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EFFECT OF BENZYLADENINE ON THE ABUNDANCE AND QUALITY OF FLOWER YIELD IN THE CALLA LILY (*Zantedeschia* Spreng.)

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Abstract

The soaking of rhizomes, 15–18 cm in circumference in the cultivars 'Black Magic' and 'Mango' as well as 20+ cm in 'Albomaculata', with leaf buds 0.5–2 cm in length, in solutions of benzyladenine at concentrations of 100, 350 and 600 mg × dm^{-3} lasted 30 and 60 minutes. After this procedure, slightly dried rhizomes were planted into 20-cm pots. Rhizome soaking in BA at concentrations of 350–600 mg × dm^{-3} for 60 minutes increases the yield of flowers 3–4 times in 'Black Magic', 'Mango', and 'Albomaculata'. BA at concentrations of 350–600 mg × dm^{-3} retards the flowering of the cultivars 'Black Magic', 'Mango', and 'Albomaculata'. However, at 100 mg × dm^{-3} it brings flowering forward in 'Mango' and 'Albomaculata'. BA at a concentration of 600 mg × dm^{-3} inhibits the growth of peduncles, while at a concentration of 100–600 mg × dm^{-3} it causes the formation of longer spathes in the cultivar 'Albomaculata'. In 'Black Magic' at a concentration of 350–600 mg × dm^{-3} and in 'Mango' at a concentration of 100–600 mg × dm^{-3}, it causes the development of flowers with a smaller weight.

Key words: *Zantedeschia*, cultivation, growth regulators

INTRODUCTION

Calla lilies with colourful spathes enjoy a great popularity among buyers, not discouraged by the high price of cut flowers which are mostly imported because the domestic production satisfies only a small portion of the market demand. Calla lilies attract attention by their original inflorescence – a spadix surrounded by a spathe in a wide variety of colours. The high price of flowers is due to the prices of rhizomes, the chief producers of which include the United States of America, The Netherlands, New Zealand, and Kenya. Reproductive plantations in those countries occupy a total area of 288 ha. Smaller plantations can also be found in Brazil, Zimbabwe, Costa Rica, and Israel. While the area of the plantations keeps growing yearly, the prices of rhizomes remain steady, this being the most important reason of why so few producers engage in growing calla lily cultivars in Poland. A factor limiting an increase in production is also the poor cropping of most cultivars. To improve calla lily flowering, use has been made so far of gibberellic acid (GA_3) (Corr and Widmer, 1991; Janowska and Schroeter, 2002; Janowska and Zakrzewski, 2005, 2006; Treder, 2003). Given the great variety of cultivars and their responses to gibberellic acid, the recommended method of soaking rhizomes in this growth regulator, while effective, does not ensure an increase in flower yield high enough to recompense the costs of setting up a plantation. Hence, it is desirable to seek more effective methods that may increase flowering. In the research reported here, benzyladenine (BA) was applied for rhizome soaking in order to assess its effect on the earliness of flowering and on the yield and quality of flowers of calla lily cultivars with colourful spathes, so much in demand on the Polish market.

MATERIAL AND METHODS

The research was conducted in the Department of Ornamental Plants of the University of Life Sciences in Poznań from 12 May to 4 November 2007 and from 18 April to 30 October 2011. The cultivars used were 'Albomaculata' deriving from *Zantedeschia albomaculata* /Hook./ Baill., 'Black Magic' coming from an inter-species hybrid of *Zantedeschia elliottiana* /Wats./ Engl. x *Z. macrocarpa* Engl., and 'Mango' deriving from *Zantedeschia* sp. The plants were grown in a plastic tunnel. Before planting, rhizomes of those cultivars were soaked in solutions of benzyladenine.

The soaking of rhizomes, 15–18 cm in circumference in the cultivars ‘Black Magic’ and ‘Mango’ and 20+ cm in the cultivar ‘Albomaculata’, with leaf buds 0.5–2 cm in length, in solutions of benzyladenine at concentrations of 100, 350 and 600 mg × dm^{-3} lasted 30 and 60 minutes. Then, the slightly dried rhizomes were planted into 20-cm pots into a medium consisting of peat with a pH of 6.2, enriched with a slow-release fertiliser Osmocote Plus (3–4M) in the amount of 3 g per dm^{-3} and mixed with fresh shredded pine bark at a rate of 3:1 (v:v). The plants, grown in a plastic tunnel, were fed starting from the fifth week of cultivation. Every 10–14 days, solutions of mixed fertilisers, Peters Professional and brown Superba, were applied at a concentration of 0.2%. At the start of vegetation when the leaves were fully developed, lime saltpetre at a concentration of 0.2% was foliar applied once.

One treatment (BA concentration x soaking time) included 5 plants, each in 3 replications.

At the stage of harvest maturity, when 1/3 of flowers in the lower part of the spadix were fully developed, the inflorescence scapes were gently broken.

The length of scapes and spathes was measured. The yield of cut flowers developing from a single rhizome, fresh flower weight, and earliness of flowering, as expressed by the mean number of days from rhizome planting to flower harvest, were determined. In calla lily, a “flower” is a conventional simplifying term used to describe the inflorescence on a scape – a spadix – surrounded by a spathe.

The results, given as means for the two years of the study, were processed by two-factor analysis of variance. The means were grouped using Duncan’s test at the = 0.05 significance level.

RESULTS

Comparing the earliness of flowering of the studied cultivars, it was found that they differ in response to the concentration of benzyladenine and the duration of rhizome soaking (Table 1). In the cultivar ‘Black Magic’ flowering was slightly retarded with increasing benzyladenine concentrations: the higher the BA concentration, the later the blooming. In this cultivar, flowering was the latest when its rhizomes were soaked for 60 minutes in solution of BA at concentrations of 350 and 600 mg × dm^{-3}. In the cultivar ‘Mango’, the plants whose rhizomes were soaked in 100 mg × dm^{-3} BA solution bloomed on average 8 days earlier than the control. At higher benzyladenine concentrations, flowering was retarded a few days. In the cultivar ‘Albomaculat’, the plants whose rhizomes were soaked in 100 mg·dm^{-3} BA solution bloomed earlier than the control plants. In this cultivar, the retardation of flowering was observed in plants whose rhizomes were soaked for 30 and 60 minutes in 350–600 mg × dm^{-3} BA.

It was shown that the yield of flowers in the cultivars under study depended significantly on both the BA concentration and the duration of rhizome soaking, with the exception of the cultivar ‘Black Magic’ in which only the concentration of benzyladenine influenced the yield (Table 2). Irrespective of its duration, rhizome soaking in benzyladenine at concentrations of 350 and 600 mg × dm^{-3} enhanced flowering, because the yield increased an average of 2–3.5 times, depending on the cultivar. In turn, in the cultivars ‘Mango’ and ‘Albomaculata’ those plants flowered more abundantly whose rhizomes were soaked in solutions of BA for 60 minutes, irrespective of the concentration.

As regards the length of scapes, this trait was found to depend exclusively on the benzyladenine concentration applied for rhizome soaking (Table 3). Irrespective of its duration, the application of benzyladenine inhibited scape elongation, the response to the concentration applied depending on the cultivar. The most sensitive cultivar turned out to be ‘Mango’, in which benzyladenine caused the development of shorter scapes at all the concentrations applied. In the cultivar ‘Black Magic’, benzyladenine had an adverse effect at concentrations of 350 and 600 mg × dm^{-3}, while in the cultivar ‘Albomaculata’ shorter scapes were recorded in flowers growing from rhizomes soaked in benzyladenine at the highest concentration.

In the cultivars ‘Black Magic’ and ‘Mango’, spathe length did not depend either on the BA concentration or on the duration of rhizome soaking, while in the cultivar ‘Albomaculata’ it depended significantly on the concentration. Irrespective of the duration of rhizome soaking, in this cultivar the benzyladenine concentrations applied contributed to the formation of more magnificent spathes (Table 4).

The weight of flowers in the three calla lily cultivars depended significantly only on the two concentrations of benzyladenine (Table 5). In the cultivar ‘Mango’, irrespective of the duration of rhizome soaking, the flowers had a lower weight than those in the control treatment. In the cultivar ‘Black Magic’, flowers growing from rhizomes soaked in solution of benzyladenine at concentrations of 350 and 600 mg × dm^{-3} had a smaller weight. The application of benzyladenine had no effect on flower weight only in the cultivar ‘Albomaculata’.

Table 1
Earliness of flowering of *Zantedeschia* (days) depending on concentration of benzyladenine and time of rhizome soaking

Concentration of BA ($mg \times dm^{-3}$)	Time of rhizome soaking (minutes)		Mean for concentration of BA
	30	60	
	'Black Magic'		
0	80.0 a	80.0 a	80.0 *a*
100	82.0 a	82.0 a	82.0 *a*
350	83.0 ab	86.0 c	84.5 *b*
600	84.0 b	87.0 c	85.5 *b*
	'Mango'		
0	68.0 c	68.0 c	68.0 *b*
100	58.0 a	62.0 b	60.0 *a*
350	72.0 d	74.0 d	73.0 *c*
600	72.0 d	72.0 d	72.0 *c*
	'Albomaculata'		
0	68.0 c	68.0 c	68.0 *b*
100	59.0 a	61.0 b	60.0 *a*
350	73.0 d	73.0 d	73.0 *c*
600	73.0 d	73.0 d	73.0 *c*

Means followed by the same letter do not differ significantly at a = 0.05

Table 2
Flower yield of *Zantedeschia* depending on concentration of benzyladenine and time of rhizome soaking

Concentration of BA ($mg \times dm^{-3}$)	Time of rhizome soaking (minutes)		Mean for concentration of BA
	30	60	
	'Black Magic'		
0	1.2 a	1.2 a	1.2 *a*
100	1.7 a	1.9 a	1.8 *a*
350	1.9 a	3.0 b	2.4 *b*
600	3.2 b	3.2 b	3.2 *b*
Mean for time of rhizome soaking	2.0 **a**	2.3 **a**	
	'Mango'		
0	1.0 a	1.0 a	1.0 *a*
100	1.5a	1.7 a	1.6 *a*
350	1.9 a	4.0 c	2.9 *b*
600	2.8 b	4.0 c	3.5 *b*
Mean for time of rhizome soaking	1.8 **a**	2.7 **b**	
	'Albomaculata'		
0	2.4 a	2.4 a	2.1 *a*
100	3.7 a	2.9 a	3.3 *a*
350	3.1 a	8.3 c	5.7 *b*
600	5.8 b	8.6 c	7.2 *c*
Mean for time of rhizome soaking	3.7 **a**	5.5 **b**	

Means followed by the same letter do not differ significantly at a = 0.05

Table 3
Flower scape length of *Zantedeschia* (cm) depending on concentration of benzyladenine and time of rhizome soaking

Concentration of BA (mg×dm^{-3})	Time of rhizome soaking (minutes)		Mean for concentration of BA
	30	60	
'Black Magic'			
0	44.0 b	44.0 b	44.0 *b*
100	42.9 b	46.6 b	44.7 *b*
350	36.2 a	38.4 a	37.3 *a*
600	36.9 a	39.5 a	38.2 *a*
Mean for time of rhizome soaking	40.0 **a**	42.1 **a**	
'Mango'			
0	33.0 b	33.0 b	33.0 *b*
100	29.0 a	26.6 a	27.8 *a*
350	28.7 a	30.0 a	29.8 *a*
600	28.0 a	29.9 a	29.0 *a*
Mean for time of rhizome soaking	29.7 **a**	30.1 **a**	
'Albomaculata'			
0	33.0 b	33.0 b	33.0 *b*
100	31.0 b	31.7 b	31.6 *b*
350	32.3 b	31.2 b	31.7 *b*
600	30.4 b	27.1 a	28.7 *a*
Mean for time of rhizome soaking	31.8 **a**	30.7 **a**	

Means followed by the same letter do not differ significantly at a = 0.05

Table 4
Spathe length of *Zantedeschia* (cm) depending on concentration of benzyladenine and time of rhizome soaking

Concentration of BA (mg×dm^{-3})	Time of rhizome soaking (minutes)		Mean for concentration of BA
	30	60	
'Black Magic'			
0	9.4 b	9.4 b	9.4 *a*
100	9.4 b	9.4 b	9.4 *a*
350	8.7 ab	9.2 b	8.9 *a*
600	8.7 ab	9.2 b	9.0 *a*
Mean for time of rhizome soaking	9.0 **a**	9.3 **a**	
'Mango'			
0	9.3 a	9.3 a	9.3 *a*
100	8.9 a	9.3 a	9.1 *a*
350	9.0 a	9.6 a	9.3 *a*
600	9.6 a	9.2 a	9.1 *a*
Mean for time of rhizome soaking	9.0 **a**	9.3 **a**	
'Albomaculata'			
0	6.0 a	6.0 a	6.0 *a*
100	7.1 b	7.1 b	7.1 *b*
350	7.2 b	8.6 d	7.9 *c*
600	7.9 c	7.1 b	7.5 *bc*
Mean for time of rhizome soaking	7.0 **a**	7.2 **a**	

Means followed by the same letter do not differ significantly at a = 0.05

Table 5

Flower weight of *Zantedeschia* (g) depending on concentration of benzyladenine and time of rhizome soaking

Concentration of BA (mg×dm^{-3})	Time of rhizome soaking (minutes)		Mean for concentration of BA
	30	60	
'Black Magic'			
0	25.0 c	25.0 c	25.0 *c*
100	25.6 c	29.2 d	27.4 *c*
350	19.4 a	23.8 b	21.6 *b*
600	16.6 a	16.6 a	16.6 *a*
Mean for time of rhizome soaking	216 **a**	23.6 **a**	
'Mango'			
0	20.0 b	20.0 b	20.0 *b*
100	15.3 a	15.8 a	15.5 *a*
350	17.1 a	17.4 a	17.2 *a*
600	15.7 a	14.5 a	15.2 *a*
Mean for time of rhizome soaking	17.0 **a**	16.9 **a**	
'Albomaculata'			
0	8.2 a	8.2 a	8.2 *a*
100	8.2 a	8.1 a	8.1 *a*
350	8.0 a	8.0 a	8.0 *a*
600	8.7 a	7.2 a	7.9 *a*
Mean for time of rhizome soaking	8.3 **a**	7.9 **a**	

Means followed by the same letter do not differ significantly at a = 0.05

DISCUSSION

Starting from the nineties of the last century, an increased interest in calla lily with colourful spathes has been observed in the world. In 2005 it already occupied a high 13th position in cut flower trading on Dutch auctions. In Poland it was started to be cultivated much later. The reason is the high prices of rhizomes, which are reproduced abroad. Producers offer them in a variety of sizes, but only the largest ones can be expected to bloom and the yield of cut flowers that can be obtained from them is often less than satisfactory (Janowska and Schroeter, 2002; Janowska and Zakrzewski, 2005, 2006; Treder, 2003), with the price at which the flowers can be sold hardly making up for it. As follows from the research conducted so far, one can increase the yield of flowers through the application of gibberellic acid (Ali and Elkiey, 1995; Brooking and Cohen, 2002; Corr and Widmer, 1991; Dennis et al. 1994; Funnell et al. 1992; Funnel and Tjia, 1988; Janowska and Krause, 2001; Janowska and Schroeter, 2002; Janowska and Zakrzewski, 2006; Reiser and Langhans, 1992; Tjia, 1987; Treder, 2003).

The present study corroborates the very poor flowering of plants without their initial treatment with growth regulators, even when very large rhizomes were planted; on the average, only 1 to 2.4 flowers were harvested from a single rhizome, depending on the cultivar. However, very good results were obtained when the rhizomes were soaked in water solutions of benzyladenine prior to planting. The highest yield of flowers was obtained in the cultivars 'Black Magic', 'Mango', and 'Albomaculata' when benzyladenine was applied for 60-minute rhizome soaking at concentrations of 350–600 mg × dm^{-3}. Owing to this practice, 3–4 times more flowers were collected in comparison with the control treatment.

In ornamental plants, benzyladenine is applied primarily as a growth regulator responsible for the branching of plants propagated *in vitro,* hence there is little information in the available literature on how it affects the intensity of flowering. From the few works published so far, one can learn that in *Zantedeschia aethiopica* benzyladenine at a concentration of 350 ppm (350 mg × dm^{-3}) enhances the formation of flowers (Luria et al. 2005). That it has a good effect on the cropping of plants has been corroborated by Pogroszewska and Sadkowska (2008b) in *Liatris spicata* 'Alba'. These authors report that this growth regulator, foliage-applied at a concentration of 400 mg × dm^{-3} in plants grown in an unheated plastic tunnel and in the soil, increased the number and fresh weight of inflorescence shoots. Similarly in *Campanula persicifolia* 'Alba', benzyladenine at the same concentration increases the number of 1st-order lateral shoots (Pogroszewska and Sadkowska, 2008a). In turn, in *Astilbe* x *arendsii* 'Amethyst' plants grown in the soil, foliage-applied benzyladenine at a concentration of 200 mg × dm^{-3} increased the yield of inflorescence shoots (Pogroszewska and Sadkowska, 2007), while in *Schlumbergera truncata* it increased the number of flower buds (Boyle, 1995). More abundant flowering after the application of benzyladenine was also noted by Gianfagna and Merritt (1998) in *Aquilegia vulgaris*. Also in *Doriotaenopsis* flowering was much more abundant after the application of benzyladenine (Blanchard and Runkle, 2008).

However, benzyladenine does not always bring the desired effects. Ngamau (2001) did not obtain an increase in the yield of *Zantedeschia aethiopica* 'Green Goddess' after its application. Neither was there an increase in the yield of *Anemone coronaria* 'Sylphide' when benzyladenine at concentrations of 50-150 mg × dm^{-3} was used in the tuber-soaking solution (Janowska et al. 2009). In *Boronia heterophylla*, benzyladenine even had an adverse effect on the intensity of flowering (Plummer and Wann, 1998), while in *Miltoniopsis* it stimulated vegetative growth, but inhibited flowering (Matsumoto, 2006).

An important aspect of floriculture is the earliness of flowering, since it allows planning plant production for a specified date. In the present research, benzyladenine had some influence on the earliness of flowering of the calla lily. Applied at concentrations of 350–600 mg × dm^{-3}, it slightly retarded blooming in the cultivars 'Black Magic', 'Mango', and 'Albomaculata', while at a concentration of 100 mg × dm^{-3} it hastened flowering forward in those two cultivars. This is partly corroborated by Tjia and Funnell (1986) who obtained earlier flowering in *Zantedeschia elliottiana* having soaked its rhizomes in solutions of benzyladenine at 50–100 mg × dm^{-3} for 30 minutes. Slightly earlier flowering after the application of benzyladenine was also obtained by Janowska et al. (2009) in *Anemone coronaria* 'Sylphide'. Additionally, these authors found that the higher the benzyladenine concentration applied, the earlier the blooming. An earlier flowering was also observed in *Bougainvillea* 'Taiped Red' treated with benzyladenine (Liang and Chang, 1998). In turn, Foley and Keever (1991) found flowering to be retarded after the application of benzyladenine in pinched plants of *Dianthus caryophyllus* 'Knight Hybrid Scarlet', which started blooming 13 days later when benzyladenine was applied at 200 mg × dm^{-3}.

Growth regulators may influence the qualitative features of flowers as expressed by the length of scapes and the size and weight of flowers, their effect being either advantageous or adverse. In the present study, benzyladenine inhibited the growth of scapes, the response to the concentration applied depending on the cultivar. It also caused longer spathes to develop in the cultivar 'Albomaculata', while in 'Black Magic' and 'Mango' it contributed to flowers having a smaller weight. The conducted research indicates that in some species benzyladenine has an inhibiting effect on the elongation of shoots, both vegetative and flowering ones. It also affects the quality of flowers. That shorter pedicels tend to develop after the application of benzyladenine is reported, e.g., by Janowska et al. (2009) in *Anemone coronaria* 'Sylphide', in which also the smallest flowers developed in plants whose tubers were soaked in benzyladenine at a concentration of 50 mg × dm^{-3}. The formation of shorter inflorescence shoots after foliage-applied benzyladenine was also observed by Pogroszewska and Sadkowska (2008a) in *Campanula persicifolia* 'Alba' cultivated in an unheated plastic tunnel in both years of the research carried out by those authors. In plants grown in the soil, a similar development only occurred in older plants, in the second year of the study. In the case of *Hedera helix* 'Brokamp', higher benzyladenine concentrations brought on a very sharp shortening not only of shoots, but also of leaf blades. The shortest main stems in this cultivar were recorded in plants treated with benzyladenine at a concentration of 5 mg × dm^{-3} (Marcinek and Hetman, 2006). However, it is not in all species that benzyladenine has an adverse effect on the length of shoots. In experiments by Pogroszewska (2002), benzyladenine at a concentration of 750 mg × dm^{-3} brought about the formation of longer scapes and more magnificent spathes in *Spathiphyllum* 'Petite'. Benzyladenine was also shown to have a beneficial effect on the quality of inflorescences in *Spathiphyllum* 'Castor' (Song and Lee, 1995). But in *Allium karataviense* inflorescences were not larger after the application of benzyladenine (Pogroszewska et al. 2007). A beneficial effect of benzyladenine on the weight of inflorescence shoots in *Liatris spicata* 'Alba' was reported by Pogroszewska and Sadkowska (2008b). In this cultivar, benzyladenine at a concentration of 400 mg × dm^{-3} increased the fresh weight of inflorescence shoots, both in plants grown in an unheated plastic tunnel and in the soil.

CONCLUSIONS

1. Benzyladenine has a beneficial effect on the yield of calla lily.
2. Rhizome soaking in solution of BA at concentrations of 350–600 mg × dm^{-3} for 60 minutes increases

the yield of flowers 3–4 times in 'Black Magic', 'Mango', and 'Albomaculata'.

3. BA at concentrations of 350–600 mg × dm^{-3} retards the flowering of the cultivars 'Black Magic', 'Mango', and 'Albomaculata'. However, at 100 mg × dm^{-3} it brings flowering forward in 'Mango' and 'Albomaculata'.
4. BA at a concentration of 600 mg × dm^{-3} inhibits the growth of peduncles, while at a concentration of 100–600 mg × dm^{-3} causes the formation of longer spathes in the cultivar 'Albomaculata'. In 'Black Magic' at a concentration of 350–600 mg × dm^{-3} and in 'Mango' at a concentration of 100–600 mg × dm^{-3}, it causes the development of flowers with a smaller weight.

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Wpływ benzyloadeniny na wielkość i jakość plonu kwiatów cantedeskii (*Zantedeschia* Spreng.)

Streszczenie

Moczenie kłączy cantedeskii o obwodzie 15–18 cm u odmian 'Black Magic' i 'Mango' oraz o obwodzie powyżej 20 cm u odmiany 'Albomaculata' z pąkami liściowymi o długości 0,5–2 cm, w roztworze benzyloadeniny o stężeniu 100, 350 i 600 mg × dm^{-3} trwało 30 i 60 minut. Po tym zabiegu lekko podsuszone kłącza sadzono do doniczek o średnicy 20 cm. Moczenie kłączy w BA o stężeniu 350–600 mg × dm^{-3} przez 60 minut zwiększa 3–4 krotnie plon kwiatów odmian 'Black Magic', 'Mango' i 'Albomaculata'. Benzyloadenina o stężeniu 350–600 mg × dm^{-3} opóźnia kwitnienie odmian 'Black Magic', 'Mango' i 'Albomaculata', o stężeniu 100 mg × dm^{-3} przyspiesza zakwitanie odmian 'Mango' i 'Albomaculata'. BA o stężeniu 600 mg × dm^{-3} hamuje wzrost szypuł kwiatostanowych, a o stężeniu 100–600 mg × dm^{-3} powoduje tworzenie się dłuższych pochew kwiatostanowych u odmiany 'Albomaculata'. U odmian 'Black Magic', o stężeniu 350–600 mg × dm^{-3}, i 'Mango', o stężeniu 100–600 mg × dm^{-3}, powoduje wyrastanie kwiatów o mniejszej masie.