively (flow rate of 2 L h⁻¹).

Plants were fertigated with a nutrient solution containing the following macro- and micro-nutrients: 1.45 mM NO₃⁻, 2.66 mM NH₄⁺, 4.36 mM N-ureic, 1.41 mM P, 4.24 mM K, 5.34 mM iron, 3.45 mM manganese, 0.84 mM copper, 0.83 mM zinc, 37 μM boron, and 2.08 μM molybdenum.

A separate set of 54 potted plants was placed on an electronic weighing balance at the same plant density of the canopy; these plants were in the center of a bench containing guard plants to form a continuous canopy. The pots were covered with plastic film to minimize evaporation. The transpiration was measured by a gravimetric method, weighing the pots before and after the irrigation episode, and was determined by noting when the leaching fraction reached 15% to 20% (Rouphael et al., 2008b; Rouphael and Colla, 2005). The assumption was made that the weight loss measured by the electronic balance was equal to the plant transpiration.

Recording, sampling, and analysis. During the whole growing cycle, the amount of water used by the plants was monitored daily in all treatments. At 171 DAT, the stomatal resistance to water vapor (s cm⁻¹) was measured between 1100 and 1300 ishr on the youngest fully expanded leaf (nine plants per treatment, three per each replication) with a diffusion porometer (AP-4, Delta-T Devices, Cambridge, U.K.). The water potential components of leaves were measured psychrometrically on the same date of the stomatal resistance measurements using a dew-point psychrometer (WP4; Decagon Devices, Pullman, WA). Leaf water potential (Ψₛ) was measured at midday. The osmotic potential (Ψₒ) was measured on frozen/thawed leaf
The dried leaf tissue were ground separately and were analyzed by atomic absorption spectrophotometry according to the method described by Walinga et al. (1995).

Statistical analysis. All data were statistically analyzed by three-way analysis of variance (ANOVA) using the SPSS software package (SPSS 13.0 for Windows; SPSS Inc., Chicago, IL). Whenever the two-way interaction was significant, a one-way ANOVA was performed. Duncan’s multiple-range test was performed at $P < 0.05$ on each of the significant variables measured. Linear regression analysis was conducted to identify relationships between stomatal resistance and leaf water potential using the GraphPad Prism Package (GraphPad Prism Software Inc., 1999). Differences between the slopes of linear regressions were examined by testing the homogeneity of regression coefficients (Gomez and Gomez, 1983).

Results

Plant growth and ornamental value. Stem, flower, and total dry biomass were significantly affected by irrigation level ($I \times G$) and genotype ($G \times S$) interaction (Table 1). The total dry biomass at the end of the growing cycle (225 DAT) decreased linearly in response to an increase in water stress with the lowest values recorded in the SDI treatment, having 25% of the control irrigation water (Tables 1 and 2). Irrespective of the shape treatment ($I \times G$ interaction), the percentage of total dry biomass reduction was significant at 160 DAT caused by irrigation level was lower in B. xbuttiana ‘Rosenka’ (by 1.7% and 5.5% for MDI and SDI, respectively) compared with those recorded in B. glabra var. Sanderiana (by 18% and 20% for MDI and SDI, respectively) and B. ‘Lindleyana’ (= B. ‘Aurantiaca’) (by 16% and 33% for MDI and SDI, respectively) (Table 2). Moreover, the flower biomass at 160 DAT decreased significantly under MDI and SDI in B. glabra var. Sanderiana (by 18% and 20% for MDI and SDI, respectively) and B. ‘Lindleyana’ (= B. ‘Aurantiaca’) (by 16% and 33% for MDI and SDI, respectively) (Table 2). More-over, the flower biomass at 160 DAT decreased significantly under MDI and SDI in B. glabra var. Sanderiana (by 18% and 20% for MDI and SDI, respectively) and B. ‘Lindleyana’ (= B. ‘Aurantiaca’) (by 16% and 33% for MDI and SDI, respectively) (Table 2). More-over, the flower biomass at 160 DAT decreased significantly under MDI and SDI in B. glabra var. Sanderiana (by 18% and 20% for MDI and SDI, respectively) and B. ‘Lindleyana’ (= B. ‘Aurantiaca’) (by 16% and 33% for MDI and SDI, respectively) (Table 2). More-over, the flower biomass at 160 DAT decreased significantly under MDI and SDI in B. glabra var. Sanderiana (by 18% and 20% for MDI and SDI, respectively) and B. ‘Lindleyana’ (= B. ‘Aurantiaca’) (by 16% and 33% for MDI and SDI, respectively) (Table 2).
shapes and, in general, flower biomass was higher in the pyramid shape (Table 2). A similar pattern was also observed for the flower biomass, where higher values were recorded in the pyramid form for both *B. glabra* var. Sanderiana (by 138% at 160 DAT and by 36% at 225 DAT) and *B. ×butiana* ‘Rosenka’ (by 168%) in comparison with the pyramid shape. The number of leaves, flowers, flower biomass at 225 DAT were significantly affected by *I × S* interaction (Table 1). The number of leaves per plant and the total leaf area were increased linearly in response to an increase in water stress with the highest values recorded in the pyramid shape (Table 2). The number of leaves, flowers, flower index at 160 DAT, and the total leaf area at 160 and 225 DAT were significantly affected by *I × G* interaction, whereas the total leaf area and number of flower at 225 DAT were significantly influenced by *G × S* interaction (Table 1). The number of leaves and flower index at 160 DAT, the total leaf area, and flower number at both sampling dates were highly influenced by *G × S* interaction (Table 1). The number of leaves per plant and the total leaf area decreased linearly in response to an increase in water stress with the lowest measured in the SDI, whereas an opposite trend was recorded for both number of flowers per plant and the flower index (Tables 1 and 3). At 160 DAT, irrespective of the shape treatment (*I × G* interaction), the percentage of number of leaves reduction caused by irrigation level was lower in *B. ×butiana* ‘Rosenka’ (–6.7% and –19.3%) compared with those recorded in *B. glabra* var. Sanderiana (–24% and –33%) and *B. ×butiana* ‘Rosenka’ (–31% and –43%) for MDI and SDI treatments (Table 3). On the contrary, when averaged overall shape treatments, the flower index increased in a response to an increase in water stress with the highest values recorded in *B. ×butiana* ‘Rosenka’ under both MDI and SDI treatments (Table 3). Irrespective of genotype treatment (*I × S* interaction), the total leaf area, at 225 DAT, was significantly reduced by 43% in *B. ‘Lindleyana’* (average 1.83 g L–1) and especially with SDI treatments (data not shown), whereas no significant differences among irrigation levels were observed for the flower biomass at 225 DAT (average 0.75 g L–1). The biomass WUE expressed over, the biomass WUE was significantly affected by the *I × G* and *G × S* interactions (data not shown). The biomass WUE expressed on a dry weight basis increased with increasing water deficit. When averaged overall treatments, the reduction in water use in plants at MDI and SDI treatments was 40% (average 38.9 L/plant) and 48% (average 33.7 L/plant), respectively, compared with the control (average 65.0 L/plant). Moreover, the biomass WUE was significantly affected by the *I × G* and *G × S* interactions (data not shown). The biomass WUE expressed on a dry weight basis increased with increasing water stress with the highest values recorded in both genotypes *B. glabra* var. Sanderiana and *B. ×butiana* ‘Rosenka’ grown under MDI (average 1.43 and 1.25 g L–1, respectively, data not shown) and especially with SDI (average 1.68 and 1.36 g L–1, respectively, data not shown), whereas no significant differences among irrigation levels were observed in *B. ‘Lindleyana’* (average 0.75 g L–1; Fig. 1). When averaged over irrigation rate (*G × S* interaction), the highest WUE was recorded in pyramid *B. glabra* var. Sanderiana (average 1.83 g L–1) followed by pyramid *B. ×butiana* ‘Rosenka’ (average 1.42 g L–1), whereas the lowest values were recorded in globe *B. ‘Lindleyana’*.
Discussion

It is well established that crop growth decreases with water limitation, although the exact effect may vary depending on the intensity of the water stress imposed (Cameron et al., 1999, 2006). Deficit irrigation reduced the morphological parameters such as shoot, flower, total biomass, leaf number, and total leaf area (Tables 2 and 3), which may be an adaptive role, restricting the evaporative surface area (Sharp, 1996). Our results are in agreement with many ornamentals studies on *Cistus albidus* and *Cistus monspeliensis* (Sánchez-Blanco et al., 2002), *Nerium oleander*, and *Lotus creticus* (Bañón et al., 2004, 2006); *Dianthus* (Alvarez et al., 2009); *Callistemon citrinus* (Alvarez and Sánchez-Blanco, 2013; Mugnai et al., 2009); and *Pelargonium ×hortorum* (Alvarez et al., 2013). The different water stress levels (MDI and SDI) applied in our experiment induced different growth responses in *Bougainvillea* genotypes with a reduction of the total biomass (at 225 DAT) by 13.4% and 21.9% under MDI and SDI, respectively, in comparison with the control, meaning that the severity of the water stress should be considered an important factor, when used as an irrigation strategy for saving water. These results are consistent with the findings of Alvarez et al. (2009) who observed a reduction in the shoot dry weight of potted carnation plants by 19.3% and 33.4% under MDI (receiving 70% of the control) and SDI (receiving 35% of the control), respectively. Similarly, Álvarez et al. (2013) and Sánchez-Blanco et al. (2009) reported a decrease in growth and biomass traits in potted geranium when exposed to different water regimes during different phenological stages.

The application of MDI and SDI reduces growth in *Bougainvillea*. However, ornamental plants subjected to water limitation may delay flowering and reduce the flowering intensity (Alvarez et al., 2012, 2013; Bernal et al., 2011; Cuevas et al., 2009). In the current study, the number of flower per plant and the flower index were significantly higher under both deficit irrigation treatments compared with fully irrigated plants (Table 3). Our results are consistent with the findings of Cameron et al. (1999), who observed that the highest number of flowers per plant in *Rhododendron* occurred after a moderate drought. In contrast, Alvarez et al. (2009), Alvarez and Sánchez-Blanco (2013), and Sánchez-Blanco et al. (2009) have reported that MDI did not reduce the number of flower in *Dianthus, Callistemon citrinus*, and potted geranium, whereas the plant quality was negatively affected (e.g., lower number of flowers) by the SDI treatment. Explanations for this disagreement could be related to the period of exposure, the intensity of water stress, and the variations between species in their sensitivity to drought. Therefore, the use of DI in *Bougainvillea* could be a potential strategy to cope with water shortage without losing the ornamental value.

Significant differences emerged in the plant growth parameters (leaf number, total
leaf area, and dry biomass) of the tested genotypes and shapes (Tables 2 and 3). Leaf number, total leaf area, and dry weight were all reduced by drought in all genotypes but the reduction was much more pronounced in *B. glabra* var. Sanderiana, whereas flower index increased, especially with the globe shape. The marked differences found between *B. glabra* var. Sanderiana and *B. xbuttiana* ‘Rosenka’ and *B. Lindleyana* (=*B. Aurantiaca*) suggest the possibility of exploiting this kind of variability in breeding programs with the aim of selecting genotypes that can better withstand water stress. The higher flower index recorded in the globe than in the pyramid shape could be related to the frequent pruning, which was responsible for the increase in flowers per unit of leaf area.

In general, ornamental species respond to water stress by reducing the daily ET (Jaleel et al., 2008; Lenzi et al., 2009) and the ET decreases as the water stress severity increases (e.g., SDI treatment), even if the intensity of this response depends on the species/variety (Lenzi et al., 2009). The reduction in water use in plants at MDI and SDI treatments was 40% and 48%, respectively, compared with the control treatment. The reduction in water use under deficit irrigation treatments has been attributed to the reduction in total leaf area (Table 3; Atkinson and Crisp, 1983) and to a higher stomatal resistance (Table 6; Bolla et al., 2010). In this study, we found that the relationship between water use and dry biomass (WUE) was modified by water supply, genotypes, and shapes. When averaged among treatments, the highest WUE was recorded in pyramid (average 1.6 g.L⁻¹) when compared with globe (average 1.0 g.L⁻¹) shape as a result of the frequent shoot trimming applied during the growing cycle. Moreover, WUE increased under MDI and SDI in both *B. glabra* var. Sanderiana and *B. xbuttiana* ‘Rosenka’, whereas the WUE remained unchanged in *B. Lindleyana* (=*B. Aurantiaca*) (Fig. 1). Increased WUE values under water stress conditions were also found in several ornamental plants (Álvarez et al., 2009; Álvarez and Sánchez-Blanco, 2013; Cameron et al., 2006; Jaleel et al., 2008). Cameron et al. (2006) reported that the WUE increased between 5% and 33% in the woody ornamental tested species (*Choisyia, Cornus, Forsythis, Lavandula, and Loniceria*). However, according to other authors, the WUE was not modified under water stress conditions (Andersson, 2001) or even decreases (Aniya and Herzog, 2004; Eiasu et al., 2012), depending on the species, genotype, water stress level, and duration (Cameron et al., 2006, and references cited therein).

The low macronutrient concentration (N, P, and K) recorded in the current study under SDI could be attributed to a decrease in soil moisture content in the root zone (Table 4). Our results are in agreement with those of

### Table 4. Effects of irrigation treatments, genotypes, and shapes on leaf mineral composition of potted *Bougainvillea* plants.

| Treatments | N (g kg⁻¹ DW) | P (g kg⁻¹ DW) | K (g kg⁻¹ DW) |
|------------|---------------|---------------|---------------|
| Irrigation (I) | N | P | K |
| 100% (C) | 24.25 | 11.95 | 31.82 |
| 50% (MDI) | 23.31 | 11.42 | 28.80 |
| 25% (SDI) | 21.21 | 9.32 | 22.04 |
| Genotypes (G) | N | P | K |
| *B. glabra* var. Sanderiana (BgS) | 22.28 | 11.43 | 28.50 |
| *B. xbuttiana* ‘Rosenka’ (BxbR) | 23.76 | 10.32 | 27.37 |
| *B. Lindleyana* (=*B. Aurantiaca*) (Ba) | 22.63 | 10.93 | 26.97 |
| Shapes (S) | N | P | K |
| Pyramid | 22.47 | 10.11 | 27.61 |
| Globe | 23.37 | 11.27 | 27.49 |
| I × G | N | P | K |
| 100 | 23.7 | 12.1 | 33.9 |
| 50 | 22.7 | 11.5 | 32.5 |
| 25 | 20.7 | 10.6 | 19.2 |
| I × S | N | P | K |
| 100 | 24.2 | 11.0 | 33.3 |
| 50 | 23.3 | 11.2 | 26.8 |
| 25 | 19.9 | 9.6 | 22.4 |
| G × S | N | P | K |
| *B. glabra* var. Sanderiana | 21.4 | 10.4 | 28.2 |
| *B. xbuttiana* ‘Rosenka’ | 23.7 | 12.6 | 28.9 |
| *B. Lindleyana* (=*B. Aurantiaca*) | 22.3 | 10.4 | 31.3 |

### Table 5. Analysis of variance for irrigation treatments, genotypes, and shapes on leaf mineral composition, stomatal resistance ($r_\text{s}$), leaf water potential ($\Psi_\text{w}$), leaf osmotic potential ($\Psi_\text{o}$), and leaf turgor potential ($\Psi_\text{t}$), of potted *Bougainvillea* plants.

| Source of variation | N (g kg⁻¹ DW) | P (g kg⁻¹ DW) | K (g kg⁻¹ DW) | $r_\text{s}$ (s cm⁻¹) | $\Psi_\text{w}$ (MPa) | $\Psi_\text{o}$ (MPa) | $\Psi_\text{t}$ (MPa) |
|---------------------|---------------|---------------|---------------|---------------------|---------------------|---------------------|---------------------|
| Irrigation (I) | Q*** | L*** | L*** | L*** | L*** | NS |
| Q = 0.98 | $R^2 = 0.98$ | $P = 0.000$ | Q = 0.73 | $R^2 = 0.76$ | $P = 0.002$ | Q = 0.91 | $R^2 = 0.98$ | $P = 0.000$ | Q = 0.98 | $R^2 = 0.98$ | $P = 0.000$ |
| Genotypes (G) | N | P | K | N | P | K | N | P | K | N | P | K |
| Shape (S) | N | P | K | N | P | K | N | P | K | N | P | K |
| I × G | N | P | K | N | P | K | N | P | K | N | P | K |
| I × S | N | P | K | N | P | K | N | P | K | N | P | K |
| G × S | N | P | K | N | P | K | N | P | K | N | P | K |
| I × G × S | N | P | K | N | P | K | N | P | K | N | P | K |

$\Psi_\text{w}$ = leaf water potential; $\Psi_\text{o}$ = leaf osmotic potential; $\Psi_\text{t}$ = leaf turgor potential; $r_\text{s}$ = stomatal resistance.

### Significance

$L = \text{linear}; Q = \text{quadratic}.$

$^a$DAT = days after transplanting.

Different letters indicate significant differences according to Duncan test ($P < 0.05$).

N = nitrogen; DW = dry weight; P = phosphorus; K = potassium; C = control; MDI = moderate deficit irrigation; SDI = severe deficit irrigation.
It can be concluded that irrespective of genotypes and shapes, the water deficit decreased the plant growth parameters, adversely affected leaf mineral composition and water status, but improved number of flowers and flower index. Reductions of 75% of the water applied (SDI) significantly reduced growth of potted Bougainvillea but increased the WUE, whereas MDI (reductions of 50%) decreased slightly the WUE. This result has important agronomical traits but improved the ornamental quality and the WUE, indicating that Bougainvillea could be considered a tolerant ornamental species. The MDI treatment can be used successfully in Bougainvillea to reduce water consumption while improving the overall quality. The results also indicated that the bougainvillea traits and WUE of Bougainvillea appear to be strongly influenced by genetic factors and shape, suggesting that specific cultivars (e.g., B. glabra var. Sanderiana and B. xbuttiana ‘Rosenka’) and shapes (pyramid: higher WUE) could be selected as interesting genotypes and shapes.
training system for ornamental and landscape purposes under moderate and severe water deficit conditions.

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