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# Effect of planting time and supplemental irradiation on growth and flowering of *Lachenalia* 'Romaud'

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**Abstract**: Growth and flowering of lachenalia 'Romaud' was studied with reference to its commercial potential as pot plant and the need to obtain flowering plants at a specific time. The experiment was carried out in a heated glasshouse. Lachenalia bulbs were planted in November, December, January and February. The plants were exposed to two lighting regimes, natural lighting and natural lighting with supplemental irradiation (HPS lamps). The later the planting date was, the faster the bulbs flowered, and they produced thicker inflorescence stems with greater number of florets. Depending on the bulb planting date and light conditions, the plants flowered from February to May. The leaves obtained from the bulbs planted in November and December were longer than those produced by the bulbs planted in January and February. Compared with control, supplemental irradiation accelerated flowering by 10–13 days and positively affected plant features by promoting the growth of thicker inflorescence stems with more abundant and longer florets. The leaves of irradiated bulbs were shorter (apart from the bulbs planted in February) and were characterised by a higher content of chlorophyll *a*, chlorophyll *a* + *b* and carotenoids as compared with control. Plants grown under HPS light also had the higher dry weight of bulbs, leaves and stems.

**Keywords**: Cape Hyacinth; light; forcing; ornamental bulbous pot plant

*Lachenalia* is a poorly known genus of ornamental and endemic bulbous plant with huge floriculture potential. Its geographic range is limited to only two areas of Africa, i.e. Namibia and South Africa (Kleynhans 2002; 2006). Species from this part of the world have always played and may still play a significant role in diversification of horticultural assortment on the international market (Jansen van Vuuren, Coetzee 1993; Kleynhans 2013). According to the current classification, lachenalia includes 133 phenotypically and genotypically diversified species belonging to Asparagaceae family. Most lachenalia species grow in rocky areas in full sun, so many of them have succulent leaves capable of storing water during prolonged droughts. The lowest temperature recorded in winter months in habitats where lachenalias grow was –15°C, but most species are sensitive to cold and may withstand only short periods of temperatures of 0°C (Duncan 2012). For several years, new lachenalia hybrids with striking colours and great potential as long-lasting flowering pot and bedding plants have been available internationally under a trade name of 'Cape Hyacinth' (Kleynhans et al. 2002). An additional, unconventional decorative feature of new cultivars is their upper leaf surface, which in wild species is marked with brown spots and blotches. The successful growth of lachenalia depends on adequate light conditions and almost all lachenalias prefer sunny locations for most of the day. In a natural environment, insufficient light may result in obtaining colourless flowers (Duncan 2012) and too long inflorescence stems that may fall over (Kleynhans 2002). To avoid excessive elongation

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of stems or leaves, which usually happens during the months with light deficit (Kapczyńska 2014), supplemental irradiation should be applied by growers considering the cultivation of lachenalia during winter and early spring. In those seasons greenhouse flowers are highly valued on the international horticultural market (Kamenetsky 2005). Mimicking natural environmental conditions of greenhouse production with additional artificial light sources helped to modulate growth and morphology of many ornamental plants and became an important subject of scientific investigation in recent years (Islam et al. 2012; Baloch et al. 2014; Śmigielska et al. 2014). Development of forced production of new flower bulbs demands extensive research and knowledge of individual cultivars regarding interactions between environmental conditions and crops (Kamenetsky 2005).

Considering the necessity of supplementary irradiation during months with light deficit for year-round production, this study was conducted to examine the use of high-pressure sodium (HPS) lamps during the photoperiod of the northern hemisphere as a tool to control growth and flowering of lachenalia 'Romaud'.

## MATERIAL AND METHODS

The study was conducted in 2012 and 2013 in a glass-glazed Venlotype greenhouse (equipped with Integro 724 process computers; Priva) at the Faculty of Biotechnology and Horticulture, University of Agriculture in Kraków, Poland (lat. 50.08°N, long. 19.95°E). Plants were grown in chambers where day/night temperatures were set at 18/15°C (the temperatures and radiation course during the experiment are presented in Fig. 1). A yellowy-green (Fig. 2a) and scented lachenalia (*Lachenalia* Jacq. ex Murray) 'Romaud', with spotted leaves (Fig. 2b) was investigated. The bulbs of this cultivar, approx. 2.0 cm in diameter and 4.5 g in weight, were purchased from Afriflowers (Cullinan, South Africa). In order to prepare the bulbs they were kept after harvest at 9°C for 25–37 weeks (depending on planting month), followed by 2 weeks at 35°C and 22 weeks at 25°C. Immediately before planting longitudinal section through the middle of the basal plate of randomly selected bulbs was made to investigate whether flowering induction was initiated in the bulbs already at storage stage.

The bulbs were planted at monthly intervals on: November 22, 2012, December 22, 2012, January 22,

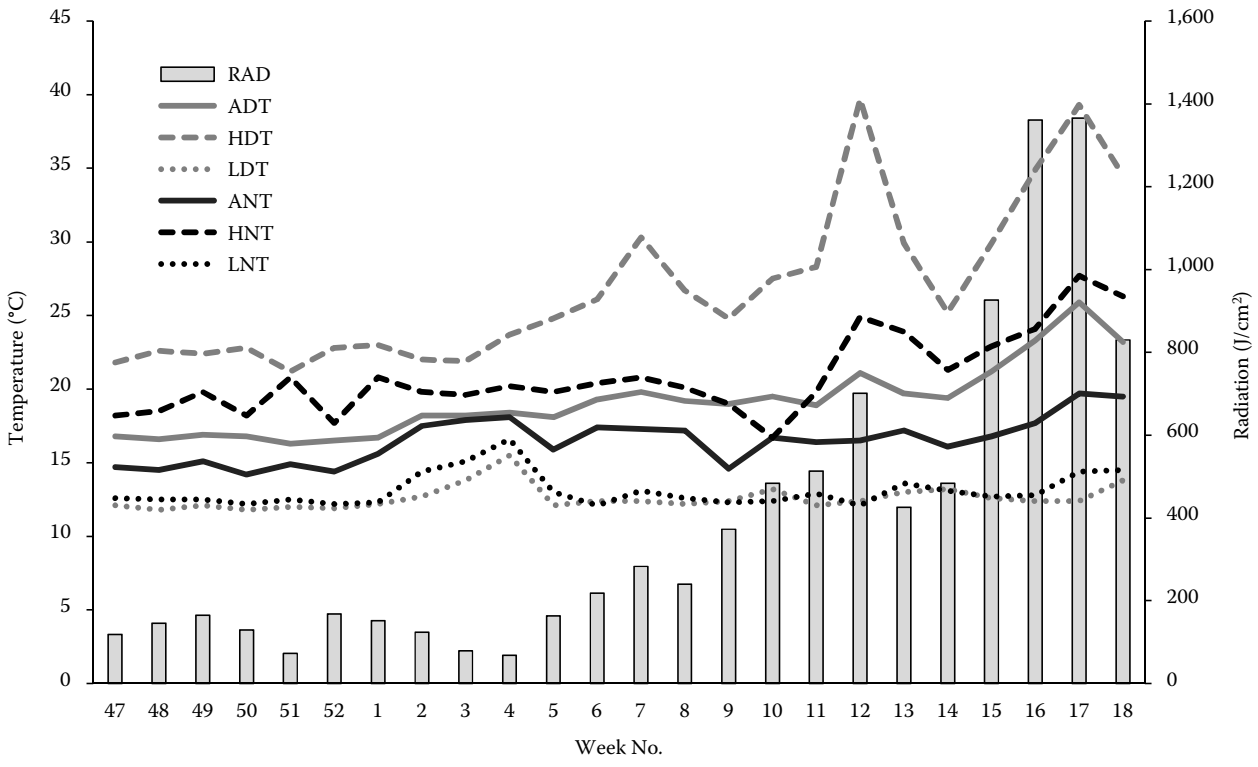


Fig. 1. Weekly average (A), lowest (L), highest (H) day (D) and night (N) temperatures (T) and radiation (RAD) during the experiment (weeks year: from 47$^{th}$ of 2012 to 18$^{th}$ of 2013)

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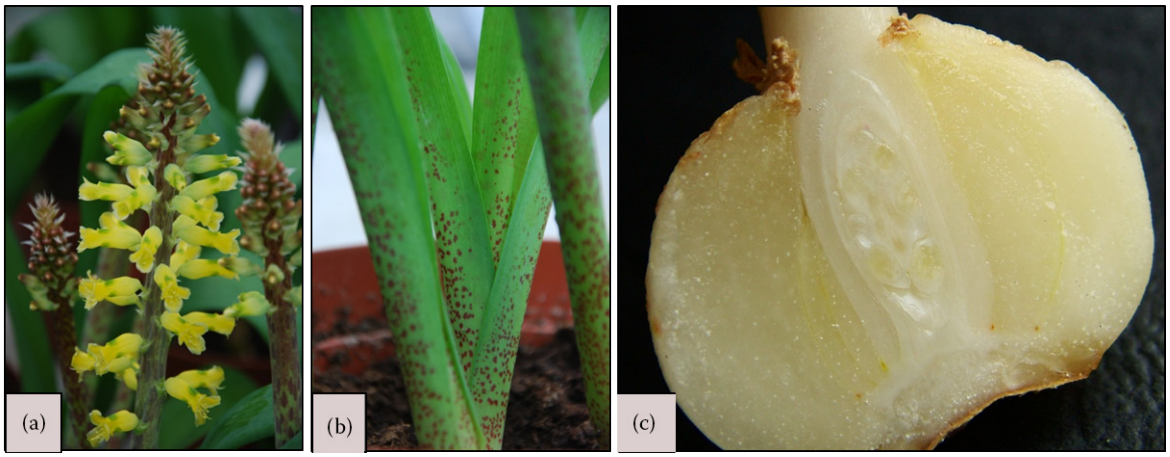


Fig. 2. Plants at flowering stage (a), spots on leaves (b), and the young flower primordium recognized in longitudinal section of a bulb (c)

2013 and February22, 2013. Each month before planting the plant material was randomly divided into two groups. The first one included plants grown only under natural light (without artificial lighting) that served as controls (CTR). The second group (irradiated, IR) involved the bulbs grown under natural light condition and additionally irradiated with high-pressure sodium (HPS) lamps of 400 W (Philips SON-T Agro, USA). Supplemental irradiation was supplied from 6.00 a.m. to 9.00 a.m. and from 3.00 p.m. to 6.00 p.m. during the entire cultivation period. Spectral quality of HPS lamps is shown in Fig. 3. In each variant, 40 bulbs were planted in four replications of 10 bulbs each. Prior to planting, the bulbs were soaked in a 0.25% captan (kaptantriadimenol) suspension for 30 min and then planted into 19 cm high plastic pots with a capacity of 3.0 l (five bulbs per pot) to a depth equal to twice the height of the bulb. The pots were filled with a peat substrate (Botanica Professional; Comeco, Poland) of pH 5.5–6.5. Since the first leaves appeared, the plants were fertilised every two weeks with a 30 N–0 P–16.6 K liquid fertilizer with micronutrients (Florovit Universal; Inco-Veritas, Warsaw, Poland) at a concentration of 1.0% (250 ml per pot).

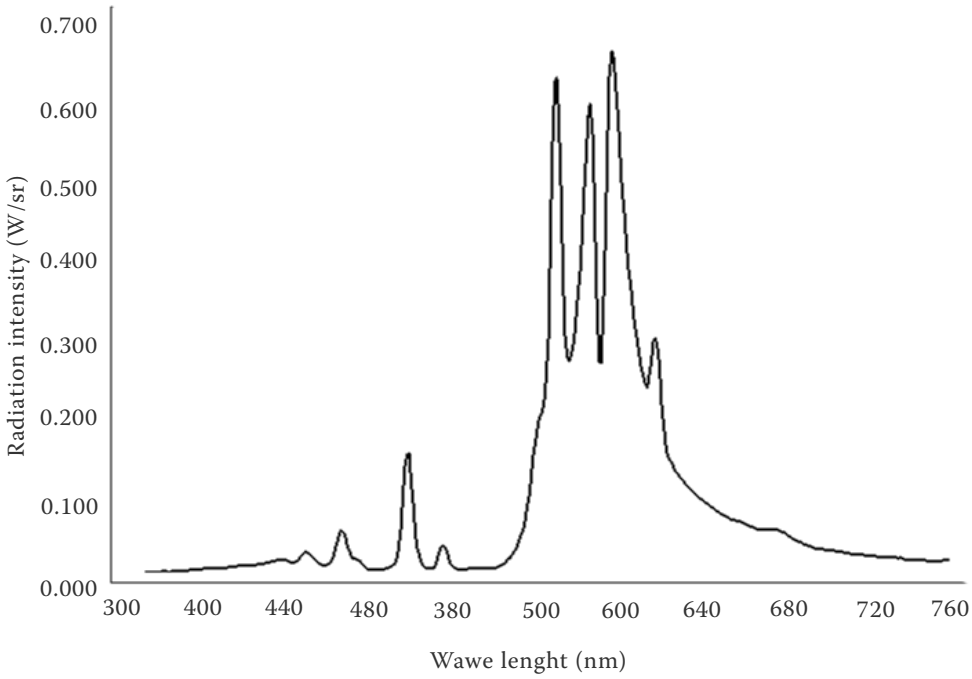


Fig 3. Spectrum distribution characteristic of HPS lamp (by M. Żupnik)

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Plant development was regularly monitored in order to capture the moment when the first floret opened and to estimate the number of days to the beginning of flowering. At this stage, measurements were taken of all plants and included inflorescence stem height (from the substrate to the uppermost part of the inflorescence), inflorescence length, number of florets per inflorescence, diameter of the inflorescence stem, length of a single floret (the first developed one), floral part ratio of the inflorescence (the quotient of inflorescence length to inflorescence stem height), number of leaves produced by a single bulb and the length and width of a leaf (i.e. mean length and width of all leaves produced by a single bulb).

For plants planted in the first month of the experiment (November) cultivated during the period of the greatest light deficiency, the photosynthetic pigments in leaves and dry weight content of bulbs, roots, leaves and stems were determined. For determination of dry weight, plant parts were dried in a steriliser (Sanyo Mov 112S, Japan) at +105°C until constant weight was reached. The leaf chlorophylls content and carotenoids were determined using spectrophotometer (Spekol 1500; Analytik Jena, Germany) and was calculated according to an equation provided by Arnon (1949). Leaf sample of 0.25 g was homogenized by grinding with 0.1 g of $CaCO_3$ and 10 ml of acetone in a glass mortar. The mixture was filtered through a filter paper into a volumetric flask and the sediment left on the filter paper was washed with acetone until the pigments were thoroughly removed. The extract was filled up to 25 ml with acetone and then diluted with distilled water so that the final concentration of acetone was 80%. Absorbance was read at the following wavelengths: 645 and 663 nm, for chlorophyll *a* (Chl *a*) and chlorophyll *b* (Chl *b*) and 470 nm for carotenoids (Car) against 80% acetone as blank. Three analytical replications for photosynthetic pigments and dry weight were performed for each treatment. Chlorophylls and carotenoids content and the dry weight of bulbs, roots and leaves were determined after two months of cultivation, dry weight of inflorescence stems during flowering stage.

Pots were arranged in randomised complete blocks within each experiment. A statistical analysis was performed using analysis of variance (ANOVA), using Statistica 10.0 data analysis software system (StatSoft, Tulsa, OK, USA). Experimental data were subjected to variance analysis, and Duncan's multiple range test was used to separate the means at a significance level of $P \leq 0.05$. Additionally, Pearson correlation coefficient at a probability $P \leq 0.05$ was calculated to determine significant correlations between morphological parameters of the plants.

## RESULTS AND DISCUSSION

Irrespective of the investigated factors, all bulbs of lachenalia 'Romaud' produced flowers. This was confirmed by the photographic documentation, made before planting, showing in the longitudinal section the initiation of floral primordia (Fig. 2c), which indicated that inflorescence primordia were formed at the stage of bulb storage. Inflorescences were found in the bulbs prior to their planting but their final quality differed depending on photoperiod prevailing at a particular cultivation time. The later the bulbs were planted, the quicker they started flowering (Fig. 4). Supplemental irradiation accelerated flowering by 10 to 13 days in each variant. These results were in line with the findings of Lee and Hwang (2014) and Han et al. (1991), who reported that the time of flowering of forced *Freesia hybrid* or *Brodiaea laxa* was shortened by one to three weeks when the plants were exposed to supplemental irradiation as compared with standard light conditions. In the present study, the first to bloom were the bulbs planted in February that needed only 64 days to develop first flowers, while the bulbs planted in November and exposed to natural light conditions needed as long as 85 days (Fig. 4). Bulb planting time was also important in the cultivation of other lachenalia cultivars, e.g. a delay in planting date made the plants of lachenalia 'Ronina', 'Rupert' and 'Namakwa' flower sooner (Kapczyńska, Kidawska 2016; Kapczyńska, Malik 2016). In this study flowering was synchronous, as inflorescences appeared within individual objects within a few days. Depending on planting date and light conditions, flowering occurred between the first decade of February and the second decade of May (Fig. 5). In this experiment, the planting date and light conditions did not affect the number of leaves produced by a single bulb (Table 1), but leaf quality depended on a combination of these parameters. The bulbs planted in November, December and January produced leaves by 2.0 to 3.1 cm shorter than corresponding control bulbs.

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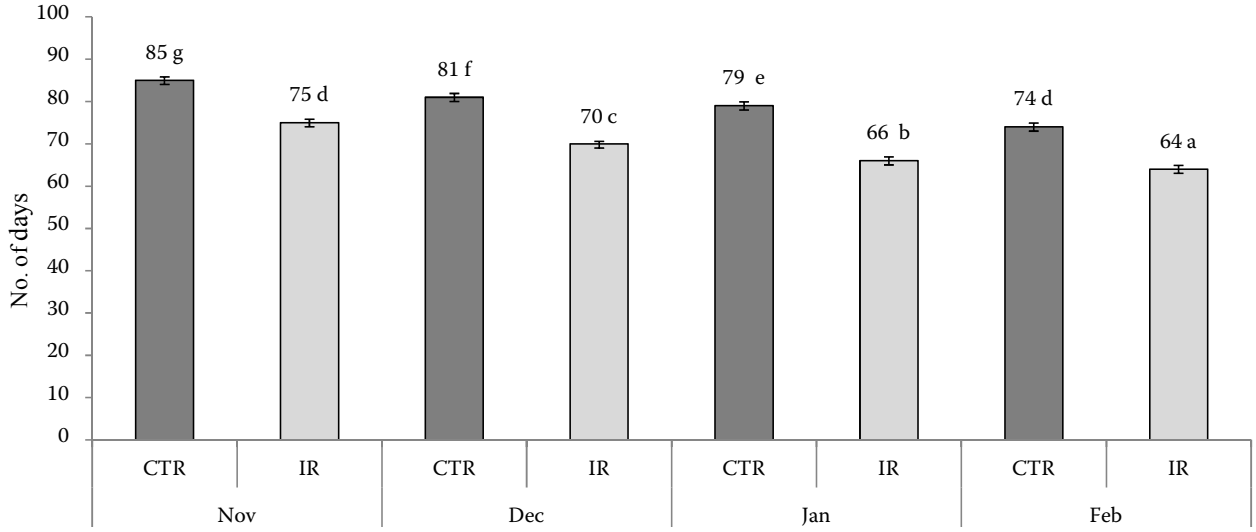


Fig. 4. Effect of planting time and different light conditions (control – CTR, irradiation – IR) on the number of days to the beginning of flowering of lachenalia 'Romaud'

mean values followed by a different letter are significantly different at $P \leq 0.05$ according to Duncan's test

The control bulbs and those planted on the latest dates and additionally illuminated, i.e. bulbs growing under the most favourable natural light conditions produced leaves of the same length. However, it should be pointed out that despite the favourable effect of supplementary lighting, the leaves of plants planted between November and January were still relatively long. Apart from supplementary lightning in this period, potential lachenalia growers should also take into account modification of greenhouse climate (cool morning, DIF) to obtain plants with appropriate habit, as commercially sold potted lachenalia should have a compact appearance and short leaves (Roh 2005). Thompson et al. (2011) also reported that decreasing irradiance resulted in increased leaf length in *Watsonia borbonica* and *W. tubularis* (African geophytes) and plant etiolation. In the present study, supplemental irradiation did not affect leaf blade width but the bulbs planted in February produced leaves by 0.5 to 0.8 cm wider than the bulbs planted between November and January. Every month the illuminated lachenalia plants produced thicker inflorescence stems than the control objects. Similar response was observed in two African geophytes *Gladiolus tristis* (Lopéz et al. 2006) and *Sandersonia auran-*

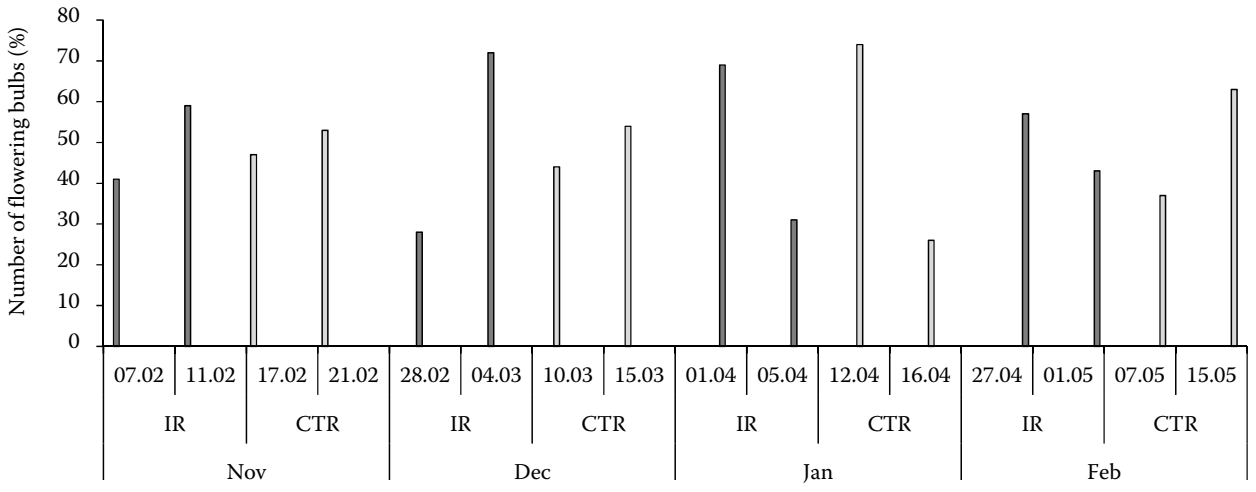


Fig. 5. Time course of flowering in lachenalia 'Romaud' grown under different light conditions (treatment: control – CTR, irradiation – IR)

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Table 1. Average of leaves No., leaf dimensions and stem diameter in lachenalia 'Romaud' grown under different light conditions (treatment: control – CTR, irradiation – IR)

| Date | Treatment | Leaf (No.) | Leaf length (cm) | Leaf width (cm) | Stem diameter (cm) |
|---|---|---|---|---|---|
| Nov | CTR | 2.5 ± 0.1$^{a}$ * | 36.4 ± 0.9$^{d}$ | 3.4 ± 0.3$^{a}$ | 0.8 ± 0.04$^{a}$ |
| | IR | 2.5 ± 0.1$^{a}$ | 33.3 ± 1.1$^{c}$ | 3.6 ± 0.2$^{ab}$ | 1.0 ± 0.08$^{c}$ |
| Dec | CTR | 2.3 ± 0.2$^{a}$ | 36.2 ± 1.2$^{d}$ | 3.5 ± 0.2$^{ab}$ | 0.9 ± 0.02$^{b}$ |
| | IR | 2.3 ± 0.2$^{a}$ | 33.4 ± 2.3$^{c}$ | 3.8 ± 0.2$^{b}$ | 1.2 ± 0.02$^{d}$ |
| Jan | CTR | 2.3 ± 0.1$^{a}$ | 31.3 ± 0.6$^{b}$ | 3.7 ± 0.1$^{ab}$ | 1.1 ± 0.05$^{c}$ |
| | IR | 2.6 ± 0.3$^{a}$ | 29.2 ± 0.5$^{a}$ | 3.6 ± 0.3$^{ab}$ | 1.2 ± 0.03$^{d}$ |
| Feb | CTR | 2.3 ± 0.1$^{a}$ | 31.2 ± 0.8$^{b}$ | 4.2 ± 0.1$^{c}$ | 1.2 ± 0.05$^{d}$ |
| | IR | 2.4 ± 0.1$^{a}$ | 30.8 ± 0.2$^{b}$ | 4.1 ± 0.1$^{c}$ | 1.3 ± 0.05$^{e}$ |
| **Main effects**** | | | | | |
| Date | | ns | < 0.0001 | < 0.0001 | < 0.0001 |
| Treatment | | ns | < 0.0001 | ns | < 0.0001 |
| Date × Treatment | | ns | ns | ns | 0.0119 |

mean values ± SD in columns followed by different letter(s) are significantly different at $P \leq 0.05$ according to Duncan's test; **significant effects ($P \leq 0.05$); ns –not significant

*tiaca* (Catley et al. 2002) after exposure to supplementary light. The thinnest stems grew from the bulbs planted in November and cultivated under natural light conditions and the thickest from illuminated bulbs planted in February. The difference was 0.5 cm in favour of the latter. Additional illumination significantly reduced the height of inflorescence stem only in the plants obtained from bulbs planted in January and February (Table 2). The most pronounced effects of irradiation on this feature were observed in January when the plants obtained from illuminated bulbs produced stems by 10 cm shorter than the control ones. Moreover, only in January supplemental irradiation resulted in shortening the inflorescence itself. Nevertheless, similarly as for other planting dates, illuminated plants produced more flowers per inflorescence (by 9–17 florets depending on the term), as compared with plants grown under natural light conditions. In the case of bulbs planted between December and February it resulted in a favourable visual perception of plants assessed by floral part ratio. Ehrich et al. (2009) reported that low light intensities during winter months in Central Europe may lead to not only deterioration of inflorescence quality, but also to total flower abortion in *Sparaxis* × *tricolor*, *Tritonia deusta* and *T. securigera*, which are, similarly to lachenalia, South Africa geophytes. Illuminated bulbs planted in November and December produced longer flowers than the control plants. A comparison of control plants alone revealed that the later the bulbs were planted, the shorter were the inflorescence stems, but they produced more florets per inflorescence. Gude and Dijkema (1992) claimed that while forcing *Hyacinthus* and *Tulipa* only small amounts of light were required to

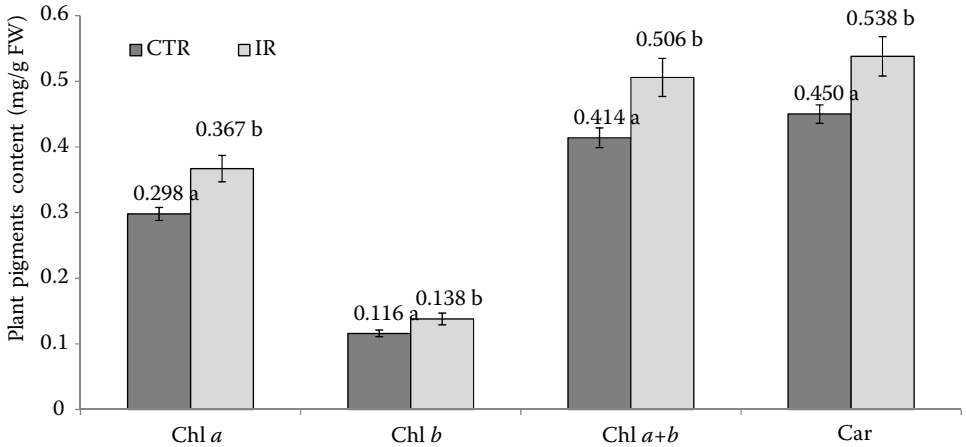


Fig. 6. Plant pigment content in lachenalia leaves grown under different light conditions (treatment: control – CTR, irradiation – IR)

mean values followed by a different letter are significantly different at $P \leq 0.05$ according to Duncan's test

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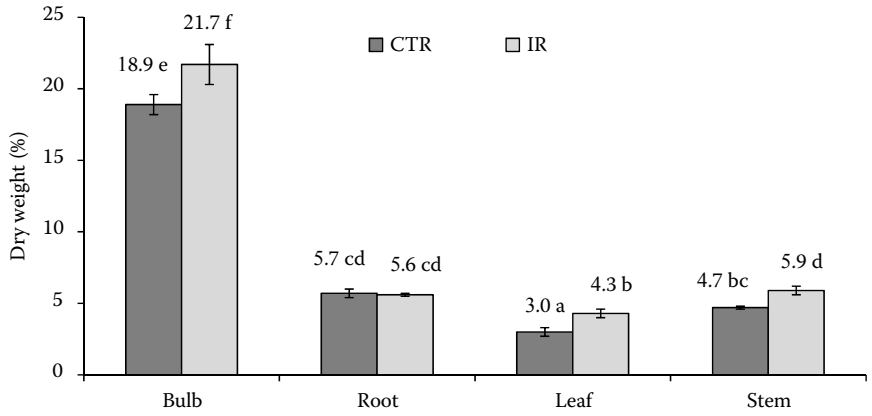


Fig. 7. Dry weight of lachenalia organs grown under different light conditions (treatment: control – CTR, irradiation – IR)

mean values followed by a different letter are significantly different at $P \leq 0.05$ according to Duncan's test

obtain good quality flowers. Contrary to this, our study demonstrated that lachenalia needed large amounts of light in order to achieve satisfactory appearance of the plants. Therefore, the development of appropriate cultivation methods of new commercial crops and novel products is necessary, as the current procedures dedicated to well known species may not be adequate for the new ones. In our study, significant correlations were observed for many analyzed morphological features, and both positive and negative correlations are presented in Table 3.

Many researchers have found that supplementation of light significantly affects the photosynthetic pigments (Letchamo et al. 1995; Sirtautas et al. 2014; Randall, Lopéz 2015) and dry weight content (Kim et al. 2004; Bagdonavičienė 2015). Also in present experiment with lachenalia 'Romaud' the investigated HPS light stimulated content of chlorophyll *a*, chlorophyll *a* + *b* and carotenoids (Fig. 6). An analysis of dry weight content in individual plant organs revealed that bulbs, leaves and stems of plants cultivated under supplemental irradiation were characterized by greater values of this parameter as compared with control plants (Fig. 7). A comparison of individual organs of control plants, showed the greatest dry weight in bulbs, the lowest in leaves.

Presented results proved that management of light in commercial production when the natural photoperiod is short, may have a widely positive impact on many morphological and physiological features that determine the quality of ornamental bulbous lachenalia 'Romaud'. In the future, supplemental irradiation in combination with appropriately selected cultivation temperatures may provide an alternative to the use of chemical plant growth regulators.

Table 2. Inflorescence quality of lachenalia 'Romaud' grown under different light conditions (treatment: control – CTR, irradiation – IR)

| Date | Treatment | Inflorescence stem height (cm) | Inflorescence length (cm) | Average of florets (No.) | Floret length (cm) | Floral ratio |
|---|---|---|---|---|---|---|
| Nov | CTR | 41.0 ± 2.4$^{d*}$ | 12.2 ± 0.9$^{bc}$ | 26.5 ± 8.0$^{a}$ | 1.9 ± 0.15$^{a}$ | 0.28 ± 0.01$^{a}$ |
| | IR | 39.2 ± 0.9$^{d}$ | 11.5 ± 1.2$^{bc}$ | 38.7 ± 6.2$^{bc}$ | 2.1 ± 0.04$^{bc}$ | 0.30 ± 0.02$^{a}$ |
| Dec | CTR | 35.8 ± 1.2$^{c}$ | 10.4 ± 1.0$^{a-c}$ | 23.5 ± 6.9$^{a}$ | 2.0 ± 0.03$^{b}$ | 0.29 ± 0.01$^{a}$ |
| | IR | 33.4 ± 2.2$^{c}$ | 10.9 ± 2.2$^{bc}$ | 40.1 ± 5.6$^{bc}$ | 2.2 ± 0.05$^{c}$ | 0.34 ± 0.03$^{b}$ |
| Jan | CTR | 33.5 ± 1.0$^{c}$ | 12.5 ± 0.4$^{c}$ | 35.1 ± 1.3$^{b}$ | 2.1 ± 0.02$^{bc}$ | 0.37 ± 0.02$^{b}$ |
| | IR | 23.1 ± 1.8$^{a}$ | 9.4 ± 1.2$^{a}$ | 46.6 ± 6.2$^{c}$ | 2.1 ± 0.09$^{bc}$ | 0.43 ± 0.02$^{c}$ |
| Feb | CTR | 25.7 ± 2.2$^{b}$ | 9.5 ± 1.2$^{a}$ | 47.3 ± 2.9$^{c}$ | 2.1 ± 0.01$^{bc}$ | 0.37 ± 0.02$^{b}$ |
| | IR | 22.2 ± 0.8$^{a}$ | 9.4 ± 0.8$^{a}$ | 55.9 ± 3.5$^{d}$ | 2.2 ± 0.04$^{c}$ | 0.42 ± 0.03$^{c}$ |
| **Main effects**** | | | | | | |
| Date | | < 0.0001 | 0.0060 | < 0.0001 | 0.0090 | < 0.0001 |
| Treatment | | < 0.0001 | ns | < 0.0001 | 0.0002 | < 0.0001 |
| Date × Treatment | | < 0.0001 | 0.0361 | ns | 0.0232 | ns |

*mean values ± SD in columns followed by different letter(s) are significantly different at $P \leq 0.05$ according to Duncan's test; **significant effects ($P \leq 0.05$); ns – not significant

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Table 3. Correlation coefficients between analysed features, irrespectively of genotype and light conditions

| | Leaf length | Leaf width | Stem diameter | Infl. stem height | Infl. length | Florets (No.) | Floret length | Floral ratio |
|---|---|---|---|---|---|---|---|---|
| Leaf (No.) | NS* | NS | NS | NS | NS | NS | –0.413 | NS |
| Leaf length | | –0.425 | –0.754 | 0.782 | NS | –0.781 | –0.475 | –0.856 |
| Leaf width | | | 0.677 | –0.657 | –0.361 | 0.732 | 0.266 | 0.499 |
| Stem diameter | | | | –0.815 | –0.428 | 0.857 | 0.647 | 0.819 |
| Inflorescence stem height | | | | | 0.666 | –0.772 | –0.420 | –0.841 |
| Inflorescence length | | | | | | NS | –0.468 | NS |
| Florets (No.) | | | | | | | 0.377 | 0.788 |
| Floret length | | | | | | | | 0.399 |

*NS – not significant; infl. – inflorescence

## CONCLUSION

Floricultural market is always open to new ornamental plants offering interesting and exotic alternatives to well known and popular flower bulb species. Lachenalia 'Romaud' with its spotted succulent leaves and yellowish-green, scented flowers has an excellent horticultural potential for commercialisation on the international potted flowers market. The presented results showed that planting time and light intensity during the cultivation process greatly affected the growth and flowering of this cultivar. To obtain the highest plant quality during autumn-winter forcing, it is recommended to apply supplemental irradiation to improve plant appearance and marketing quality.

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