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The growth and flowering of *Rhodohypoxis baurii* (Baker) Nel cultivars depending on rhizome weight

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ABSTRACT

Rhodohypoxis baurii is an ornamental plant recommended for pot and garden cultivation. The aim of this study was to determine the relationships between rhizome weight and the growth, flowering and rhizome yield in two cultivars ('Dusky' and 'Ruth') of *R. baurii* grown as pot plants. The rhizomes were sorted into three groups by weight: 0.10-0.20 g, 0.21-0.30 g and 0.31-0.40 g. The study revealed that the plants developed from the largest rhizomes were the highest, the widest, produced the most leaves, inflorescences per rhizome, flowers per inflorescence and were the first to flower. The plants developed from rhizomes of 0.21-0.30 g and 0.31-0.40 g did not differ in their flowering rate, flower diameter or the weight of rhizomes at the end of the growing season. Flowers developed in all of the plants grown from rhizomes weighing at least 0.2 g. A comparison of cultivars showed that 'Dusky' plants were higher, wider, had more leaves, inflorescences and flowers per inflorescence, flowered earlier and produced rhizomes of greater weight than 'Ruth' plants, which had a higher greenness index and larger flowers. Both cultivars did not differ in their flowering rate. Rhizome weight gain after the cultivation period depended rather on the cultivar than on the size of the planted rhizomes.

Key words: ornamentals geophytes, pot plant, storage organ size

INTRODUCTION

The selection of ornamental geophytes offered as pot plants in the summer is limited and needs to be enriched with new species and cultivars. One of of the more interesting geophytes is *Rhodohypoxis baurii* (Baker) Nel from the Hypoxidaceae family (Duncan 2013). It is an endemic plant that grows naturally in mountainous regions of South Africa, Lesotho and Swaziland, covering moist, grassy slopes at about 2,400 m a.s.l. (Upfold et al. 1992, Pooley 1998). According to Thompson (1976) and Nordal (1998), the underground storage organs of species of the *Rhodohypoxis* Nel genus and of related genus *Hypoxis* have a tuberous erect rhizome. Following a dormancy period, the rhizomes produce grassy leaves in the form of a rosette and 10-15 cm long shoots ending with inflorescences composed of 1-3 star-shaped flowers of different shades of pink, red or white (Pooley 1998, Duncan 2003). The inflorescences develop gradually over a period of several weeks (Singh 2000). The horticultural market offers a few botanical forms and several varieties of *R. baurii*, differing mainly in the colour, shape and size of flowers. *R. baurii* is used as a pot plant for decorating interiors, balconies and terraces or as a ground-cover plant in rock gardens in England, Japan, Australia and New Zealand (Mori and Sakanishi 1990). *R. baurii* is still uncommon in Central and Eastern Europe.

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The main factor affecting the growth and yield of geophytes is the size of their underground organs (Werger and Huber 2006, Addai and Scott 2011, Puntieri et al. 2014). Numerous studies have proven that the weight of corms, bulbs or rhizomes significantly affects morphological traits (Morales et al. 2009, Thompson et al. 2011, Noor-Ul-Amin et al. 2013), flowering (Shinoda and Murata 2005, Bezu and Kassa 2014, Salachna 2014), and progeny multiplication (Clark et al. 2013, Douglas et al. 2014, Kapczyńska 2014).

The available literature lacks detailed data on the effects of agricultural procedures on the growth and development of *R. baurii*, including the relationship between the size of the underground organs and yield. Considering the above, the aim of this study was to find out how the rhizome weight affects morphological traits and flowering in two varieties of *R. baurii* grown as pot plants.

MATERIAL AND METHODS

Dried rhizomes of two *Rhodohypoxis baurii* cultivars, 'Dusky' (pink) and 'Ruth' (white-pink) were imported in the spring from the Netherlands by the horticultural company Ogrodnictwo Wiśniewski Jacek Junior. The rhizomes were sorted by weight into three groups (0.10-0.20 g; 0.21 -0.30 g; 0.31-0.40 g), after weighing on an electronic scale (RADWAG PS 200/2000/C/2) with an accuracy of 0.001 g. *Penicillium* and *Fusarium* protection was provided by treating the rhizomes for 30 min with a suspension of 0.7% (w/v) Topsin M 500 SC (Nippon Soda, Tokyo, Japan, active ingredient: thiophanate-methyl) and 1% (w/v) Kaptan 50 WP (Organika-Azot Chemical Company, Jaworzno, Poland, active ingredient: Captan). After drying, the rhizomes were planted on 16 April 2014 at a depth of 2 cm into 0.4 dm^{-3} black PVC pots 10 cm in diameter (one rhizome per pot) containing TS1 substrate (Klasmann-Delimann, Germany), mixed 2:1 (v:v) with 2-6 mm perlite (Knauff, Dortmund, Germany). Chemical analysis performed at an accredited laboratory of the Chemical and Agricultural Station in Szczecin revealed that the salinity of the TS1 substrate was 1.86 g NaCl dm^{-3}, pH was 5.5 and it contained 181 mg dm^{-3} $N\text{-}NO_3$, 131 mg dm^{-3} P, 402 mg dm^{-3} K, 1646 mg dm^{-3} Ca, 172 mg dm^{-3} Mg, and 18 mg dm^{-3} Cl. The pots were placed on 80 cm high tables in a tunnel covered with a double layer of plastic belonging to the West Pomeranian University of Technology in Szczecin (53°25' N, 14°32' E; 25 m a.s.l.). Mean monthly air temperatures were: April 15.1ºC, May 18.9ºC, June 19.7ºC, July 24.1°C, August 19.6ºC, September 18.3ºC, October 16.2ºC.

The beginning of flowering was the day on which fully opened flowers were noticed in 5% of plants per individual variant. Biometric measurements were performed on 20 July 2014, when the plants were in full bloom. The measured parameters included plant height (measured from the soil level to the uppermost part of the inflorescence), plant width (measured at the widest point of the plant), the number of leaves per plant, percentage of flowering plants, the number of inflorescences per rhizome, the number of flowers per inflorescence and the diameter of the first flowers in inflorescence. A SPAD 502 chlorophyll meter (Konica-Minolta Corporation, Osaka, Japan) was used to evaluate the leaf greenness index. The measurements were performed on five randomly selected and well-developed leaves. At the end of the growing season, on 15 October 2014, the plants were removed from the pots, the dried overground parts were discarded and the lifted rhizomes with bulbous roots were weighed.

The experiment was conducted in a completely randomized design. Six experimental variants were evaluated, i.e. three different rhizome weights and two cultivars. Each variant included 40 rhizomes, planted in four replicates of 10 rhizomes. The results were statistically analysed using a two-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

There was no significant interaction between rhizome weight and cultivar for any of the evaluated parameters (Tab. 1). The height of *Rhodohypoxis baurii* plants depended on the cultivar and weight of the planted rhizomes (Tab. 2). The plants grown from the largest rhizomes, i.e. 0.31-0.40 g, were significantly higher than those grown from smaller rhizomes. 'Dusky' was found to be 3.2 cm higher than 'Ruth', irrespective of rhizome weight. These results are consistent with those reported in a study on the effect of corm and bulb size on the yield of two South African native plants – *Sparaxis tricolor* and *Lachenalia* (Kapczyńska 2008, 2014), which showed that the plants obtained from organs with a larger circumference and weight were significantly higher.

The widest plants were obtained from 0.31 -0.40 g rhizomes (Tab. 2). 'Dusky' plants were 5.6 cm wider than 'Ruth' ones. They also had more leaves, irrespective of the weight of the rhizomes. A similar number of leaves (13.1) was reported in

Table 1. ANOVA *p*-values showing the effect of rhizome weight and cultivar on the growth and flowering of *Rhodohypoxis baurii*

Trait	Source		
	Rhizome weight	Cultivar	Rhizome weight × Cultivar
Plant height (cm)	**	**	ns
Plant width (cm)	*	*	ns
Number of leaves	*	**	ns
Greenness index (SPAD)	ns[a]	*	ns
Days to flowering	*	**	ns
Flowering (%)	*	ns	ns
Number of inflorescences	**	*	ns
Number of flowers	*	*	ns
Flower diameter (cm)	*	*	ns
Final rhizome weight (g)	**	**	ns

[a] not significant; * $p < 0.05$; ** $p < 0.01$

R. baurii var. *platypetala* grown under long-day conditions at 20-30°C (Mori and Sakanishi 1990).

This study showed a significant relationship between the rhizome weight and number of *R. baurii* leaves. The highest number of leaves (11.7) was found in the plants developed from the largest rhizomes. The plants grown from smaller rhizomes weighing 0.10-0.20 g and 0.21-0.30 g developed 8.4 leaves on average (Tab. 2). A similar relationship between underground organ weight and number of leaves was reported for other South African geophytes. Thompson et al. (2011) found the greatest number of leaves in *Watsonia borbonica* and *Watsonia pillansii* plants grown from the largest corms (41-60 g in *W. borbonica* and 21-40 g in *W. pillansii*).

A comparison of the investigated cultivars indicated that the leaves of 'Ruth' were darker and their greenness index was 13.6 SPAD units higher than in 'Dusky' (Tab. 2).

The weight of planted *R. baurii* rhizomes determined the weight of rhizomes with bulbous roots obtained at the end of the growing period (Tab. 2). Plants developed from the rhizomes originally weighing 0.31-0.40 g and 0.21-0.30 g yielded significantly greater rhizomes with bulbous roots than the plants grown from the smallest rhizomes of 0.10-0.20 g. The weight of the final rhizomes with bulbous roots was over two times greater in 'Dusky' than in 'Ruth'. A direct relationship between the initial weight of the underground organs and their weight after the growing season was reported for *Aconitum napellus* (Watad et al. 1999), *Babiana rigens* (Clark et al. 2013), *Dichelostemma ida-maia* (Han 2001), *Erythronium* 'Pagoda' (Shinoda and Murata 2005) and *Triteleia bridgseii* (Han 2001).

Advanced flowering is particularly important in the cultivation of ornamental plants, as it facilitates planning the production for specific dates. According to Mori and Sakanishi (1990), the advanced flowering of *R. baurii* depends on the temperature during rhizome storage, cultivation and planting date. According to these authors, the first to flower (35 days from planting) were the plants grown from the rhizome planted on 14 April and stored for 18 weeks at 6°C. In our study, the number of days from planting to flowering depended on the cultivar and rhizome weight (Tab. 3). 'Dusky' plants flowered 11 days before 'Ruth'. Regardless of the

Table 2. Effect of rhizome weight and cultivar on morphological features, greenness index and final rhizome yield of *Rhodohypoxis baurii*

Experimental factors		Plant height (cm)	Plant width (cm)	Number of leaves	Greenness index (SPAD)	Final rhizome weight (g)
Rhizome weight (g)	0.10-0.20	6.5 b*	13.0 b	8.3 b	48.7 a	2.4 b
	0.21-0.30	6.5 b	12.0 b	8.5 b	49.4 a	2.7 a
	0.31-0.40	9.2 a	14.3 a	11.7 a	48.4 a	2.8 a
Cultivar	Dusky	9.0 a	13.0 a	15.8 a	42.0 b	3.6 a
	Ruth	5.8 b	7.4 b	10.4 b	55.6 a	1.7 b

*Mean values in each column followed by a different lowercase letter are significantly different by Tukey's least significant difference test (LSD) at $p < 0.05$

Table 3. Effect of rhizome weight and cultivar on flowering time, its efficiency and flower quality of *Rhodohypoxis baurii*

Experimental factors		Days to flowering	Flowering (%)	Number of inflorescences	Number of flowers per inflorescence	Flower diameter (cm)
Rhizome weight (g)	0.10-0.20	67 a*	79 b	4.4 b	2.5 b	2.6 b
	0.21-0.30	65 a	100 a	4.8 b	2.7 b	2.7 a
	0.31-0.40	61 b	100 a	6.0 a	3.2 a	2.8 a
Cultivar	Dusky	59 b	92 a	6.2 a	3.2 a	2.5 b
	Ruth	70 a	94 a	3.9 b	2.4 b	2.7 a

*Explanations: see Table 2

cultivar, the first to flower were the plants grown from the largest rhizomes weighing 0.31-0.40 g. The plants developed from smaller rhizomes of 0.21 -0.30 g and 0.10-0.20 g flowered 4 and 6 days later, respectively. In other species of Cape Province, i.e. *Sparaxis tricolor* and *Babiana ringens*, flowering also started with plants grown from the largest corms (Kapczyńska 2008, Clark et al. 2013).

The weight of *R. baurii* rhizomes affected plant ability to flower (Tab. 3). Flowers developed in 79% of the plants grown from the smallest rhizomes and in all of the plants grown from the other rhizome sizes. The studied cultivars did not differ in their flowering ability. As shown by Mori and Sakanishi (1990), the percent of plants flowered in *R. baurii* var. *platypetala* depended on planting date, temperature and rhizome storage period. The authors observed a 100% flowering rate when the rhizomes were stored for 12-18 weeks at 6-10°C and then planted between 20 February and 20 March and grown at a minimum temperature of 10°C. The flowering ability of geophytes is largely determined by the size of their underground organs (Shinoda and Murata 2005, Clark et al. 2013), which was also confirmed in this study. The minimum size of underground organs ensuring 100% flowering is different for individual taxa and is often affected by environmental conditions. For example, in *Aconitum napellus* the minimum weight is 30-40 g, in *Dichelostemma ida-maia* 1.35 g, in *Erythronium* 'Pagoda' 15.4 g, in *Babiana ringens* 1.0 g, in wild species of *Triteleia bridgesii* and *Triteleia ixioides* 0.9 g and 0.3 g, respectively, and in cultivars of these species 0.8 g and 3.6 g, respectively (Watad et al. 1999, Han 2001, Shinoda and Murata 2005, Clark et al. 2013). In some species, flower formation ability is determined by the size of the apical meristem rather than the bulb weight (Halevy 1990, Han et al. 1991).

The highest number of inflorescences and flowers per inflorescence was observed in *R. baurii* plants developed from rhizomes weighing 0.31 -0.40 g (Tab. 3). Significantly fewer inflorescences and flowers per inflorescence formed on the plants grown from 0.10-0.20 g and 0.21-0.30 g rhizomes. Irrespective of rhizome weight, 'Dusky' plants produced more inflorescences and flowers per inflorescence than 'Ruth' ones. An analysis of *R. baurii* var. *platypetala* flowering (Mori and Sakanishi 1990) revealed that the plants produced from 1.7 to 5.7 inflorescences, depending on temperature, planting time, photoperiod and rhizome storage period.

The size of *Rhodohypoxis baurii* flowers depended on the cultivar and weight of the planted rhizomes (Tab. 3). The largest flowers were produced by plants grown from 0.31-0.40 g and 0.21-0.30 g rhizomes. The flowers of 'Ruth' had a greater diameter. The influence of underground organ size on flower quality was also observed in other African plants, such as *Ornithogalum saundersiae* (Salachna 2014), *Lachenalia* (Kapczyńska 2014) and *Gladiolus grandiflorus* (Kareem et al. 2013).

CONCLUSIONS

1. Rhizome weight of *Rhodohypoxis baurii* has a major effect on morphological traits and flowering ability.
2. Commercial producers of *R. baurii* as potted plants may wish to consider the use of rhizome weight of at least 0.2 g in order to achieve 100 percent flowering plants.
3. 'Dusky' plants were higher, had more leaves, flowers per inflorescence and inflorescences per rhizome, flowered earlier and produced rhizomes of greater weight than 'Ruth' plants, which had a higher greenness index and larger flowers.

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AUTHOR CONTRIBUTIONS

P.S. designed and performed the experiments, analysed data and wrote the paper; A.Z. analysed the data and wrote the paper; R.P. and A.W. performed the experiments. The manuscript has been read and approved by all authors.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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