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# REGULATED DEFICIT IRRIGATION OF RHODODENDRONS GROWN IN CONTAINERS

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### *Abstract*

The effect of deficit irrigation imposed in July-August period on shoot growth and flower formation in container grown rhododendron in commercial nursery were assessed. Plants were exposed to three irrigation regimes based on potential evapotranspiration rates (100% $ET_0$ – well-watered control plants, 75% $ET_0$ – moderate drought and 50% $ET_0$ – severe drought). The values of evapotranspiration were calculated using the Penman-Monteith model. The degree of drought had significant effect on the plant growth and water status of plants. Severe drought inhibited secondary shoot elongation compared to less stressful regime but did not affect flower formation. ‘Catawbiense Boursault’, ‘Nova Zembla’ and ‘Pearce’s American Beauty’ plants exposed to severe drought were shorter, respectively by 39, 45 and 86% than well-irrigated plants and two of the three cultivars ‘Catawbiense Boursault’ and ‘Pearce’s American Beauty’ produced fewer secondary branches (5.9 and 0.3) compared to control plants (9.2 and 1.7, respectively). Moderate drought did not affect plant growth but resulted in flower bud formation in ‘Nova Zembla’ and ‘Pearce’s American Beauty’s cultivars. Estimated water consumption by rhododendrons throughout the whole growing season was reduced by 15% for moderate and 25% for severe drought compared to control, well-watered plants. The results have significant implications for water conserving in commercial production of rhododendrons.

**Key words:** evapotranspiration, irrigation, ornamental nursery, regulated deficit irrigation (RDI), *Rhododendron*

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## INTRODUCTION

Regulated deficit irrigation (RDI) is defined as an irrigation practice whereby a crop is irrigated with an amount of water below the full requirement for optimal plant growth, at times when the crop is drought-insensitive. The objective of this method is to reduce the amount of water used for irrigating crops and improve the response of plants to the certain degree of water deficit in a positive manner (Chai *et al.* 2016).

Rhododendrons are one of the most widely grown ornamental plants in the world and are important crops in nursery production. However, the response of rhododendrons to deficit irrigation has been relatively little studied. Previous horticultural observations and research on this plant species suggest that appropriately applied irrigation deficits may improve shrubs quality and enhance flowering. Cameron *et al.* (1999) demonstrated that controlled water stress improved plant quality in container-grown *Rhododendron* 'Hoppy'. Sharp *et al.* (2009) noted that limited water stress applied to *Rhododendron* 'Hatsugiri' resulted in earlier induction of flower buds set, forming more flowers per inflorescence and shortening branch length. Koniarski and Matysiak (2013) demonstrated that imposing *Rhododendron* 'Catawbiense Boursault' and 'Old Port' plants to deficit irrigation for 14 week period starting with the period of active vegetative growth enhanced shape, plant quality and increased number of floral buds set, but 'Catawbiense Boursault' plants were more responsive to stronger water scarcity. These results demonstrated also that 'Old Port' plants exposed to severe water deficit for four-week period during floral buds initiation improved significantly floral bud set. These results suggest that deficit irrigation can considerably reduce water consumption in nursery production without causing severe damage, but flowers and vegetation may be improved. However, response of *Rhododendron* plants may vary depending on cultivar, intensity and timing of the water stress imposed (Cameron *et al*. 2006).

The success of regulated deficit irrigation method depends on both accurate measurement of plant irrigation requirements and accurate delivery of water to the plants. The ideal system desired is one in which water can be applied in accordance with the plant's need. Determining plant irrigation requirements can be a complex process that takes such factors as plant size and type, canopy density and microclimate conditions into consideration (Allen 1993). These factors, which include solar radiation, air temperature, relative humidity and wind speed influence evapotranspiration (ET) dynamics. Because both environmental and plant factors influence ET, water use is never constant.

The aim of the study was to investigate whether irrigation scheduling based on different levels of evapotranspiration could conserve water without negatively impacting plant growth of *Rhododendron* plants grown in containers in commercial nursery. The second aim was to analyze the morphological and physiological response of rhododendrons to deficit irrigation imposed during July-August period.

## MATERIAL AND METHODS

Three cultivars of elepidote rhododendrons (*Rhododendron* L.) ‘Catawbiense Boursault’, ‘Nowa Zembla’ and ‘Pearce’s American Beauty’, evergreen shrubs with large leathery leaves, were chosen to the study. The experiment was established in commercial nursery KZD Nowy Dwór (Poland) and they were cultivated according to standard nursery practice. Two-year-old plants grown in 2-litter pots filled in sphagnum peat moss (Klasmann-Deilmann) at pH 3.6 were placed on 24 May 2016 on container field. Plants were fertilized ($2 g\cdot L^{-1}$) with Blaucorn ($12N\text{-}8P_2O_5\text{-}16K_2O\text{-}3MgO$; Compo Gmbh, Germany) two times between May and July 2016. Plants were irrigated by micro sprinklers (SuperNet$^{TM}$, Netafim – Israel). For the first 6 weeks, before the beginning of experimental period (5 July 2016) all plants were irrigated at a rate 100% of the estimated reference evapotranspiration (ETo).

The values of evapotranspiration were calculated using the Penman-Monteith model (Allen *et al.* 1998). Irrigation was carried out using a prototypical computerized controller (VIK, Sensor Tech Poland) equipped with the necessary sensors (air temperature, relative humidity, solar radiation) for automatic calculation of $ET_{0.}$ Additionally, $ET_0$ levels were determined using an agro-meteorological station (iMetos, Pessl Instruments, Austria). These data were used to control irrigation during the periods when constructional modifications were made to the prototypical controller.

Three irrigation regimes balancing water loses by evapotranspiration were used:

– 100% $ET_0$ – control

– 75 % $ET_0$ – periodic stress ($RDI_{75\%}$) imposed from 5 July to 4 September 2016.

– 50% $ET_0$ – periodic stress ($RDI_{50\%}$) imposed from 5 July to 4 September 2016.

For RDI treatments, irrigation after 4 September 2016 was at the control level. The threshold for starting irrigation was set to 2 mm. After exceeding this value, the controller automatically carried out irrigation taking into account the dose specified above (irrigation regime variants). Measurements of substrate moisture were performed with GS3 capacitance probes (Decagon Devices, USA). The probes were connected to the weather station; information on moisture content was transmitted wirelessly along with the weather parameters together as one data packet. If the level of moisture was high (close to the container water capacity), operation of irrigation system was discontinued. There were three replications of 10 plants for each watering regime, and the replications were organized in a randomized complete-block design.

*Measurements*

Stomatal conductance ($g_s$) was measured 5 times (27 July, 3 August, 16 August, 30 August, 20 September 2016) between 10:00 and 15:00 (UTC) during clear skies, using SC-1 Leaf Porometer (Decagon Devices, USA). All measurements were made on the young, fully expended leaves. Two matures leaves from two individual plants per block, water deficit treatment and cultivar at each of 5 times were selected for $g_s$ measurements.

At the termination of growing period (28 October 2016), plant height and diameter, leaf area (young, fully expended from the secondary branch), number and the length of primary and secondary branch were determined. The leaf blade area was measured using WinDIAS image analysis system (Delta-T Devices, UK). Additionally, the percentage of plant flowering and the number of floral buds per plant were counted. In case of poorly developed, difficult to distinguish buds, nodes were dissected longitudinally and analysed under stereoscopic microscope (CX41, Olympus, Japan).

The effects of regulated deficit irrigation (RDI) treatment on a range morphological and plant quality parameters were examined using one-way ANOVA. When the ANOVA indicated significant effects, means were separated using Tukey's HSD test, with $p < 0.05$ considered to be statistically significant.

## RESULTS AND DISCUSSION

Weather conditions and estimated daily reference evapotranspiration ($ET_0$) during the period of rhododendrons cultivation were presented in Figure 1. Air temperatures during the majority of this season were relatively average when compared to multiannual observations however above-average precipitation and high frequency of rainfall were noted.

Under temperate climate conditions most elepidote rhododendrons have usually two flushes of growth that terminated with a rosette of leaves followed by a flower bud. The first vegetative shoot flush occurs in the late spring, usually after the flowering period. Then there is often another flush of growth from new vegetative buds. The new shoots harden up after expanding, and vegetative and floral buds are formed for the next season's growth and bloom. In our experiment, water deficit treatments were imposed for nine weeks, starting from 5 July when growth of first flush terminated with the rosette of leaves was finished and secondary flush was visible. There was no significant effect of either moderate ($RDI_{75\%}$) or severe ($RDI_{50\%}$) deficit irrigation during the July-August period on the plant height, diameter, leaf area, the number and length of primary branch for all tested cultivars of *Rhododendron*, except significantly lower plants of 'Nowa

Zembla' exposed to RDI$_{50\%}$ compared to control (Table 1). However, secondary branches of 'Catawbiense Boursault', 'Nova Zembla' and 'Pearce's American Beauty' plants exposed to severe drought (RDI$_{50\%}$) were shorter, respectively by 39, 45 and 86% than well-irrigated plants and two of the three cultivars 'Catawbiense Boursault' and 'Pearce's American Beauty' produced fewer secondary branches (5.9 and 0.3) compared to control plants (9.2 and 1.7, respectively). Moderate to heavy rainfall occurred at the end of June and early July (Figure 1.) disrupted the methodical approach of reducing the amount of water for the plant at that time, which could cause a lack of difference between control, well-watered plants, and plants subjected to moderate deficit irrigation. Several authors were reported shorter internode in *Rhododendron* plants in response to water deficit. However, the effect of intensity irrigation on shoot elongation may vary depending on intensity and timing of the water stress imposed. Moderate water deficit imposed in July-August period suppressed significantly shoot length of *Rhododendron* 'Hoppy' only in July-August period and did not affect shoot elongation in June-July and August-September periods. Likewise, exposing plants to severe drought resulted in significant reduction in shoot growth in all these periods Cameron *et al.* (1999).

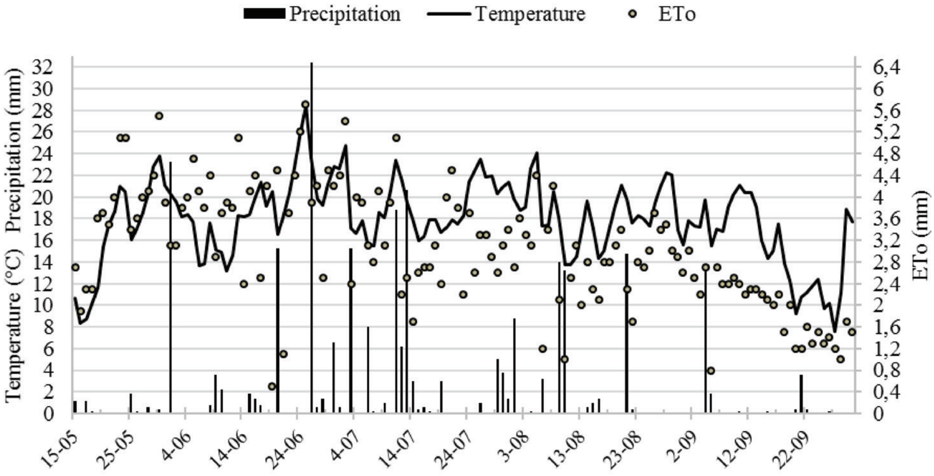

**Figure 1.** The average daily air temperature, precipitation and estimated daily reference evapotranspiration (ET$_0$)

Rhododendrons as some other woody ornamental species initiate more flowers under water stress as a result of resource mobilization for reproductive development (Sharp *et al.* 2009). In our experiment flower buds production in *Rhododendron* was dependent on the cultivar (Table 1). Well-watered two-years old 'Catawbiense Borsault' and 'Pearce's American Beauty' plants produced very few flower buds in contrast to more flower buds formed in ‘Nova Zembla’ plants (23% plants with at least one flower bud). Moderate deficit irrigation in July-August period affected flower bud formation in ‘Catawbiense Borsault’ and ‘Pearce’s American Beauty’ plants. The percentage of flowering plants imposed to moderate drought was 47% and 17% for ‘Catawbiense Borsault’ and ‘Pearce’s American Beauty’ plants compared to 23 and 3 % respectively for control treatment. Although values were not significantly greater than for similar well-watered plants, imposing a moderate degree of water stress after shoot growth has terminated may indeed enhance flower induction. Such a response has been observed in *Rhododendron* ‘Hoppy’ where water stress during late summer increased flowering (Cameron *et al.* 1999). The large variability in flowering the between individual *Rhododendron* plants may suggest that other factor as temperature or irradiance which can vary between individual shoot apices, also influence flowering response, as suggested by Cameron *et al.* (1999). There was no significant effect of either moderate or severe deficit irrigation treatments on the number of floral buds per plant.

In the literature there is a lot of research concerning the effect of drought stress on the stomatal conductance ($g_s$) in plants (Hura *et al.* 2007, Lenzi *et al.* 2009, Mafakheri *et al.* 2010, Kusvuran 2012, Ĉerekoviĉ *et al.* 2013, Cai *et al* 2015, Chowdury *et al.* 2016). The cultivars that have the high $g_s$ value under optimal water conditions and the low value during the drought stress as well as the fast recovery of $g_s$ after the cessation of water deficit, are characterized by an effective mechanism of adjustment of $g_s$ and are more drought tolerant than the plants in which no such an adaptation was observed.

The results of our experiment show that for all three tested cultivars of rhododendrons the using of moderate irrigation treatment during the July-August period ($RDI_{75\%}$) does not affect the reduction in $g_s$ value compared to control, well-watered plants (Figure 2). The application of severe deficit irrigation in this period ($RDI_{50\%}$) does not affect the $g_s$ value of ‘Pearce’s American Beauty’ plants in relation to the control. Similar observation was made for ‘Catawbiense Boursault’ shrubs except for the measurement on 16 August (6 weeks after the beginning of the diversified irrigation) when $g_s$ for this irrigation treatment was significantly lower than the control. However, when the $RDI_{50\%}$ irrigation treatment was applied for ‘Nova Zembla’ cultivar, it had been noted significantly lower $g_s$ for four measurement dates during the 9-week period of diversified irrigation. On 20 September, when the plants were watered the same way, the $g_s$ value did not differ significantly between the applied irrigation treatments for all three cultivars. The measurements of $g_s$ show that among the three *Rhododendron* cultivars examined, ‘Nova Zembla’ was characterized by the most sensitive mechanism of cellular regulation of stomatal conductance under drought stress. The level of water stress imposed by our treatments was lower than the $g_s$ reported in the study (Sharp *et al.* 2008). Deficit irrigation treatments in these studies caused large decreases in $g_s$ value for 'Hatsugiri' cultivar to the value about 50 mmol $m^{-2}$ $s^{-1}$, compared to about 400 mmol $m^{-2}$ $s^{-1}$ in well-watered plants. In our experiment during measurement dates $g_s$ was not lower than 200 mmol $m^{-2}$ $s^{-1}$.

**Table 1**. Effects of the irrigation regimes well-watered (control), moderate ($RDI_{75\%}$) and severe ($RDI_{50\%}$) regulated deficit irrigation on vegetative growth, plant brunch production, percentage of plants with floral buds and floral buds per plant in *Rhododendron* 'Catawbiense Boursault', 'Nova Zembla' and 'Pearce's American Beauty'

| Treatment | Plant height (cm) | Plant diameter (cm) | Leaf area ($cm^2$) | Number of primary branch | Length of primary branch (cm) | Number of secondary branch | Length of secondary branch (cm) | Percentage of plants floral | Number of flower buds per plant |
|---|---|---|---|---|---|---|---|---|---|
| **Catawbiense Boursault** | | | | | | | | | |
| Control | 37.4 a | 33.8 a | 24.0 a | 6.2 a | 4.5 a | 9.2 b | 8.5 b | 0 | - |
| $RDI_{75\%}$ | 37.0 a | 32.8 a | 26.5 a | 4.8 a | 4.0 a | 10.8 b | 7.9 b | 0 | - |
| $RDI_{50\%}$ | 34.4 a | 33.5 a | 25.4 a | 5.4 a | 5.5 a | 5.9 a | 5.2 a | 10.0 | 2.0 |
| **Nova Zembla** | | | | | | | | | |
| Control | 40.5 b | 32.8 a | 26.4 a | 4.9 a | 6.3 a | 6.7 a | 8.6 b | 23.3 a | 1.8 a |
| $RDI_{75\%}$ | 42.6 b | 32.4 a | 32.2 a | 4.5 a | 6.8 a | 6.6 a | 8.4 b | 46.7 a | 1.8 a |
| $RDI_{50\%}$ | 37.3 a | 33.8 a | 26.6 a | 4.6 a | 8.0 a | 4.9 a | 4.7 a | 46.7 a | 1.6 a |
| **Pearce's American Beauty** | | | | | | | | | |
| Control | 28.4 a | 30.4 a | 32.7 a | 4.8 a | 5.6 a | 1.7 b | 4.4 b | 3.3 a | 1.0 a |
| $RDI_{75\%}$ | 27.6 a | 29.1 a | 36.7 a | 4.5 a | 6.6 a | 0.8 ab | 2.1 ab | 16.7 a | 1.0 a |
| $RDI_{50\%}$ | 27.3 a | 30.1 a | 36.0 a | 4.6 a | 6.6 a | 0.3 a | 0.6 a | 3.3 a | 2.0 a |

Scagel *et al.* (2011) examined $g_s$ in 'English Roseum' and 'P.J.M Compact' *Rhododendron* cultivars plants applied diversified irrigation from July to August. The higher value of $g_s$ averaged for using irrigation treatments observed for 'P.J.M Compact' compared to 'English Roseum', although 'English Roseum' cultivar is characterized by a greater plant size and thus also higher water demand. 'English Roseum' cultivar was subjected to greater water stress than 'P.J.M Compact'. The recovery of $g_s$ in the fall was greater in 'P.J.M Compact' than 'English Roseum'. The recovery response of $g_s$ often observed in plants in autumn after the cessation of water deficit may indicate the strength of drought stress (Vaz *et al.* 2010).

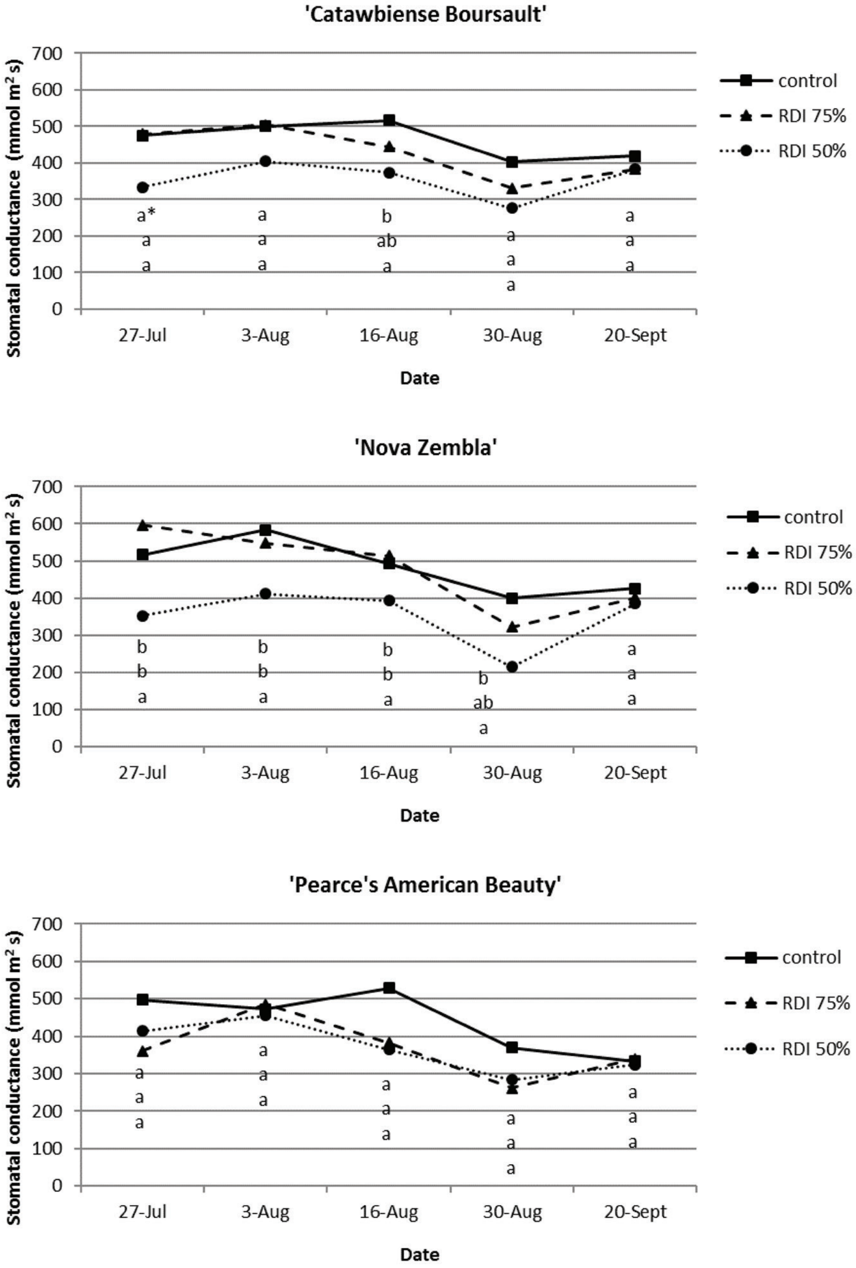

**Figure 2**. Diurnal response of *Rhododendron* Catawbiense Boursault, Nova Zembla and Pearce's American Beauty in well-watered (control), moderate (RDI 75%) and severe (RDI 50%) regulated deficit irrigation

Low value of $g_s$ as a result of the closing of the stomata and thus reduced maximal net photosynthetic rate in winter is characteristic for *Rhododendron* may be adaptations to winter drought (Ranney *et al.* 1995, Harris *et al.* 2006). Muras and Lukosek (2000) conducting research on the cold hardiness of rhododendrons showed that in the first research season of 'Catawbiense Boursault' and 'Nova Zembla' had similar frost tolerance, while in the next year it reported significantly lower levels of frost damages for 'Nova Zembla' than for 'Catawbiense Boursault'. It may demonstrate a more effective mechanism of adjustment of stomatal conductance in 'Nova Zembla' cultivar under frost stress, which is also consistent with our observations $g_s$ under drought stress.

## CONCLUSIONS

Improving the efficiency of irrigation and conserving water supply have become of high importance to commercial nurseries. The results presented here demonstrated that water consumption by irrigation system can be reduced by 25% over the nine week July-August period without significantly affecting final growth and by 50% without incurring serious plant injury. The estimated relative use of water throughout the whole growing season was 85% for $RDI_{75\%}$, 75% for $RDI_{50\%}$ and 100% for control, well-watered plants. Additional advantages other than controlling excessive growth of rhododendrons associate with imposing moderated water stress through controlled irrigation may be enhanced cold tolerance (Anisko and Lindstrom 1996) and belter growth after planting out (Scagel *et al.* 2011).

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