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Flowering initiation in *Amaryllis belladonna*

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Abstract

An understanding of initiation and influencing factors are necessary to develop forcing techniques for flowering plants. The March lily (*Amaryllis belladonna*) is a late summer flowering bulbous plant of South Africa. The inflorescence bears 2-12 soft pink fragrant funnel-shaped flowers on 'naked' (leafless) stems. It makes an excellent potted plant and fresh cut flower lasting up to a week in a bouquet. Preliminary data of the aspects influencing the morphological changes to promote flower-bud initiation are discussed. These include physical traits of bulb size, age and dormancy; planting establishment with relevance to methods and bulb disturbance and the environmental factors of temperature, watering, day length and seasonal fire. This review is aimed to encourage further research and popularization to enhance the year-round growing of *A. belladonna* to expand its economic and commercial potential.

Keywords: naked ladies, cut flower, *Amaryllidaceae*, initiation, hysteranthous bulb

INTRODUCTION

Flowering of *Amaryllis belladonna* occurs in late summer which is different to many other flowering bulbous species, which flower in autumn, winter, spring and early summer. *A. belladonna* exhibits active growth in winter with the senescence of their leaves at the beginning of summer before the bulb goes dormant. As several environmental factors can affect bulb development and play a major role in flower development (De Hertogh and Le Nard, 1993) it remains unclear which are the contributing factors to initiate flower development in *A. belladonna*.

The family *Amaryllidaceae* consist of 59 genera and about 850 species with the biggest diversity in South America (28 genera), South Africa (18 genera), Mediterranean region (8 genera) and Australia (3 genera) (Adams, 2001; Snijman, 2004). *Amaryllidaceae* bulbs such as *Galanthus*, *Leucojum* and *Narcissus* are more adaptable to cooler temperate climates while *Amaryllis*, *Clivia*, *Hippeastrum*, *Nerine* and *Zephyranthes* are more suitable for warm temperate and subtropical climates (Snijman, 2004). Southern Africa has 210 endemic species consisting of 111 species in Namaqualand and the Cape Region with 77% of these found nowhere else in the world (Snijman, 2004). Most species in South Africa are well adapted and dependant to the occurrences of natural wildfires for their flowering and reproductive phases. Unfortunately, due to habitat loss, 59 species have become endangered and or vulnerable and 58 species are near threatened due to their habitat loss. Habitats consist mainly of ephemeral pools, river banks, seasonally dry places and the understorey of rainforests (Snijman, 2004). Species such as *Clivia*, *Cryptostephanus* and *Scadoxus*, have rhizomes while most other *Amaryllidaceae* have bulbous storage organs which grow well below ground (Snijman, 2004). While most *Amaryllidaceae* species have ornamental economic value many are traded as Traditional African Medicines. Most bulbs are highly toxic in large dosages and were mainly used for their psychoactive effects, *Amaryllis* which was used as arrow poison by Khoi and San tribes (Snijman, 2004; Duncan, 2010; Solomon, 2018).

This mini review is aimed at exploring factors which effect morphological changes in flowering initiation of *A. belladonna* to expand future research in improving flowering for economic and commercial potential.

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AMARYLLIS BELLADONNA L.

Most *Amaryllidaceae* species, especially *A. belladonna* L. are highly valued as garden plants, potted plants and excellent cut flowers however its commercial potential has been left unexplored (Bryan, 2002). A full understanding of the influencing factors which cause morphological changes to initiate flowering in *A. belladonna* is necessary to establish methods to develop forcing techniques in the species. *Amaryllis* is a feminine Greek word named after a beautiful shepherdess meaning beautiful lady (Adams, 2001). The genus is regarded as having two species *A. belladonna* and *A. paradisicola*. *A. belladonna* L. commonly known as the “Belladonna lily, March lily, Naked lady (Eng.); and the Belladonna lelie, Maartblom, Maartlelie (Afr.)” are one of the most beautiful of all species (Bryan, 2002).

Several cross breeding of *Amaryllis* has been done with *Brunsvigia*, *Crinum* and *Nerine* to produce intergeneric hybrids. Some of these are: var. *blanda* which has large white blossoms and var. *spectabilis* with rose colored tepals and white on the inside. Several cultivars include ‘Baberton’: dark rose pink; ‘Cape Town’: deep rose red; ‘Hathor’: white; ‘Jagersfontein’: deep pink; ‘Johannesburg’: pale pink with lighter throat; ‘Kewensis’: pink with yellow throat; ‘Kimberley’: deep carmine red with white center; ‘Major’ with dark stems and dark pink flowers; ‘Pallida’: rose pink; ‘Purpurea’: purple-rose; ‘Rosea’: white stripes on rose tepals; ‘Rubra’: has more red than pink and ‘Windhoek’: shows lovely rose pink with a white center (Bryan, 2002). As *Amaryllis* has so much potential as cut flowers, more crosses are expected in the future (Bryan, 2002). While some forms of *A. belladonna* are more naturally free flowering some with rapid vegetative growth rates tend not to flower that readily (Duncan, 2004).



Figure 1. *A. belladonna* flowering in nature showing the striking intense pink flower color of the flowers (http://www.biodiversityexplorer.org/plants/amaryllidaceae/amaryllis_belladonna.htm).

Growing cycle, bulb maturity and planting requirements

1. Understanding the natural growing cycle and flower initiation.

A. belladonna is native to a naturally Mediterranean climate of South Africa and found growing on lower slopes, rocky hillsides, in low growing bush and by rivers. The species is endemic to the south-western Cape (Olifants River to Cape Town), southern parts of the Western Cape to George and the Richtersveld in the Northern Cape (Philips and Rix, 1989;

Mustart et al., 1997; Adams, 2001; Duncan, 2010). *A. belladonna* has gained international popularity with naturalization in many Mediterranean climates of the world (Manning et al., 2002). It has a large brown, rounded ovoid bulb to 750 mm covered with spongy brittle outer tunics with perennial fleshy roots (Pienaar, 1987; Adams, 2001). The bulbs are poisonous to livestock and humans causing respiratory paralysis if eaten (Bryan, 2002). During the last summer months flower stems emerge from the bare ground to signal the end of a hot summer in the region. The bulbs flower at a specific time when few other plants are in flower (Adams, 2001; Duncan 2010). Bulbs produce 2 to 12 soft white, pink to rose pink strongly fruity and sweet scented trumpet-shaped flowers on 'naked' (leafless flower stalks) and purplish-red stems (50-90 cm tall) (Philips and Rix, 1989; Johnson and Snijman, 1996; Mustart et al., 1997; Adams, 2001; Bryan, 2002; Manning et al., 2002; Duncan, 2010) (Figure 1). The flowers appear before the leaves (hysteranthly) and continue to flower over a three-month period with the arrival of the first rains and the change in season (Adams, 2001).

After flowering and during the wet winter growing period bulbs produce six to 11 long strap-like channelled leaves which remain green throughout the winter period (Johnson and Snijman, 1996; Mustart et al., 1997; Manning et al., 2002). These leaves continue to grow through photosynthesis while starch reserves are built up in the bulb (Johnson and Snijman, 1996; Mustart et al., 1997) (Figure 2). The bulb senescence as summer arrives, the leaves die back and the bulb becomes dormant and becomes uninteresting during this season (Adams, 2001). It is noteworthy that *A. belladonna* does not flower regularly each year in their natural habitat (Pienaar, 1987). Irregular flowering of this species show potential for experimental trials to explore flowering initiation under several conditions as further indicated.

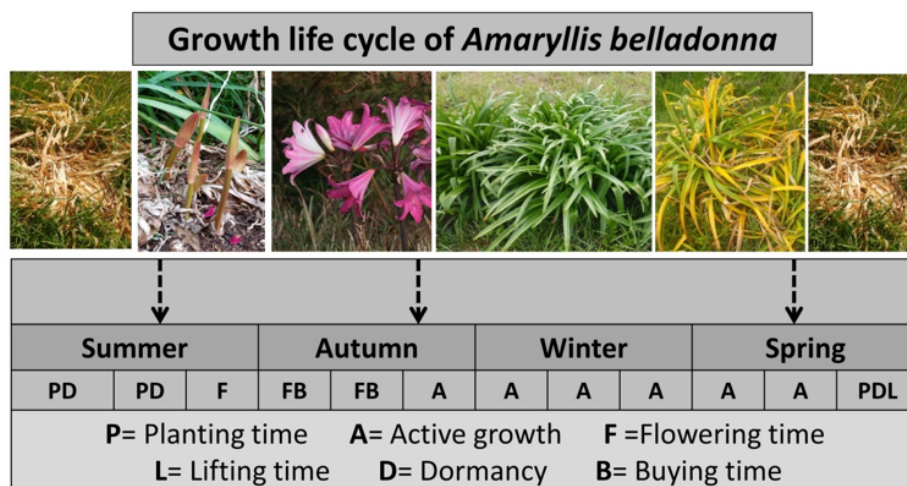


Figure 2. A photographic representation of the annual growth cycle of *Amaryllis belladonna* during the climatic seasons. Cultivation times for a one year period are given. (Pictures: Laubscher C; <https://www.houseplantsexpert.com/growing-belladonna-lily-plants-indoors.html>; http://www.biodiversityexplorer.org/plants/amaryllidaceae/amaryllis_belladonna.htm).

2. Bulb maturity, avoiding disturbance and flower initiation.

As certain genotype variances could favor the initiation of inflorescence, development stages such as bulbs size (500-750 mm), age (4-5 years old) and possibly a minimum number of leaves (6-9) could indicate when a critical bulb size is reached. This is when flowering would be initiated in *A. belladonna* (Figure 3). During active growth above ground, carbohydrates accumulate to enhance bulb development. The planting of bulbs is essential to synchronize flower initiation. While it is recommended to plants bulbs when they are dormant, the exact planting time of *A. belladonna* seems to vary (Pacific Bulb Society, 2018).

Some sources recommend bulbs to be planted from mid-summer to the beginning of the last summer month of a year to ensure that they have settled in the ground before the inflorescences appear (Pienaar, 1987; Duncan, 2010), others indicate bulbs should be planted with emergence of the new leaves to bloom the following year (Pacific Bulb Society, 2018). Planting *A. belladonna* bulbs during different seasons could result in a total decline in flowering for the following years as some summer planted bulbs could not flower for at least two years after planting (Pacific Bulb Society, 2018). Prior to lifting the bulbs should be watered. Thereafter bulbs can be dug up, clumps separated with saving as many roots as possible and kept moist to prevent bulbs drying out. When bulbs mature, offsets will develop or new plants can be raised from fresh sown seeds which could take between 4 to 6 years to flower. Clump division is done in late spring or summer (Solomon, 2018). *A. belladonna* bulbs resent disturbance and may not flower the first summer or after several seasons after replanting (Barnhoorn, 2013; Hadeo, 2018; Solomon, 2018). When roots are damaged or exposed to air flowering can be affected (Duncan, 2010). *A. belladonna* bulbs prefer to be left in the ground undisturbed for several years to flower more readily (Duncan, 2010). On the other hand, bulbs left undisturbed for a longer period of time could also decrease the flowering, therefore it is recommended that bulbs be lifted and replanted every five years to improve flowering (Duncan, 2010).

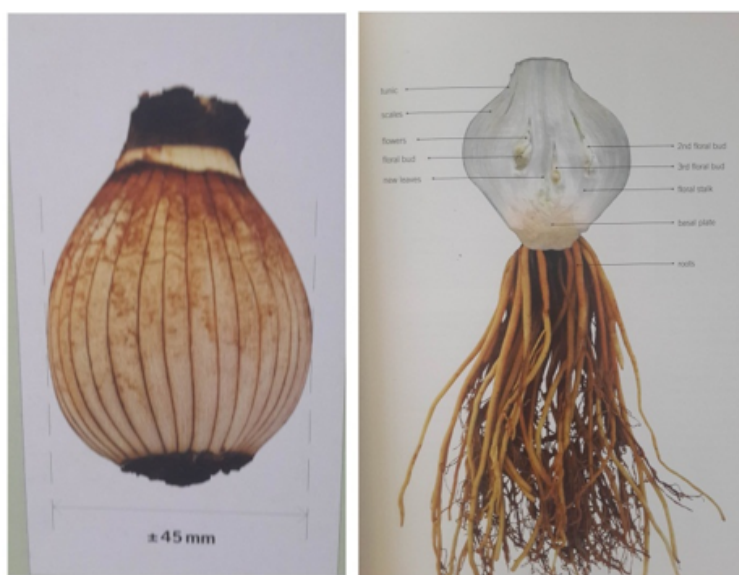


Figure 3. A presentation of the bulbs size, root growth and flower bud development of *Amaryllis* (Barnhoorn, 2013).

3. Planting requirements and flower initiation.

Although *A. belladonna* requires very little attention to grow it prefers a hot sunny position if flowering quantity per bulb is required (Philips and Rix, 1989; Adams, 2001; Barnhoorn, 2013; Solomon, 2018). Bulbs grown in full sun should be more floriferous in blooming than those grown in shade (Bryan, 2002; Pacific Bulb Society, 2018). *A. belladonna* should be planted in a well-drained sandy to fertile loam soil with some compost (Pienaar, 1987; Rix, 2006; Barnhoorn, 2013; Solomon, 2018). The bulbs should not be cultivated in rich soils or receive supplementary feeding as they have low nutritional requirements (Duncan, 2010). A top-dressing of 10-10-10 can be beneficial when flowers begin to fade and foliage emerges (Bryan, 2002). Bulb leaves should not be removed until they have completely died down (Solomon, 2018). *Amaryllis* is suitable to use for water-wise plantings and in arid conditions but require regular watering (Bryan, 2002; Duncan, 2010). Begin watering as the flower spikes appear and increase watering after flowering till the foliage dies down and allow pots to dry out (Bryan, 2002). *A. belladonna* is ideally suitable to be

grown in large pots (30-25 cm) to accommodate large bulbs and root systems, especially suitable for cold climates where bulbs could be spaced 5-6 cm away from the pot wall (Bryan, 2002; Duncan, 2010; Pacific Bulb Society, 2018; Solomon, 2018).

A. belladonna bulbs should be planted with the neck of the bulb exposed or planted just below or at soil level where light and heat possibly will encourage inflorescences to emerge (Adams, 2001; Bryan, 2002; Duncan 2010; Barnhoorn, 2013; Solomon, 2018; Pacific Bulb Society, 2018). Bulbs should be planted deeper where temperatures drop below freezing while the addition of lightweight mulch on top of the bulbs is beneficial to prevent bulbs from freezing (Bryan, 2002). Unfavorable planting methods could greatly affect flowering percentage (Figure 4). Due to these reasons further studies are important to establish a suitable planting protocol to ensure successful flowering of this popular flowering bulb.



Figure 4. *A. belladonna* cut flower with dark red stems at a flower market (<https://www.newcoventgardenmarket.com/blog/flowermarketreport-oct-2012>).

Environmental and climatic conditions

1. Temperature changes and flower initiation.

Proper environmental growing conditions could stimulate successful flowering for *A. belladonna* to be grown as a potential commercial cut flower. The emergence of florescence could be stimulated by a long dry summer resting period of high temperatures (15-27°C) and then possible triggered by cooler autumn temperatures (5-13°C). The bulbs are dormant during summer and exposed to higher (27°C) day temperatures which support flowering (Manning et al., 2002) (Table 1). Simulated conditions could be induced with heated storage of bulbs followed by vernalization at cooler temperatures. This cooling period is important in flower development or spring flowering bulbs to prevent root growth functions and flowering disorders (Kamenetsky and Okubo, 2013). The growing of *A. belladonna* in Mediterranean type climates experiences flowering more readily (Pacific Bulb Society, 2018). As bulbs lose their leaves the plants act like sclerophyllous plants to act with a strategy to become dormant during the hot summer period. Some dry-climate plants use this strategy of extremes to cope with survival where no leaves allow photosynthesis, hence no water loss (Filippi, 2008). The bulbs remain underground and are ready to signal flower production as a survival mechanism with a change in temperature and possible first arrival of autumn rains.

Table 1. Climatic conditions depicting the season, maximum and minimum temperatures, humidity, and average rainfall of the natural habitat for *A. belladonna* L. in the Western Cape province of South Africa. Source adapted: [http://www.signaturetours.co.za/south-african-information/weather-and-climate], (2018).

	Summer	Autumn	Winter	Spring
Temperature	Max 27°C Min 15°C	Max 25°C Min 14°C	Max 22°C Min 7°C	Max 19°C Min 9°C
Humidity	77%	77%	80%	80%
Average rainfall per month	17 mm	25 mm	82 mm	53 mm

Amaryllis tolerates moisture during summer rain provided bulbs have good drainage (Barnhoorn, 2013). Many species of the Mediterranean-climate regions have in the course of their evolution developed a range of remarkable strategies to cope with dry conditions (Filippi, 2008). *A. belladonna* occurs naturally in this climate type with hot dry summers and mild wet winters (5 to 22°C). The species is also frost hardy and can withstand temperatures to -5°C (Duncan, 2010) and have adapted to the southern parts of England where it can survive to -15°C although it requires a very warm position to flower (Philips and Rix, 1989). Climatic requirements should be copied for commercial planting as the example in Northern California indicates where bulbs have survived in receiving moisture during autumn and a hot dry summer period (Bryan, 2002).

2. Seasonal rain, moisture and flower initiation.

A. belladonna bulbs receive an average of 17 mm rain during the hot summer months in its natural Mediterranean climate type habitat (Table 1) which indicate that low amounts of watering in summer is needed to initiate flowering. As *A. belladonna* is known for its difficulty to flower, it is important to protect plantings from excessive rain in summer to prevent rotting of the bulbs (Pacific Bulb Society, 2018). Bulbs are remarkably resilient to garden irrigation during the summer dormant period when they are grown in well-drained soils (Duncan, 2010). Occasional summer watering should keep fleshy roots from drying out and could possibly trigger flowering at the end of summer; however dry summer dormancy after the leaf senescence could also be responsible for flowering initiation. Similarly, the advance of early autumn rain could also be responsible for triggering flower initiation (Bryan, 2002; Pacific Bulb Society, 2018). Begin watering as soon as the flower spike appears. During the wet winter growing conditions with a short day length (8–11 h day⁻¹) and full sun exposure the leaves are actively growing to produce and store starch energy for the next flowering season (Honig, 2014). While thermoperiodicity is an important factor in flowering and not a photoperiod of many species, only a small number of bulbous species respond to both temperature and day length (Ofir and Kigel, 2006). Winter freezing in cold climates should be avoided as bulbs could be killed by freezing conditions (Pacific Bulb Society, 2018). *A. belladonna* occurs mainly along coastal areas in South Africa and California, and is widely grown in Australia. It is uncertain if improved flowering along coastal regions are due to milder temperatures, higher humidity during summer or fog along the coast (Pacific Bulb Society, 2018). It is possible that withholding water could induce flowering or the arrival of the first moisture after a long summer could trigger flowering initiation.

3. Wildfire, heat, vegetation clearing and flower initiation.

The ecological cycle of Cape Flora has a natural occurrence of frequent natural fires which result in burning areas in the habitat that provide a spectacular flowering in diversity of bulbous plants after bush fires (Mustart et al., 1997; Filippi, 2008). *A. belladonna* is one species which produces a showstopper display against a background of sun/fire-scorched vegetation (Pienaar, 1987) (Figure 5). It remains uncertain why species such as *A. belladonna* flower successfully especially after bush fires (Philips and Rix, 1989). Bulbs can

also totally render flowering for possibly 5 to 40 years and then be triggered to flower on mass possibly due to the heat of wild fires and or the exposure to smoke (Johnson and Snijman, 1996; Adams, 2001; Duncan 2004; Pacific Bulb Society, 2018). In cultivation, dry plant material can be burnt over the bulbs to assimilate wild fires to induce flowering (Duncan, 2010). Smoke treatments induced in other bulbous species such as *Cyrtanthus ventricosus* has initiated flowering (Johnson and Snijman, 1996) and a top dressing of hot wood ash followed by watering in early autumn could encourage flowering of *A. belladonna* (Rix, 2006).

It remains uncertain what triggers flowering in some *A. belladonna* bulbs to ensure that they flower year after year (Johnson and Snijman, 1996). *A. belladonna* requires bright light, a preferably warm position with morning to full day sun to flower (Duncan, 2010). Often bulbs become overgrown with vegetation which reduce flowering. It is therefore important to remove overgrowth and shading on a regular basis to encourage flowering of *A. belladonna* (Johnson and Snijman, 1996; Duncan, 2010). Studying these and other plant strategies are necessary to formulate an understanding of the species survival techniques in plantings to enhance commercial cultivation to ensure flowering at its fullest potential (Filippi, 2008).



Figure 5. *A. belladonna* flowering after fire in a natural habitat (http://www.biodiversityexplorer.org/plants/amaryllidaceae/amaryllis_belladonna.htm).

CONCLUSIONS AND RECOMMENDATIONS

Almost all data on the aspects influencing the morphological changes to promote flower-bud initiation have shown that there are many possibilities to increase flowering in *A. belladonna*. Physical traits such as bulb size, age and dormancy; planting establishment with relevance to methods and bulb disturbance and the environmental factors of temperature, watering, day length and seasonal fire could all be important to stimulate flower initiation. Although there have been many studies on the storage of bulbs, the data found on aspects that triggers flowering of *A. belladonna* shows great variation. Further studies are needed on the stages from planting to flowering and the post flowering period of the species. An understanding and testing of the influencing factors are necessary to establish the factors responsible for initiation of flowering of *A. belladonna*. This could lead to the development of flower forcing techniques and extending the short-lived flowering period in further enhancing year round growing and expansion of economic cut flower potential of *A. belladonna*.

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