The effect of irrigation frequency on growth, flowering and stomatal conductance of osteospermum ‘Denebola’ and New Guinea impatiens ‘Timor’ grown on ebb-and-flow benches

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(Received: 16.05.2001)

S u m m a r y

The response of osteospermum ‘Denebola’ and New Guinea impatiens ‘Timor’ grown on ebb-and-flow benches to different water potential of growing medium applied during whole growing period was investigated by measuring plant growth parameters and stomatal conductance (g_s). After cutting establishment, four different irrigation treatments based on soil water potential were applied to osteospermum: at -0.5 , -3.0 , -10.0 , -20 kPa. In the case of impatiens the last water treatment was omitted. Plants were evaluated when they reach one of the three growth stages: lateral shoots development, visible flower buds (osteospermum) or beginning of flowering (impatiens) and at flowering. All plants produced with a moderate water deficit (irrigation at -3 and -10 kPa) were more compact than plants irrigated at -0.5 kPa but their flowering were not affected. Strong decrease in plant growth and flowering was observed when plants were irrigated at the lowest water potential (-20 kPa). However, for impatiens the highest irrigation frequency was also not favorable. As a result of water stress the decrease in stomatal conductance (g_s) in both plants was observed. Osteospermum was more resistant to water stress than impatiens.

Key words: osteospermum, New Guinea impatiens, soil water potential, stomatal conductance, ebb-and-flow benches

INTRODUCTION

Bedding plants are very often cultivated on ebb-and-flow benches with very good results. Usually these plants are grown in small pots with low amount of soil and need frequent fertigation. Flooded bench fertigation system is very suitable to ensure proper irrigation, saving water and nutrients and could be easily automated (Molitor, 1990; Otten, 1994). This closed system allows complete recycling of nutrient solutions, which preserve clean water sources.

Plants chosen in this research, impatiens and osteospermum show similar pattern in response to excess of water during the production phase, yellowing and dropping leaves and problems with root system. Impatiens transpires large quantities of water but does not grow well in water logged media. However, this plant is known to show very fast the symptoms of water deficit as a loss of leaves turgor and plant wilting. Good water management is crucial for the success of New Guinea impatiens culture (Hartley, 1995). Osteospermum belongs to *Asteraceae* family. In the last few years many new varieties with attractive flower colors and also variegated foliage appeared on the market, however it is still rather new plant. Osteospermum could be grown as a pot, balcony boxes or bedding plant (Erwin, 1994; Deiser, Eichin, 1998). These plants are usually propagated by cuttings, well tolerate moderate water stress, require for good flowering sunny places, and should be prevented from excessive temperature and feeding.

Usually growth retardants such as flurprimidol, uniconazole, chloromequat and paclobutrazol are recommended to keep plant short (Deiser, Eichin, 1998; Erwin, 1994; Wichers-Olsen, 1993; Olsen, Andersen, 1995). However, low phosphorus level in growing medium caused also plant dwarfing and accelerated flowering of New Guinea impatiens (Nowak, Sroka, 2001) but delaying flowering time of osteospermum (Nowak, 2001). There have been no studies on the effect of water stress on osteospermum shape and flowering. It seems promising to use moderate water stress as a tool to control plant height without losing plant quality.

The objective of the research was to determine how the bedding plants: osteospermum and impatiens respond to different levels of steady-state water deficit during production phase on ebb-and-flow benches.

MATERIALS AND METHODS

Rooted cuttings of *Osteospermum ecklonis* 'Denebola' were planted on 10 March 1999 into 10-cm-wide pots, using a sphagnum peat as a growing medium and placed on ebb-and-flow benches (Clauhan Project A/S, Denmark). The growing medium was amended before planting with P at 2.07 mM dm⁻³ (from triple superphosphate) and pH was adjusted to 5.8 with CaCO₃. Plants were pinched once, 10 days after potting. Nutrient solution used for fertigation (EC 1.5 mScm⁻¹) contained all macro and microelements except P: NO₃⁻ 8.57; K⁺ 9.12; Ca²⁺ 2.15; Mg²⁺ 0.63; SO₄⁻ 0.026 (mmol dm⁻³); and Mn 4.6; Fe 8.9; B 6.2; Cu 0.56; Mo 0.09; Zn 4.8 (μmol dm⁻³). After cutting establishment, four different irrigation treatments based on soil water

potential were applied. Plants were irrigated according to soil water potential: at - 0.5, - 3.0, - 10.0, - 20 kPa. Soil water potential was measured using tensiometers. The tensiometer's cup was inserted vertically halfway between the bottom of the pot and top of the growing medium. Plants from each irrigation treatments were placed on separate benches in completely randomized design. There were 60 plants per each treatment. Plant density, 36 plant per one square meter, was decreased after 6 weeks to 30 plants per square meter. The temperature was initially kept at 13°C (5 weeks vernalization period) and later on was risen to 15–18°C. Morphological growth parameters such as: plant height, number of flower buds, flowers, leaves and leaf area were determined at three different plant growth stages: lateral shoots sprouting, visible flowering buds and flowering. Ten uniform plants were randomly sampled and harvested from each growing phase and experimental treatment. Leaf area was measured using Leaf Area Meter (Delta-T Devices LTD, Cambridge, UK). The stomatal conductance (g) was determined three times at each growing stage (during few days around the stage) on 6 plants and 3 fully developed leaves per each plant using portable porometer (LICOR, 1600M, Nebraska, USA). The measurements were taken when growing conditions were favorable for stomata opening and transpiration (only on sunny days between 10-12 a.m., and when soil water potential reached the desirable values). The results were shown on graphs and the differences between treatments were evaluated using standard errors.

Uniform, rooted cuttings of New Guinea impatiens 'Timor' (*Impatiens hawkerii* Bull.) were planted on 28 July 1999. Plants were grown in the same conditions as osteospermum, except water stress treatments. Knowing the greater sensitivity of impatiens to water than osteospermum only three soil water potential treatments were applied. Plants were irrigated at: - 0.5, - 3.0 and - 10.0 kPa of soil potential. Plants were grown without pinching. The night temperature in the greenhouse was kept at 16°C and the day ventilation set-point was 22°C. The growing stages for impatiens were specified as: lateral shoots sprouting (two weeks after potting), beginning of flowering and full flowering. All measurements were made in similar way as for osteospermum.

The data were subjected to analysis of variance and the means were tested by Duncan's multiple range test. The results of stomatal conductance were shown on graphs and the differences between treatments were evaluated using standard errors.

RESULTS AND DISCUSSION

Water stress, applied during whole growing period, significantly reduced plant growth, (tables 1 and 2). However, plant responses to water stress depended on growth stage. During the first growth stage - lateral shoot sprouting (evaluated one month after planting for osteospermum and two weeks for impatiens) plant growth was not suppressed, irrespective the water treatment, except plant height. The heights of osteospermum and impatiens grown at the lowest irrigation frequencies were reduced by 20% and 11%, respectively, as compared with plants irrigated at - 0.5 kPa. Strong, positive correlation between irrigation frequency and growth of spray chrysanthemum cuttings has been observed by B u w a l d a, K i m (1994). H e i n s, E r w i n (1993)

have also reported that water is one of the most powerful non-chemical tools to manage the height of bedding plant. According to Liptay et al. (1998) mild water deficit stress, could be desirable in transplant production (flowers and vegetables) resulting not only in optimal plant shape but also better tolerance to other stresses after outdoor transplanting.

During the second growth phase (evaluation at visible flower buds for osteospermum and beginning of flowering for impatiens) the symptoms of water stress become more pronounced for both plants. The highest osteospermum and impatiens plants were obtained at the highest irrigation frequency (-0.5 kPa). Osteospermum irrigated at -20 kPa had reduced plant height, fresh and dry weight, leaf number and leaf area and flower buds number by 14.5, 24, 16, 22, 30 and 24%, respectively, comparing with plants irrigated at -0.5 kPa. Water stress decreased also leaf number and leaf area in potted roses (Williams et al., 1999), poinsettia (Nowak, Strojny, 1998) and plant height in *Begonia elatior* (Hassenbusch, 1994). Impatiens irrigated at -10 kPa reduced plant height, fresh and dry weight and flower buds number by 22, 36, 25 and 28%, respectively, comparing with plants irrigated at -0.5 kPa, but their leaf number, leaf area and open flower number were not affected. Except plant height, there have been no differences between plants irrigated at -0.5 and at -3.0 kPa.

At flowering, both tested plants, irrigated with the lowest frequencies (at -20 kPa osteospermum and -10 kPa impatiens) exhibit the worse quality. The production time from planting to flowering of osteospermum and impatiens was not influenced by reduced water availability. In the case of osteospermum this results are consistent with earlier reports, presented by Nowak (2000). Both plants increased fresh and dry matter production with increasing irrigation frequency. Similar results has been shown for impatiens (Meyer et al., 1993), pot roses (Williams et al., 1999) and for plants with ornamental foliage like *Codiaeum* (De Kreij, Straver, 1988), *Ficus lyrata* and *F. benjamina* 'Exotica' (Treder et al., 1996). Frequent irrigation enhanced strongly vegetative growth of osteospermum but flowering was not better. The results of present study showed that osteospermum flower number was not affected by irrigation treatment but flower buds number was greater when plants were irrigated at -3 kPa. Flower diameter was also strongly restricted due to water stress. Similar results for osteospermum has been shown by Nowak (2000). Some flowering pot plants like *Petunia* also exhibited decreased flowering with less frequent watering but pansy flowering was not altered (Flöhr, Conover, 1995). However, *Cyclamen* performed better and had more flowers at lower irrigation frequencies (D'Angelo et al., 1988). Not only the irrigation frequency but also water quantity during irrigation could affect plant flowering. Pot roses formed fewer flower buds when plants were steady-state irrigated at 60 and 75% of daily water consumption of the control plants (Williams et al., 1999). In the case of ebb-and-flow benches water quantity applied to the plants could be operated by time of plant flooding and irrigation frequency. Considering the better plant shape and good flowering of osteospermum irrigation at -3 to -10 kPa is advised.

Optimum plant shape and the best flowering of impatiens were obtained when plants were irrigated at -3 kPa. Plants irrigated at -0.5 kPa had similar plant heights,

Fig. 1. Stomatal conductance (g) of osteospermum (A) and impatiens (B) as affected by irrigation frequency and plant growth stage

Table 1.
Effect of irrigation frequency on growth and flowering of osteospermum, evaluated at three different growth stages

Growth stage	Soil water potential (kPa)	Plant weight (cm)	Fresh weight (g)	Dry weight (g)	Leaf number	Leaf area (cm ²)	Flower buds number	Flower number	Flower diameter (cm)	Plant diameter (cm)
Lateral shoots sprouting	-0.5	11,4 b	12,9 a	1,2 a	7,6 a	92 a				
	-3.0	10,3 ab	13,6 a	1,2 a	8,4 a	112 a				
	-10	10,0 ab	10,6 a	0,9 a	8,0 a	69 a				
	-20	9,1 a	12,0 a	1,1 a	6,8 a	101 a				
Visible flower buds	-0.5	28,3 f	53,1 d	6,2 c	112 de	606 e	16,6 f			
	-3.0	25,9 de	50,6 d	6,1 c	110 de	536 d	17,4 f			
	-10	20,5 c	37,9 b	4,8 b	93 bc	451 c	13,2 e			
	-20	24,2 d	40,3 b	5,2 b	87 b	424 b	11,8 d			
Flowering	-0.5	35,6 g	70,2 f	10,0 f	165 g	616 e	4,4 bc	12,9 a	6,8 c	31,1 c
	-3.0	34,2 g	64,4 e	9,8 f	152,1 f	547 d	5,5 c	12,1 a	6,8 c	29,1 b
	-10	28,8 f	51,1 d	8,2 e	118 e	489 c	3,1 b	12,1 a	6,3 b	29,2 b
	-20	27,3 ef	46,0 c	7,1 d	103 cd	419 b	1,3 a	12,3 a	4,9 a	23,6 a
Significance level		**	**	**	**	**	**			
Growth stage		**	**	**	**	**	**		**	**
Soil water potential		**	**	**	**	**	**	NS		
Interaction		**	**	**	**	**	**			

Explanations:

Values followed by the same letter are not different at 5% level of significance, according to Duncan's range test,

**, *, NS means: significant at 0,01, at 0,05 and not significant.

Table 2.

Effect of irrigation frequency on growth and flowering of impatiens, evaluated at three different growth stages

Growth stage	Soil water potential (kPa)	Plant weight (cm)	Fresh weight (g)	Dry weight (g)	Leaf number	Leaf area (cm ²)	Flowers buds number	Flower number
Lateral shoots sprouting	-0.5	7,9 b	8,8 a	1,0 a	15,0 a	143 a		
	-3.0	7,9 b	7,8 a	1,0 a	17,2 a	140 a		
	-10	7,0 a	8,1 a	0,9 a	15,8 a	100 a		
Beginning of flowering	-0.5	12,4 ef	38,7 c	3,2 c	29,4 b	358 b	10,2 b	7,4 a
	-3.0	11,5 d	33,9 c	3,2 c	29,2 b	363 b	10,3 b	6,0 a
	-10	9,7 c	24,9 b	2,4 b	31,2 b	332 b	7,4 a	7,6 a
Full flowering	-0.5	12,4 ef	41,9 d	3,5 d	39,0 c	426 c	8,4 ab	8,4 a
	-3.0	12,8 f	49,0 e	4,0 e	40,3 c	439 c	9,9 bc	13,5 b
	-10	11,7 de	33,0 c	3,0 c	30,5 b	384 bc	6,3 a	6,9 a
Significance level								
Growth stage		**	**	**	**	**	**	**
Soil water potential		**	**	**	NS	NS	**	**
Interaction		**	**	**	*	NS	NS	**

Explanations:

Values followed by the same letter are not different at 5% level of significance, according to Duncan's range test, **, *, NS means: significant at 0,01 at 0,05 and not significant.

leaf number and leaf area, however they had significantly fewer flowers (38%) and flower buds (15%) than plant irrigated at - 3 kPa. The reason for worse growth and flowering of impatiens grown with frequent irrigation could be explained by sensitivity of root system to excess of water in the growing medium. It seems that the optimum soil moisture range of growing medium for impatiens is narrower than that of osteospermum. Exposing impatiens to severe and longer water stress could lead to bud and leaf dropping, plant dwarfing and consequently lost of plant quality (Hartley, 1995). Container-grown *Rhododendron* showed also restricted growth and flower bud setting as a result of drought stress (Cameron et al., 1999).

The worse growth obtained when plants were irrigated at the lowest irrigation frequencies (- 20 kPa, for osteospermum and - 10 kPa for impatiens) could be affected not only by water availability but also the higher salinity levels, building up in the growing medium, between the irrigations. Morgan and Reed (1998) showed that New Guinea impatiens growth and quality decreased as salinity level in growing medium was increased.

Comparing the ratio of dry weights per unit area (mean for all water treatments) of both plants the obtained data for osteospermum were twice higher (16.95 mg cm^{-2}) than for impatiens (8.37 mg cm^{-2}), indicating that osteospermum is more efficient in dry matter accumulation and is more resistant to water stress. The dry mass production per unit leaf area and volume of used water of pot roses exposed to moderate water stress were greater than that of non-stressed plants (Williams et al., 1999).

One of the mechanisms developed by plants in response to moderate water stress is better water management thorough decreased leaf area and stomata opening (Barr et al., 1986). Osteospermum regulated leaf area in greater proportion to the level of water stress experienced by the plant than impatiens did (tables 1 and 2). These data were in accordance with results of stomatal conductance (g_s) of osteospermum (Fig. 1A) and impatiens (Fig. 1B.), evaluated during three growth stages. Irrespective the water treatment and growth stage, g_s level was higher for impatiens than for osteospermum. However, in both plants g_s decreased with increasing water stress level and growth phase. During the consecutive growth phases, the differences of g_s between plants irrigated with the highest and lowest irrigation frequency was: 20%, 52%, 80% for osteospermum and 22%, 38 and 52% for impatiens, respectively. The behaviour of osteospermum and impatiens was similar to that of pot roses (Williams et al., 1999), poinsettia (Schuch et al., 1996) and *Salvia* (Eks et al., 1991). Williams et al., (1999) reported also that decrease of g_s of pot roses was followed by decline in photosynthesis activity but in lesser extent than g_s . The results of present study pointed out that using proper water management on ebb-and-flow benches is possible to obtain high quality osteospermum and impatiens, with good shape, many flowers and well adapted to post-production conditions. Due to different water requirements these plants should not be placed together, on the same benches during greenhouse production.

Acknowledgement

The financial support of Polish State Committee for Scientific Research, Project No. 0691/PO6/98/15 (1998-2001) is gratefully acknowledged

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Wpływ częstotliwości nawadniania na wzrost, kwitnienie oraz przewodność szparkową *Osteospermum* „Denebola” i *Impatiens* New Guinea „Timor” uprawianych na stołach zalewowych

Streszczenie

Badano wpływ częstotliwości nawadniania na wzrost, kwitnienie i przewodnictwo szparkowe dwóch roślin rabatowych: *Osteospermum ecklonis* „Denebola” i niecierpka nowogwinejskiego „Timor”. Rośliny uprawiano przy czterech częstotliwościach nawadniania (*osteospermum*) i trzech (niecierpek). Częstotliwość nawadniania oparto na pomiarach siły ssącej podłoża. *Osteospermum* nawadniano przy - 0,5, - 3,0, - 10,0 i - 20 kPa, zaś niecierpek podobnie, z pominięciem ostatniego poziomu (- 20 kPa). Wzrost roślin oceniano w trzech fazach rozwojowych: krzewienia, fazy widocznych pąków i kwitnienia u *osteospermum* oraz fazy krzewienia, początku kwitnienia i pełni kwitnienia u niecierpka. Rośliny poddane umiarkowanemu stresowi wodnemu podczas uprawy miały lepszy pokrój niż rośliny nawadniane przy sile ssącej - 0,5 kPa, natomiast ich kwitnienie nie było zaburzone. Silne zahamowanie wzrostu i pogorszenie kwitnienia obserwowano stosując podlewanie przy najniższym potencjale wodnym podłoża. W wyniku stresu wodnego zaobserwowano znaczne ograniczenie przewodnictwa szparkowego liści. *Osteospermum* lepiej tolerowało ograniczenie częstotliwości nawadniania podczas uprawy niż niecierpek.