PGRs and AMF Stimulate Flowering of Colored *Zantedeschia*

Subjects: Horticulture

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Species from the *Zantedeschia* genus, described almost 200 years ago, belong to the numerous picture family Araceae, in which the inflorescence is a spadix with numerous small flowers set on a succulent stem surrounded by a colourful inflorescence spathe. Initially, the cultivation was dominated by *Zantedeschia aethiopica* /L./ Spreng. Its importance is currently low and cultivars with colourful inflorescence spathes derived from *Z. rehmanii* Engl., *Z. elliottiana* (W. Wats.) Engl. and *Z. albomaculata* (Hook.) Baill, among others, are becoming increasingly important. Their obtainment was possible thanks to intensive breeding work carried out initially in the United States of America and New Zealand, and later in South Africa and the Netherlands. The cultivar range is large. The yield of cut flowers that can be obtained from them is often not very satisfactory and is not compensated by the price that can be obtained from the sale of flowers.

Zantedeschia cultivation vase life flowers leaves cytokinins gibberellins mycorrhizae

1. Introduction

Species from the *Zantedeschia* genus, described almost 200 years ago, belong to the numerous picture family Araceae, in which the inflorescence is a spadix with numerous small flowers set on a succulent stem surrounded by a colourful inflorescence spathe [1]. The generic name was given in tribute to the Italian researcher and scientist Giovanni Zantedeschi (1773–1846) [2][3]. Initially, the cultivation was dominated by *Zantedeschia aethiopica* (L.) Spreng. Its importance is currently low and cultivars with colourful inflorescence spathes derived from *Z. rehmanii* Engl., *Z. elliottiana* (W. Wats.) Engl. and *Z. albomaculata* (Hook.) Baill, among others, are becoming increasingly important. Their obtainment was possible thanks to intensive breeding work carried out initially in the United States of America and New Zealand and later in South Africa and the Netherlands. The cultivar range is large. In the 1990s, 120 cultivars were already known and a dozen new ones appear every year (**Figure 1**). Cultivar breeding focuses primarily on obtaining a high yield of cut flowers, although only a few cultivars meet this criterion [4][5].

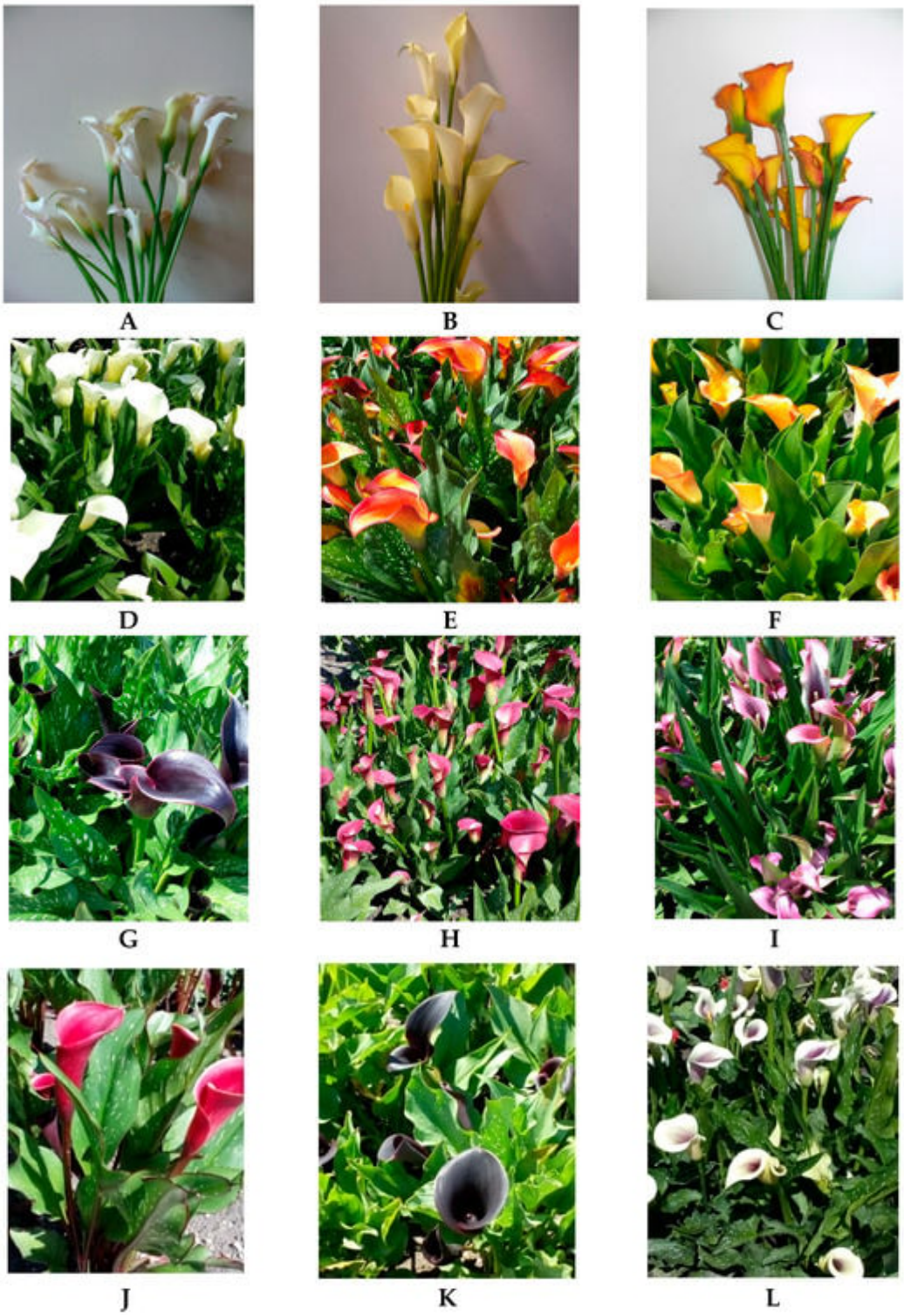

Figure 1. *Zantedeschia* cultivars: (**A**)—'Albomaculata', (**B**)—'Black-Eyed Beauty', (**C**)—'Mango', (**D**)—'Siberia', (**E**)—'Morning Sun', (**F**)—'Mercedes', (**G**)—'Cantor', (**H**)—'Le Chique', (**I**)—'Lavender Gem', (**J**)—'Red Charm', (**K**)—'Black Art', (**L**)—'Picasso' (Beata Janowska 2010–2017).

Since the 1990s, the world has seen an increased interest in *Zantedeschia* with colourful inflorescence spathes. In Poland, its cultivation began much later. The reasons for this phenomenon can be traced to the high price of rhizomes reproduced in the United States of America, the Netherlands, New Zealand and Kenya. The total area of

reproductive plantations in these countries occupies 288 hectares. Smaller plantations are also found in Brazil, Zimbabwe, Costa Rica and Israel. The area of reproductive plantations is increasing every year, but this does not affect the decrease in the price of rhizomes, which is the main reason that only a few producers are cultivating *Zantedeschia* cultivars in Poland. Producers offer rhizomes in various sizes, with flowering expected only from the largest ones. However, the yield of cut flowers that can be obtained from them is often not very satisfactory [6][7][8][9][10] and is not compensated by the price that can be obtained from the sale of the flowers. It is the low yield of cut flowers that is the main problem in the cultivation of *Zantedeschia* cultivars, hence research conducted worldwide focuses on the use of growth regulators from the group of cytokinins (CKs) and gibberellins (GAs) in the cultivation of *Zantedeschia* with colourful inflorescence spathes. The post-harvest life of flowers and leaves of cultivated *Zantedeschia* cultivars is also an important problem. The ageing process is controlled by growth regulators—CKs and GAs—considered ageing inhibitors. During the ageing process, their content in plant tissues decreases, whereas the level of growth regulators, such as ethylene, salicylic acid (SA), brassinosteroids (BR), abscisic acid (ABA), and jasmonic acid (JA), increases and the ageing process accelerates [11]. Recent studies indicate that the post-harvest life of *Zantedeschia* leaves is improved by topolins (Ts). Ts are a new group of endogenous, aromatic cytokinins isolated from poplars at Palacky University Olomouc and at the Institute of Experimental Botany in the Czech Republic. The Ts used are derivatives of benzyl amino purine. In their benzene ring, there is a hydroxyl group in the ortho or meta position. In very few studies conducted so far, Ts have been used only in order to assess their usefulness in in vitro cultures. It was determined in standard biological tests that these substances strongly prevent leaf ageing [12].

2. Cultivation of *Zantedeschia* for Cut Flowers

Zantedeschia elliottiana, *Z. rehmanii* and *Z. albomaculata* go through a rest period from October to February. Rhizomes are stored in openwork containers and covered with sawdust in a storage room at 12–15 °C, and for long-term storage, they are stored at only 8 °C [13]. In Poland, *Zantedeschia* flowers with colourful inflorescence spathes are grown primarily under cover—in greenhouses and plastic tunnels (**Figure 2**). Ground cultivation (**Figure 3**) is also possible. Its advantage is the better quality of the flowers, which, while shorter, have stiffer stems and better coloured inflorescence spathes. Moreover, rhizomes grow better in the ground [7]. The reasons for this phenomenon can be traced to the intensity of light, which is reduced under cover in order to reduce the temperature, which is often excessively high during the summer for the cultivation of *Zantedeschia*, in which, although it does not show a photoperiodic response, both the colouration of inflorescence spathes and the rigidity of the stems depend on good sunlight [14].

Figure 2. Beginning of flowering ‘Mango’ cultivar grown in plastic tunnel (Beata Janowska 2010).

Figure 3. *Zantedeschia* cultivars in the botanical garden in Wrocław (Beata Janowska 2017).

In Poland, due to the high demand for flowers in spring and the best light conditions at that time, they are planted in greenhouses from early February to March. In heated plastic tunnels, rhizomes can be planted at the same time. For unheated plastic tunnels, rhizomes can be planted only in April. Plants are grown in ground beds, boxes, pots or cylinders. Cultivation in containers is more advantageous as it allows rapid isolation of diseased plants [13].

Small rhizomes with a circumference of 8–9 cm are planted in the amount of 40 per m^2, while those with a circumference of 16–18 cm are planted in the amount of 20 per m^2. Rhizomes with a circumference of more than 20 cm are planted in the amount of 15 per m^2 [7]. They are covered with a 6–10 cm thick substrate to shield the roots growing out of the upper part of the rhizome. Before planting, the rhizomes are treated with 1% Captan for 20 min [7][13].

The substrate should be humus and permeable, with a pH of 5.8–6.2, enriched with slow-release fertilizers such as Osmocote Plus 3–4 M, in the amount of 3 $g \cdot dm^{-3}$. Substrates of various compositions are used around the world. In New Zealand, it is a mixture of composted pine bark (70%) and 3 mm diameter pumice (30%). In the Netherlands, coconut husks, high peat or pearlite are added instead of pumice. *Zantedeschia* flowers are also grown in mineral wool, which, on the one hand shortens the cultivation cycle and, on the other hand, enables rapid isolation of diseased plants. Rhizomes are planted in cubes, which are then placed in a special camera for 2–3 weeks for “initial sprouting” (**Figure 4**) [13]. There is also the possibility of growing in pearlite itself, which does not heat up in hot weather thanks to its white colour [15].

Figure 4. Rhizomes soaking in water solution of growth regulators (Beata Janowska 2010).

Zantedeschia should be grown in large, bright greenhouses or plastic tunnels as, although it is a photoperiodically neutral plant [14], both the colouration of the inflorescence spathes and the rigidity of the stems depend on good lighting. Plants are shaded only on very sunny days to reduce the temperature in the greenhouse. In summer, the temperature should not exceed 24–28 °C during the day and 16–18 °C at night. In spring and autumn, the temperature at night can be lowered to 11–12 °C, and then the inflorescence sheaths will have a better colour. For the first two weeks after planting, the temperature of the substrate should be kept at 15–16 °C, but later it can be raised a few degrees. In summer, the substrate temperature should not exceed 22 °C. Mulching with straw or sawdust effectively prevents the overheating of the substrate. During the growing season, *Zantedeschia* with

colourful inflorescence spathes are watered moderately. It is beneficial to use perforated hoses and, in container cultivation, driplines. Flowering begins 8–10 weeks after planting the rhizomes. Inflorescences in which the sheath is well-coloured and the flowers in the lower part of the sheath are ripe are suitable for cutting. The stems are not cut but gently broken off. After flowering, plants should continue to be nurtured to maximize rhizome growth, with watering gradually reduced to bring plants into dormancy [13].

Flowering in *Zantedeschia* depends on the cultivar, the size of the rhizomes and the length of storage [12]. Research conducted around the world focuses on improving flowering through the use of growth regulators as the yield of most *Zantedeschia* cultivars with colourful inflorescence spathes is not very satisfactory. The efficacy of gibberellins (GAs), in particular gibberellic acid (GA_3) [6][7][8][10][16][17][18][19][20][21][22]; cytokinins (CKs), especially benzyladenine (BA) [23]; a mixture of GA_3+BA [21][23][24][25][26]; and from among preparations of Promalin (preparations containing GA_{4+7} and BA [24][27]) has been demonstrated.

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