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RESEARCH NOTE

Measuring the length of the juvenile phase and corm growth in the Chilean endemic geophyte *Conanthera bifolia* Ruiz et Pavon

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Abstract

F. Schiappacasse, P. Yáñez, P. Peñailillo, and E. Misle. 2023. Measuring the length of the juvenile phase and corm growth in the Chilean endemic geophyte *Conanthera bifolia* Ruiz et Pavon. Int. J. Agric. Nat. Resour. 84-91. The geophyte *Conanthera bifolia* is endemic to Chile and belongs to the family Tecophilaeaceae. When in flower, the plant produces an inflorescence with blue florets. Conanthera plants arise from underground structures called corms; these have been reported to have been consumed as food in the past. These plants also have ornamental potential as garden or pot plants. The new corm starts growing on top of the mother corm by the end of summer; blooming occurs in the spring, and the plant goes dormant after fruit set. The corm flowering size and juvenile phase length in *C. bifolia* are unknown. The study objective was to determine the weight of the corm that is necessary for flowering and the number of seasons required to reach that weight. Corms were collected from the wild, separated into 10 weight categories from 0.2 to 5 g, and planted in trays in an unheated greenhouse in Talca, Chile. Corms weighing more than 1 g were able to flower, and the greatest flowering (48 to 70%) was found in corms weighing 3.5 to 5 g. The plant propagation coefficient decreased as the initial corm weight increased. The number of seasons to reach flowering size was estimated to be 8 years, placing this species in the group of geophytes with slow growth.

Keywords: Chilean endemic plant, corm weight, fibrous tunic, flowering corm fraction, length of juvenile phase, Tecophilaeaceae.

Introduction

The geophyte *Conanthera bifolia* Ruiz et Pavon, endemic to the Mediterranean climate area of Chile, belongs to the Tecophilaeaceae family. As with some other Chilean geophytes (*Tecophilaea*, *Zephyra*, and other species of *Conanthera*), the underground storage organ is a corm. In the same family is found the genus *Cyanella*, which originated in Africa; it has acknowledged ornamental use (Reinten et al., 2011) and grows from a corm. In *C. bifolia*, this cream-white organ (2 cm maximum diameter) is surrounded by a dark brown fibrous tunic and has a summer rest period (Schiappacasse et al., 2002).

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As in many cormous plants, the new underground structure grows on top of the previously planted corm. However, the new corm does not form roots as in *Gladiolus* spp.; the roots are produced exclusively in the mother corm. Interestingly, only one daughter corm replaces the mother corm (Yáñez et al., 2005). In *Zephyra elegans*, another endemic geophyte from the Tecophilaeaceae family (Kim et al., 1997), the planted corms occasionally form droppers, as in juvenile *Tulipa* spp. bulbs (Rees, 1992; De Hertogh & Le Nard, 1993). No cormels are produced in *Conanthera*, and under certain circumstances (i.e., in storage or dry years), corms undergo pupation as occurs in *Freesia* spp. corms (Rees, 1992).

The leaves of *Conanthera* lie at the base of the 12-46 cm high plant. They are linear and start to emerge from the soil at the end of autumn. Flower initiation in cultivation occurs when the plant has 3-4 leaves in the middle of September (data not presented). Weeks later, in the spring (September to November), anthesis takes place (Yáñez et al., 2005). The inflorescence (only one flowering stem per corm) holds several florets with six blue– violet tepals curved toward the outside. The three inner tepals have spots at their bases. There are six stamens with yellow–orange anthers joined together forming a cone that protrudes the floret, giving a special shape to the floret that differentiates it from other species of the same genus (Schiappacasse et al., 2002). After fruit set in mid-summer, seeds are shed, and the plant becomes dormant.

There are reports about corms of *Conanthera* spp. being consumed raw or cooked as food in impoverished areas (Muñoz et al., 1981; Philippi, 2008) and by the Chilean endemic subterranean rodent *Spalacopus cyanus* (Contreras et al., 1993). In addition to its edible potential, *Conanthera* spp. has ornamental potential as a garden and potted plant (Olate & Schiappacasse, 2013).

In geophytes, the flowering capacity relies on genetics and environmental factors, especially on the size of the underground structure, usually expressed in terms of weight or perimeter. For example, the length of the juvenile phase in years in the cormous plants *Crocus*, *Gladiolus* and *Freesia* is 3-4 years, 1-2 years, and 1 year and the minimum flowering sizes are 4-5, 3-6, and 2-3 cm in perimeter, respectively (Le Nard & De Hertogh, 1993). In *Z. elegans*, it has been determined that the quality of the flower improves in corms weighing more than 0.8 g, although the minimum corm size for flowering is 0.3 g (Kim et al., 1997). Botanical and taxonomic studies are available in *Conanthera* species, while cultivation and flowering issues have not been addressed. Thus, this study aimed to determine the flowering corm size in *C. bifolia* and to estimate how many growing seasons are needed to reach the flowering size when the plants are started from seeds.

Materials and methods

Corms of *C. bifolia* were collected during the fruiting stage in mid-summer (January) at a natural site in the premountain range area where they are abundant in the Maule region (central Chile) (Vilches, 35°32'S, 71°10'W; 586 m a.s.l.). Corms were stored for six weeks at room temperature (18-22 °C) until planting time. After the fibrous tunic was removed, the corms were classified according to their weight into 10 categories, from 0.2 to 5.0 g. In a completely randomized design, five replicates were considered per corm weight class; the experimental unit was a plastic tray with 10 corms.

Planting was performed in March, the start of autumn in Central Chile, in an unheated polyethylene-covered greenhouse located at Universidad de Talca, Talca (35°23'S, 71°38'W). Corms were planted at a depth of 6 cm in plastic trays (27 cm × 34 cm × 14.5 cm) filled with compost, sand and peat (3:1:1 v/v). The electrical conductivity of the mixture was 0.3 dS m^{-1}. Irrigation was performed every 3-7 days. After leaf emergence, at every three irrigations, a nutrient solution of 100 ppm

N (ammoniacal and nitric nitrogen) was applied, prepared with a soluble compound 25-10-10 fertilizer ($N-P_2O_5-K_2O$ + 1MgO + 1S + microelements).

At flowering (September, 180 days after planting), the number of plants with one flowering stem per replicate (expressed as a percentage) was recorded. In addition, total stem length (from the stem base to the inflorescence tip) and number of florets per inflorescence were measured. In the following summer dormant period, corms were dug up, cleaned and immediately weighed and measured (perimeter) after removing their tunic.

Analysis of variance was performed, and Duncan's multiple range test was applied ($p \leq 0.05$) when appropriate. Arcsin transformation was used for percent data. A regression analysis was performed to relate initial corm weight with corm weight at harvest and for calculations of the length of the juvenile phase. In these cases, the discriminants for evaluating fit were R^2, the absolute sum of squares and the standard deviation of residuals.

Results and discussion

No flowering was observed in the *Conanthera* plants that were grown from corms smaller than 1 g. In corms that weighed between 1.01 and 2 g (includes two weight categories), there was 10 to 18% flowering, and in corms 2.01 to 3.5 g (also includes two weight categories), flowering was 30 to 40%. The greatest flowering (48 to 70%) was observed in corms weighing 3.51 to 5 g (Table 1). Flowering increased as the corm size increased but not in a linear fashion (Fig. 1).

A corm perimeter of 7-9 cm would be the best to assure a high flowering level (approximately 48%, not different from 70%) with *Conanthera*

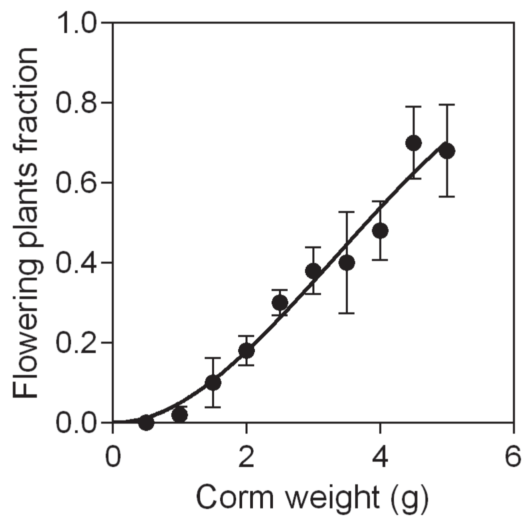

Figure 1. Proportion of flowering plants of *Conanthera bifolia* in relation to initial corm weight (g) that generated the plant.

Table 1. Effect of initial corm weight and perimeter on flowering percentage, plant height and floret number per inflorescence in *Conanthera bifolia*. Standard error is indicated.

Corm weight class (g)	Corm perimeter (cm)	Flowering plants (%)	Inflorescence length (cm)	Florets per inflorescence
0.20-0.50	2-4	0 ± 0.000 e	-	-
0.51-1.00	2-4	2 ± 0.020 e	-	-
1.01-1.50	3-6	10 ± 0.061 de	29.4 ± 0.600 b	8.5 ± 1.00 d
1.51-2.00	4-6	18 ± 0.037 cd	32.4 ± 1.84 ab	10.3 ± 0.90 bcd
2.01-2.51	5-7	30 ± 0.032 bc	28.8 ± 2.31 b	8.1 ± 1.24 d
2.51-3.00	6-8	38 ± 0.058 bc	34.0 ± 1.55 ab	12.2 ± 1.21 abc
3.01-3.51	6-8	40 ± 0.127 bc	31.4 ± 2.17 b	9.1 ± 0.70 cd
3.51-4.00	6-8	48 ± 0.073 ab	33.1 ± 0.77 ab	12.0 ± 0.92 abc
4.01-4.51	7-9	70 ± 0.089 a	37.4 ± 1.81 a	15.0 ± 1.14 a
4.51-5.00	7-9	68 ± 0.116 a	34.8 ± 1.17 ab	13.4 ± 1.22 ab

Values within a column followed by the same letter do not differ significantly (Duncan, $p \leq 0.05$).

(Table 1). Vogel et al. (1999) grew corms of *C. campanulata* and *C. trimaculata* in an unheated greenhouse, observing 75% flowering in corms heavier than 0.9 g, the maximum weight observed. This suggests that there could be a maximum achievable flowering percentage of approximately 70% for the species due to genetic modulation. Such a limit could be related to the effects of environmental growing factors (temperature, light and/or moisture) that were present in both experiments. The flowering percentage according to corm weight in nature has not been studied.

No consistent trend was found in terms of initial corm weight and inflorescence length. In terms of florets per inflorescence, the minimum was 8 and the maximum was 15.

The newly formed corm (daughter corm) had a higher weight than the initial corm; however, not all the corms produced new corms with increased weight (Table 2). A significant part (96-97%) of the smaller corms (0.38 and 0.74 average initial weight) more than doubled in weight, seeming to waste no energy in an additional sink such as flower production. A lower proportion of corms that increased in weight was observed among corms weighing more than 1.28 g. There was a trend toward a decrease in weight gain as the planted corm weight increased (Fig. 2). This finding demonstrates the competition for resources in terms of the plant biological cost between two sinks: flowering and growth of underground structures. This phenomenon has been addressed before by Boonekamp (1997) and leads to the early removal of the flower bud in the production of *Lilium* bulbs (Okubo & Sochacki, 2013) and other geophytes. Boonekamp (1997) reports that in most flower bulbs, flower (or inflorescence) growth is completely supported by the partitioning of carbohydrate assimilates from underground structures and not from the aerial parts of the plant. Perhaps the decrease in growth of the new corm as the planted corm increases in size is a mechanism to stop a permanent increase in corm size and form more florets, thus assuring species survival by means of seed production. This is in accordance with Zohary (1997), who argues that the natural underground vegetative propagation in most geophytes serves as protection against animal herbivory and keeps favorable sites occupied, while seed propagation is much more important and the rule in these species.

In general, corms increased in weight by less than 1 g (0.48 to 0.92 g, data not presented). The harvested bulb weight to planted bulb weight ratio, or plant propagation coefficient, in commonly known species ranges from 2-3 (*Lilium*, *Narcissus*, *Tritonia* and *Tulipa*) to 20-40 (*Allium*) (Le Nard & De Hertogh, 1993); in this study on *C. bifolia*, the highest values of approximately 2 were found in nonflowering corms. The rest of the values

Table 2. Effect of initial corm weight on newly produced corm weight in *Conanthera bifolia*. Standard error is indicated.

Average planted corm weight (g)	Average harvested corm weight (g)	Percentage of corms that increased in weight	Harvested corm weight per planted corm weight ratio (plant propagation ratio (%))
0.38 ± 0.011	0.84 ± 0.045	97.0 a	2.21
0.74 ± 0.017	1.55 ± 0.062	96.0 a	2.09
1.28 ± 0.016	1.82 ± 0.094	71.7 bc	1.42
1.70 ± 0.019	2.38 ± 0.094	79.2 b	1.40
2.28 ± 0.011	2.80 ± 0.128	75.0 bc	1.23
2.83 ± 0.016	3.06 ± 0.096	68.0 bc	1.08
3.29 ± 0.016	3.46 ± 0.096	58.7 bc	1.05
3.74 ± 0.019	3.81 ± 0.104	55.2 c	1.02
4.28 ± 0.018	4.44 ± 0.125	60.0 bc	1.04
4.75 ± 0.019	4.70 ± 0.148	56.1 c	0.99

Values within the column followed by the same letter do not differ significantly (Duncan, $p \leq 0.05$).

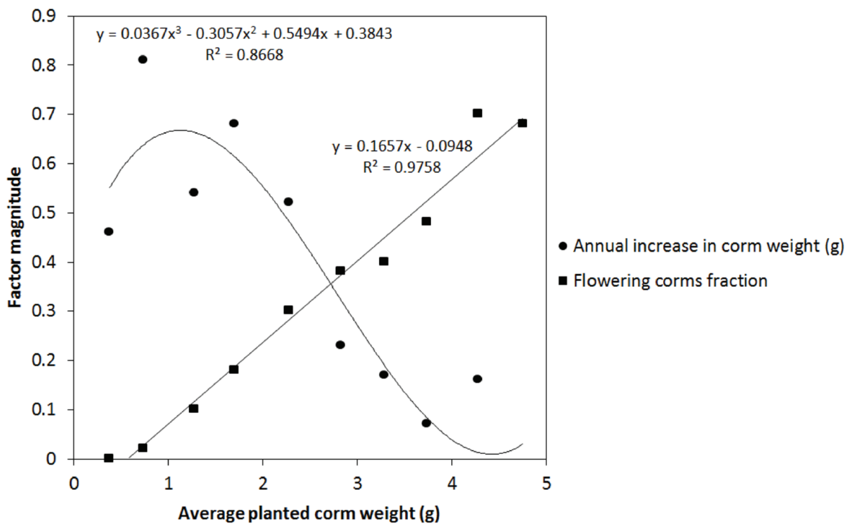

Figure 2. Annual increase in corm weight and flowering corm proportion in *Conanthera bifolia*. y = annual increase in corm weight (g); x = initial corm weight (g) at planting.

ranged from 0.99 to 1.42, highlighting the poor growth of flowering corms, which in addition to the low multiplication rate, makes conventional corm production difficult for this species.

The number of seasons needed to reach the production of a flowering corm starting from seed, also called the length of the juvenile phase, was estimated through a regression that was performed using the initial and annual variation in corm weight (Fig. 2). The regression function developed was $y = 0.0367\,x^3 - 0.3057\,x^2 + 0.5494\,x + 0.3843$. It was used for estimating the number of years (or seasons) required to reach 3.5 g, which was the critical corm weight to achieve 48% flowering (Table 1). It was assumed that seeds produce corms that weigh 0.38 g, the smallest average mass found in nature in this study. Therefore, starting the sequential annual increase in weight from corms of this mass, the regression function reveals that 8 years are needed to produce corms weighing 3.51 g, which in this study were able to present 48% flowering. This juvenile period length is longer than those reported for the bulbous crops *Narcissus* (4-6 years) and *Tulipa* (4-7 years) and much longer than the period reported for other cormous crops, such as *Crocus* (3-4 years), *Freesia* (1 year) and *Gladiolus* (1-2 years) (Le Nard & De Hertogh, 1993).

It is possible that in nature, the length of the juvenile phase could be longer under unfavorable environmental factors (e.g., low water or low nutrient availability). *In vitro* experiences to speed up the corm growth of *Z. elegans* starting from seeds have been successful (Vidal et al., 2012) but have not been attempted in *Conanthera* spp.

Further analysis of the results revealed an allometric relationship between the initial corm diameter (mm) and the harvested corm weight (g) (Fig. 3), considering the 461-point dataset (R^2=0.9328). Naturally, it also exists for the relationship between the initial corm diameter and the initial corm weight, but the first relationship has a practical application since by just measuring the initial diameter (D), it is possible to assess the corm weight (W) at harvest under similar climatic conditions as in the present study by the following function:

$$\frac{W}{W_x} = A_0 \left(\frac{D^b}{D_x}\right)$$

where A_0 is a normalization constant, also called the allometric constant and equals 0.9448, and b is the allometric exponent (1.711); D_x is the maximum diameter recorded in this study (25.24 mm), and W_x is the maximum corresponding corm weight at harvest (4.765 g).

Allium is a renowned geophyte genus that in the wild is usually found in arid climates in different habitats and in light-exposed areas (with very few exceptions) because the plants are weakly competitive (Brewster, 2008). *C. bifolia* is also weakly competitive, and this study confirms that it is a slow-growing plant, slower than known cultivated ornamental species, as 8 seasons are needed from seed to the production of corms with a good flowering level. Another difference from other cultivated geophytes, which is certainly a drawback, is that *C. bifolia* does not achieve 100% flowering. Further research is needed to determine methods of flowering control to allow cultivation in different seasons. At the same time, selective breeding would be necessary to increase the number of flowering plants and to improve plant and flower size, among other traits.

Conclusions

The corm weight in *C. bifolia* is a good indicator of the number of plants that flower. The highest number of flowering plants was found in corms weighing approximately 3.75 g, equal to or larger than 6 to 8 cm in perimeter, while corms weighing less than 1 g (2 to 4 cm in perimeter) were unable to flower.

An allometric relationship between the initial corm diameter and the harvested corm weight allowed estimates of corm weight at harvest. The estimated time from seed to flowering is equal to 8 seasons, which is a relatively long period compared to other geophytes.

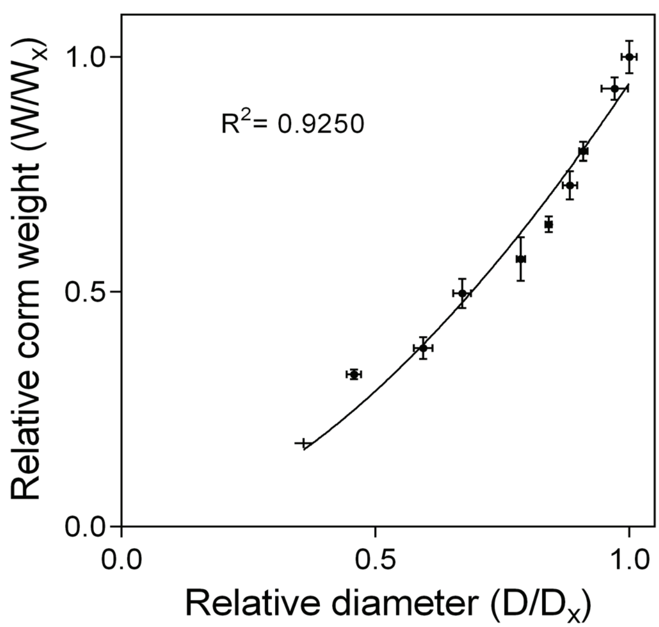

Figure 3. Allometric curve for relative initial corm diameter (D/Dx) of *Conanthera bifolia* in relation to relative corm weight at harvest (W/Wx) for 461 samples measured. The fit indicators R^2, absolute sum of squares, and standard deviation of residuals were: 0.9250, 0.2379, and 0.07114, respectively.

Resumen

F. Schiappacasse, P. Yáñez, P. Peñailillo, y E. Misle. 2023. Midiendo la duración de la fase juvenil y crecimiento del cormo en la geófita chilena *Conanthera bifolia* Ruiz et Pavon. Int. J. Agric. Nat. Resour. 84-91. La geófita *Conanthera bifolia* es endémica de Chile y pertenece a la familia Tecophilaeaceae. En floración, la planta produce una inflorescencia con florecillas azules. Las plantas de Conanthera crecen desde estructuras subterráneas llamadas cormos; hay antecedentes de que éstos fueron consumidos como alimento en el pasado. Estas plantas también poseen potencial ornamental como plantas de jardín o de maceta. Hacia el final del verano, el nuevo cormo comienza a desarrollarse sobre el cormo madre; la floración ocurre en primavera y la planta inicia su receso luego de la fructificación. En *C. bifolia* se desconocen el tamaño que debe tener un cormo para ser capaz de florecer y la duración de la fase juvenil. El objetivo de este estudio fue determinar el peso que debe alcanzar el cormo para poder florecer y el número de temporadas requeridas para alcanzar dicho peso. Se recolectaron cormos desde el ambiente natural, fueron separados en categorías de peso de 0,2 a 5 g y se plantaron en bandejas en un invernadero sin calefacción en Talca, Chile. Los cormos que pesaban más de 1 g fueron capaces de florecer, y la mayor floración (48 a 70%) fue observada en cormos de 3,5 a 5 g. El coeficiente de propagación disminuyó a medida que el peso inicial del cormo se incrementó. El número de temporadas para alcanzar el tamaño floral fue estimado en 8 temporadas (años), ubicando a esta especie en el grupo de geófitas de crecimiento lento.

Palabras clave: Duración de fase juvenil, peso del cormo, planta endémica chilena, proporción de cormos florales, Tecophilaeaceae, túnica fibrosa.

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