Growth and Flowering of *Ornithogalum dubium*

Gideon Luria[1], Abed A. Watad[2*], Yoash Cohen-Zhedek[1], Amihud Borochov[11*]

[1]Kennedy-Leigh Centre for Horticultural Research,
The Hebrew University of Jerusalem,
P.O. Box 12, Rehovot 76100
Israel
Giluria@shaham.moag.gov.il

[2]Dept of Ornamental Horticulture
Agricultural Research Organization
The Volcani Center
P.O. Box 6, Bet Dagan 50250
Israel

Keywords: Bulb size, growth regulators, light, stem length, temperature.

Abstract

***Ornithogalum dubium* is a frost-tender bulbous plant native to South Africa. It is mainly grown for cut flower and flowering pot-plant production. It generally produces 10-25 cm-long flowering-stems, bearing 5-25 yellow to orange flowers with a dark green/brown center. It is in great demand in Europe and North America as a cut flower and a flowering-house pot plant. *O. dubium* was introduced as a new cut-flower crop less than a decade ago and is still only grown on a small scale due to its variable flower quality. The main objective of the present study was to improve flowering-stem length. A three week preplanting temperarture treatment of 13°C resulted in significantly longer flowering-stems than treatments at 2, 9 or 25°C. Controlled growth-temperature and day length experiments indicated that warm day/night tempertures of 27/22°C induce early anthesis. Under this temperature combination, earliest flowering occurred under long day conditions. Stem length was maximal at moderately-low production temperatures, and long days further increased length. The number of florets per inflorescence depended on temperature. Under the two lower temperature regimes, many flowers developed per inflorescence and, again, long days enhanced this number. However under the highest temperature regime tried, this effect was reversed. Bulbs of different size were planted and even the smallest, flowered during the first year. Leaf production was proportional to planted bulb size. The rate of growth, time to flowering and total yield of daughter bulbs also depended on size of the planted bulb. Gibberellin, applied either as a preplanting dip or as foliar sprays, moderate shading (20%), as well as, a 24-h pre-planting exposure of bulbs to 10 ppm ethylene all increased flowering-stem length.**

INTRODUCTION

Ornithogalum (Family Hyacinthaceae, formerly Liliaceae), a genus of some 150 species of bulbous plants mainly found in the Mediterranean (and also in the temperate) regions of Africa, Asia and Europe (Bryan, 1993). *Ornithogalum dubium* Houtt. is native to South Africa. It is a frost tender plant grown mainly for cut flower and flowering pot-plant production. The inflorescence is generally a 10-25 cm long raceme, bearing 5-25 yellow to orange flowers with a dark green/brown center (Du Plesis and Duncan 1989). These flowering-stems are in great demand in Europe and North America as cut flowers. The plants are also gaining popularity as a potted flowering-plant. *O. dubium* was introduced as a new cut-flower crop less than a decade ago and it is still grown on a small scale due to several limitations. Some of these are related to the availability of high-quality planting material. Propagation from seed introduces wide genetic variability, whereas propagation from bulbs is more expensive and results in fast accumulation of virus disease. The main problem however is the often poor flower quality characterized by short flower stems which are unacceptable on the cut flower market.

---

[1]* Deceased

Growth and flowering of all commercially grown geophytes are significantly affected by environmental conditions at all stages of their development. These can be manipulated for controlled and predictable production (De Hertogh and Le Nard, 1993). Bulb storage, forcing treatments, temperature, daylength and light intensity during growth, as well as, the use of plant growth regulators and shading, have all been used to improve flower quality which also includes elongation of the floral stem (De Hertogh and Le Nard 1993, Halevy 1990). Since little has so far been published for *O. dubium* (De Hertogh and Gillitano 1997), the objective of the present study was to examine the effects of production temperature, daylength and light intensity, gibberellin and ethylene treatments, as well as bulb size, on growth and flowering of *O. dubium*. The work was conducted over 4 years.

MATERIALS AND METHODS

All bulbs used in the following experiments were lifted in July after one season's growth from seed. They were stored in a well ventilated shed for 150 days, under ambient conditions with a daily average temperatures ranging between 25 and 30°C. Bulbs were planted in early November.

1. Precooling Temperature. Bulbs sized 2-3 cm in circumference, were precooled for three weeks at 2, 9, 13 or 25°C. Twenty five bulbs per treatment replicated four times were planted in sandy loam, in unraised beds in an unheated, plastic clad greenhouse. Flowering-stem length was measured at anthesis of the first floret.
2. Precooling duration. In the following year, the effect of precooling duration, ranging from 0 to 8 weeks, was tested at 13°C, as above.
3. Effect of Growth Temperature. Bulbs stored for 150 days and precooled at 13°C were used for this experiment which was conducted in The Hebrew University Phytotron at Rehovot. The temperatures in the different units were:- 32/27, 27/22, 22/17 and 17/12°C (day/night) with a deviation of up to 0.5°C. Light conditions in the units were either 8 h of daylight (short day) or 8 h of daylight plus 8 h of incandescent light at 5 mmol m^{-2} s^{-1} (long day). Twenty bulbs (2-3 cm in circumference) were planted individually in 15 cm pots for each treatment. Days to flowering, flowering- stem length and the number of florets per stem were recorded.

Growth Regulator Treatments

1.Gibberellin and Shading. Stored and precooled bulbs were planted in a greenhouse as described above. The treatments were:- a 20 min preplanting bulb dip in a 100 ppm GA_3 solution, a single canopy spray with a 100 or 200 ppm GA_3 solution when plants were either at the rosette stage (~30 days after planting), or, when the flowering-stem had reached a length of 5 cm (~ 60 days after planting).

Shading treatments to reduce natural light intensity by 20 to 40% were combined with the GA treatments. Twenty bulbs were replicated four times per treatment.
2.Ethylene. Twenty bulbs weighing 2g each which were stored for 150 days were held in the presence of 10 ppm ethylene for 24 h at room temperature prior to planting. Sprouting date, leaf length at flowering and flowering stem length were recorded.
3. Effect of Bulb Size on Growth and Flowering. Eighty stored and precooled bulbs were weighed individually and planted at random in a large polystyrene box placed in an unheated greenhouse.To facilitate recording of data, each bulb position in the box was marked. The number of leaves per plant 65 days after planting, days to flowering, and the total weight of daughter bulblets per plant, were recorded at lifting.

RESULTS

Following 150 days of storage and a three week dry, precooling treatment at 2, 9, 13 or 25°C, all planted bulbs flowered well. Stem length varied with temperature, the 13°C treatment resulting in significantly longer flower stems than in all other temperatures tried (Table 1). The duration of precooling at 13°C did not affect the time from planting to flowering which was 20 ± 1 weeks. However, just a short two week precooling treatment resulted in. significantly longer flowering-stems over those produced by uncooled bulbs. Maximum stem lengths were obtained following six weeks at 13°C prior to planting (Table 2).

The effect of various temperature regimes on flowering under short and long day conditions is presented in Table 3. The time required from planting to flowering was shortest under the 27/22°C day/night temperature regime. Furthermore, long days promoted earlier flowering under all temperature combinations tried. Flowering-stems were longest under low growing temperatures (17/12°C), and again, LD conditions resulted in longer flowers. The number of florets per inflorescence was not significantly affected by temperature, however, the highest temperature combination (32/27°C) drastically reduced the number of florets. The affect of day length was less clear, at moderate temperatures, long days may improve flower number, however under the high temperature regime, this was reversed.

A single gibberellin treatment applied at 100 ppm GA_3 either as a 20 minute preplant dip, or as a foliar spray at the rosette stage or when the flowering stem was 5 cm high, all resulted in markedly longer floral stems at anthesis. Adding moderate shading (20%) further increased stem length. (Table 4). However, further reduction in light intensity (40% shade), resulted in shorter stems.

A 24 h pre-planting exposure of bulbs to 10 ppm ethylene had no marked effects on the rates of sprouting or vegetative growth. In contrast, a significant increase in the length of the flowering stem was observed at anthesis (Table 5). Since all the bulbs flowered, the ethylene treatment apparently caused no flower abortion.

Bulbs lifted after one season's growth from seeding ranged in weight from 0.2 to 3.5g. They all sprouted and flowered when planted after 5 months' storage and a 3 week precooling treatment at 13°C. The number of leaves per bulb visible 65 days after planting is shown in Fig.1. The capacity for leaf differentiation which was very high with each slight weight increase in the smallest bulbs, was less marked in bulbs weighing 1 g or over. Time to flowering was greatly affected by the size of bulb planted (Fig 2). Whereas bulbs weighing approximately 0.5 g require more than 150 days from planting to flowering, bulbs larger than 2.0 g flowered after approximately 120 days.

The effect of planted bulb weight also had a long term effect on growth rate as was expressed in the yield of daughter bulbs at the end of the growing season (Fig. 3)

DISCUSSION

The control of flowering by manipulation of temperature, day length and light intensity during the different stages of plant development, as well as, the use of growth regulating substances, are commonly used in commercial floriculture as has been reviewed by Halevy (1990). The tools available in the case of geophytes are especially complex because there is usually a relatively long period of time between lifting of the perrenating organ and its replanting for flowering in the following season. The conditions under which the geophyllic organ is stored and is treated prior to planting, are critical for subsequent growth and flowering (De Hertogh and Le Nard 1993)

Early work (Cohen-Zhedek 1992) indicated that *Ornithogalum dubium* bulbs stored at 25°C for 150 days sprouted, grew and flowered well wheras those stored at 17°C or at 30°C and over, sprouted sporadically and flowering was severely inhibited. Therefore, all bulbs used in the present study were stored for five months in a well ventilated shed with no temperature control, in which, daily mean temperature ranged from 25 to 30°C.

It is generally accepted that 'bulbs' will only flower if at planting they weighed above a certain critical mass. In this study we found that even the tiniest *O. dubium* bulbs, weighing no more than a seed, flowered. However, flowering was delayed. Bulbs weighing above 2g at planting, flowered approximately one month earlier than smaller bulbs (Fig. 2).

Low preplant temperatures break dormancy and hasten flowering in many geophytes. Flowering time of *O.dubium* was not affected by low preplant temperature treatments but flowering-stem length was. Longest stems were obtained following six weeks at 13°C (Tables 2, 3).

Temperatures during the growing season influence both growth and flowering. Temperatures markedly above or below the optimum may delay flowering and affect flower quality, including diminishing flower height. For 'dubium' we found that 27/22°C day/night temperature significantly reduced the number of days from planting to flowering, but the longest flowering-stems developed under 17/12°C which was the lowest temperature regime tried (Table 3).

Daylength is one of the cardinal factors involved in induction, differentiation and development of flowers. In the controlled temperature /daylength experiment, long days (8h of natural daylight + 8h artificial illumination) were found to enhance all the floral qualities examined (Table 3). The period from planting to flowering under LD was shorter than under SD conditions, and flowering-stems were longer. Under LD, the number of florets per inflorescence was higher at all temperature regimes except the highest one tried.

Gibberellin treatments are frequently used in floricultural practice to enhance flower stem length and such treatment was also effective with *O. dubium* (Table 4). In recent work (results not shown) we have found that GA_3 treatments advance flowering without affecting flower quality Shading plants by 20 or 40% increased flowering-stem length (Table 4). In combination with GA treatment a synergistic effect was only observed under the low level of shade. In contrast to some other other geophytes where shading is deleterious to flowering as in lily (Halevy 1990), no abortion of florets was observed in shaded *O. dubium*.

There have been reports that ethylene enhances flowering as in Iris (Imanishi et al. 1992) and increases the number of florets per inflorescence as in Triteleia (Han et al. 1990). In our preliminary experiment with a preplant ethylene treatment, we found a slight hastening in sprouting and growth and a marked increase in flowering-stem length.

CONCLUSION

The results of this study have shown the way to improving flower production in *Ornithogalum dubium*, by addressing preplant temperature, gibberellin and ethylene treatments, as well as, environmental factors during the growing period. The emphasis was on advancing flowering time, increasing flowering-stem length and raising the number of florets per inflorescence. In the meantime much breeding and selection work has been going on with the objective of solving the same problems genetically. Some success in the development of types with longer floral stems has ben achieved. We look forward to introducing superior, uniform cultivars as soon as they are released.

ACKNOWLEDGEMENTS

The authors wish to thank Hannah Lilien-Kipnis for editing the manuscript and making many helpful comments and suggestions for improvement.

Literature Cited

Bryan, J.E. 1989. Bulbs. Christopher Helm., London. Vol II:297-299.

Cohen-Zhedek, Y. (1992) Control of flowering and growth of *O. Dubium* Dapi Mida 4:6-8 (in Hebrew)

De Hertogh, A.A.and Le Nard, M.1993. The Physiology of Flower Bulbs. Elsevier, Amsterdam.

De Hertogh, A.A. and Gallitano, L.1996. Basic forcing requirement for Israeli grown *Ornithogalum dubium.* Acta Horiticulturae 430:227-232.

Du Plessis, N. and Duncan, G. (1989). Bulbous Plants of Southern Africa. Tafelberg:75-76.

Halevy, A.H. 1990. Recent advances in the control of flowering in horticultural crops. Adv. Hort. Sci. 1:39-43

Han, S.S., Halevy, A.H., Sachs, R.M. and Reid, M.S. (1990). Enhancement of growth and flowering of *Triteleia laxa* by ethylene. J. Amer. Soc. Hort. Sci. 115:482-486

Imanishi, H., Halevy, A.H., Kofranek, A.M, Han, S.S. and Reid, M.S. (1992). Respiratory and carbohydrate changes during ethylene-mediated flower induction in Iris. Scient. Hort.

<u>Tables</u>

Table 1. Effect of a 3 - week preplant cooling treatment at different tempertutrs on *O. dubium*

flowering-stem length at anthesis of the first floret

Temperature (°C)	**Stem length (cm)**
2	$26.5^{a\ *}$
9	36.9^{b}
13	41.7^{c}
25	25.6^{a}

* Means followed by different letters differ significantly at P= 0.05 (Duncan's Multiple Range test)

Tabel 2. The effect of *O. dubium* bulb precooling (13^0C) treatment duration on the length of flower stems at harvest.

Time at 13°C (weeks)	Stem length (cm)
0	20.5^{a}
1	22.8^{a}
2	28.0^{b}
3	27.8^{b}
4	26.9^{b}
5	27.0^{b}
6	31.7^{c}
8	35.0^{c}

- Means followed by different letters differ significantly at P= 0.05 (Duncan's Multiple Range test)

Table 3. The effects of controlled growth-temperature and day length on: time from planting of *O. dubium* bulbs to flowering, floral stem length at harvest, and the number of florets per inflorescence. (Means of 20 replicates ± SE).

Temp.	**Days to Flowering**		**Stem Length(cm)**		**No Flowers/Stem**	
(°C)	**L.D**	**S.D**	**L.D**	**S.D**	**L.D**	**S.D**
17/12	121±1	127±3	37.9±1.8	33.4±1.3	23.1±1.9	20.0±6.2
22/17	90±3	102±2	29.9±1.2	25.0±0.8	26.7±4.2	16.6±2.5
27/22	75±2	89±2	26.3±1.9	19.7±0.9	19.1±4.0	11.0±2.2
32/27	90±4	100±2	19.6±1.1	16.1±0.8	9.8±1.2	16.2±4.0

Table 4. Effects of gibbereling (GA_3) bulb dip, or foliar spray treatment in combinatin with shading on *O. dubium* flower stem length at harvest (Means of 20 replicates ± SE.

Shade (%)	GA (ppm)	Plant stage	Stem (cm)
-	0	-	20.9±0.9
-	100	Bulb dip	26.8±0.6
-	100	Rosette	24.1±0.8
20	-	-	23.4±1.1
20	100	Rosette	29.5±1.4
20	200	Rosette	29.1±0.9
20	100	5 cm stem	31.1±1.0
40	-	-	24.5±1.1
40	100	Rosette	22.2±1.2

Table 5. The effect of a 24h, 100 ppm ethylene preplant treatment on growth and flowering of *O. dubium.* (Means of 20 replicates ± SE).

	Emergence (days)	Leaf length (cm)	Stem length (cm)
Control	16.6±0.6	8.7±0.4	13±1
Ethylene	18.9±0.3	9.8±0.6	22±1

Figures

.

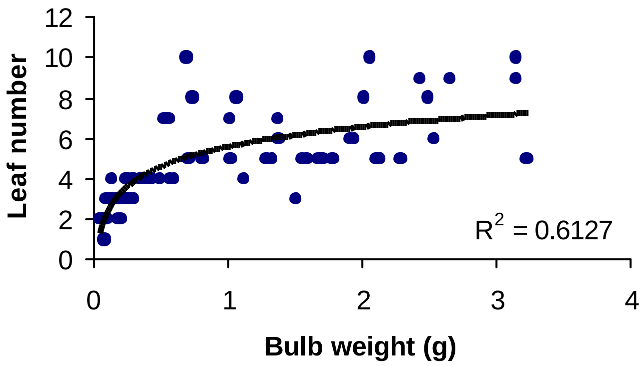

Fig 1. The relationship between *O. dubium* bulb weight at planting and the number of leaves produced after 65 days growth

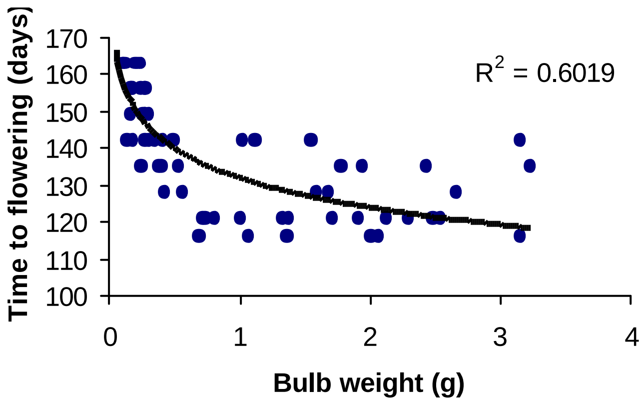

Fig 2. The relationship between *O. dubium* bulb weight at planting and the number of days to flowering.

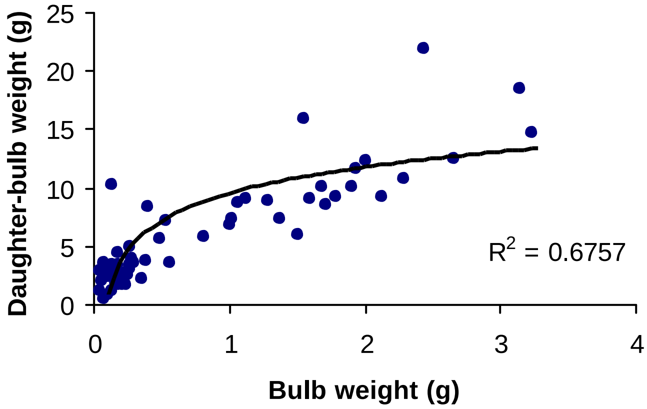

Fig 3. The relationship between *O. dubium* bulb weight at planting and the total weight of daughter bulbs harvested.