GROWTH AND DEVELOPMENT IN *ACHIMENES* CULTIVARS

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GROWTH AND DEVELOPMENT IN *ACHIMENES* CULTIVARS

Proefschrift

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STELLINGEN

I

Growth and development in *Achimenes* is promoted when the same irradiance energy is provided over a long photoperiod rather than a short one.

This thesis

II

Differences in the levels of endogenous hormones may be responsible for differences observed between *Achimenes* 'Flamenco' and 'Hilda' in their shoot and rhizome development. Nevertheless, the effects of increased assimilation of the above ground parts and the subsequent accumulation of metabolites into rhizomes cannot be excluded.

This thesis

III

Leaf morphology is responsible for differences observed among *Achimenes* cultivars. Large thin leaves assure a high net assimilation rate whereas small and thick leaves reduce it.

This thesis

IV

The flowering stimulus is rather a physiological concept, than a chemical reality. Determination of its nature remains a challenge to plant physiologists.

V

It remains unclear whether light intensity affects plant sensitivity to air pollutants by affecting stomatal opening or by causing internal physiological changes related to the photosynthetic apparatus.

M. Rogers, 1985. Air Pollution Effects on Ornamental Crops.
The Ball Red Book Greenhouse Growing, 14th ed.

VI

Future dormancy research will be greatly faciliated if a universally accepted specific classification system for defining dormancy is established. Endodormancy, Paradormancy and Ectodormancy are terms based on processes and imputs that can be easily understood.

G. A. Lang, 1987. Dormancy, a New Universal Terminology. HortScience 22 (5): 817-820.

VII

Inadequate basic understanding of hormone action, decreasing profit margins in agriculture, and increasing regulatory requirements for clearence of new compounds are expected to be the major impedements for future developments of plant bioregulator application.

VIII

Liberty Hyde Bailey (1858-1954) has rightly been called the "Dean of Horticulture" . His life should serve as an inspiration and a model for all horticulturists.

John G. Seeley, 1990. HortScience 25(10): 1204-1210

IX

The flora and vegetation of Europe must be protected recognizing their scientific, educational, recreational, economic, aesthetic and cultural value. Emphasis should be put on preserving the ecological niches for rare, threatened and endemic plants in each country.

X

Mobility programmes on education and training of university students and staff in the 12 Member States of the EEC, contribute greatly towards the Unity of Europe in view of the 1992 objective.

XI

The Netherlands is a small big country of great contrasts and contadictions. It is a respectable conformist country but the night life in Amsterdam leaves little to the imagination.

XII

The Spirit of the Olympic Games and the Olympic Ideal are threatened by commercialization and local conflicts. The I.O.C should seriously consider to have the Games permanently held in the place where they were first performed almost 3000 years ago.

XIII

Ithaca granted you the lovely voyage
Without her you would never have departed on your way
She has nothing else to grant you any more.
And though you find her squalid, Ithaca did not cheat you.
So wise have you become, so experienced!

Constantine Cavafy (1863-1933). A Greek poet.

Stellingen behorend bij het proefschrift van Jannis C. Vlahos
'Growth and Development of *Achimenes* cultivars'.
Wageningen, 26 June 1991.

J.C. Vlahos

GROWTH AND DEVELOPMENT IN *ACHIMENES* CULTIVARS

Thesis

submitted to fulfil the requirements for the degree of
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to my children,

my wife,

my mother

CONTENTS

FOREWORD

I would like hereby to thank all those who assisted in making this thesis to materialize. I particularly wish to thank all those at the Department of Horticulture who welcomed and assisted me during the course of my research programme. Many of them became and remained friends. The resulting relationships and memories from my three year stay in Wageningen I deeply cherish as the most rewarding experience along with my scientific accomplishments.

Sincere appreciation is extended to my promotor Prof.dr.ir. J. Doorenbos for his understanding , encouragement and assistance which continued even after his retirement in 1986 and to Mr. J. J. Karper for his help and organizational support. I would especially like to thank secretaries Klaske Schuurmann for her warm and loving personality and Miep Vogelzang for typing the manuscripts of most of my publications at various stages of completion. Special thanks are extended to Ben Aagten, for his willingness to assist me on my research in the library ; to H.H.W. van Lent and R. Jansen for their drawings and photographs used in this thesis and Mariet de Geus for the scetch on the cover pages. The useful discussions on *Achimenes* with Dr. C. Broertjes are greatly appreciated.

I am also grateful to collegues Ep Heuvelink for his valuable assistance and cooperation and to George Martakis for his contribution to experimental design and statistical analyses. I wish also to express my sincere gratitude to the late J.van Bragt for his personnal encouragement, scientific suggestions, editorial comments and above all his friendship. I shall always remember him.

Financial support from the States Scholarship Foundations (I.K.Y.) of Greece is greatfully acknowledged . However, this study could not have been completed without the experimental facilities provided by the Agricultural University of Wageningen, The Netherlands.

Finally, I would like to thank my mother, my wife and children who all through these long years patiently supported my efforts and encouraged me to accomplish the goal of receiving the Ph D degree.

I. GENERAL INTRODUCTION

Origin and history of *Achimenes*

The genus *Achimenes* Pers. belongs to the Gesneriaceae. About 25 species originate from Central and South America, from Mexico to Argentina (Moore, 1975). The first cultivated species was *A. erecta*, also known as *A. coccinea*, from Jamaica which was brought to England by W. Forsythe in 1778 (Jungbauer,1977). By 1840 several more species such as *A. longiflora*, *A. pedunculata* and *A. antirrhina* had been introduced into Europe. Following hybridization, European nurserymen were able to offer more than 60 varieties by 1860 (Townsend, 1984). *Achimenes* thus became a favorite pot plant of the Victorian era but subsequently interest diminished. After 1945 it was revived however and many new cultivars were introduced by H.E.Moore of Cornell University and by Paul Arnold,also from the USA.

Many new introductions came also from Konrad Michelssen of Hannover, West Germany. In the Netherlands, work by C. Broertjes in the Institute of Atomic Sciences in Agriculture (ITAL) at Wageningen, resulted in the production of several important mutants. In view of the increased interest in *Achimenes* extensive work on evaluating the existing 150 cultivars was undertaken in the Experimental Station of Floriculture at Lent in the Netherlands in 1983 (Broertjes et al , 1983).

Etymology of *Achimenes*

The generic name *Achimenes* was introduced in 1756 by Patrick Browne (Burtt, Moore, 1975; Nicolson,1981;Townsend, 1985). Browne illustrated two species; the first one was *Achimenes major* which is now considered to be a member of the genus *Columnea*. The second species however , *Achimenes minor*, was actually an *Achimenes* as it is currently understood. In order to save *Achimenes* from synonymy with *Columnea* it was decided in 1969 by the Spermatophyta Committee to reject Brown's names and to base *Achimenes* on *Achimenes coccinea* (Scopoli) Persoon, 1806 (Nicolson, 1981).

Browne gave no derivation of the generic name but the word is certainly of Greek origin. Several hypotheses have been proposed for the etymology of *Achimenes*. The most likely are the following: It is either a compound word formed from the a-privative and cheimaino (χειμαινω) meaning to "distress by storm" and the suffix -es interpeted as "one who.." or "something which...". Thus a-cheimaines could be "something not overwintering". Or the name suggests Achaimenes, the mythic Persian king ,founder of the Achaimenid dynasty. No one knows for sure what Browne had in mind when he adopted *Achimenes*. It seems unlikely though that he was refering to a plant not overwintering as the Jamaican plants he was describing were not subject to cold winters. It is rather suspected that Browne ment to honor Achaimenes.

Furthermore, Wittstein (1852) suggested that the name Achimenes was an alteration of the name Achaemenis ,a mythical plant, which Pliny reported as mentioned by Democritus as possesing magic powers. Arnold (1954) accepted this derivation and adopted the name "magic plant" as a common name for Achimenes. Commercial trade catalogues sometimes offer *Achimenes* as "magic plant" .

Plant and flower morphology

Commercial *Achimenes* varieties are herbaceous perennials with short, hairy erect stems which branch and flower early and form big flowers. The leaves are hairy and toothed. They are either opposite or whorled (in 3's and 4's) and have short petioles. Flowers occur singly, in pairs, or on several flowered stalks in the axils of the leaves (Everett, 1980; Moore, 1957). The number of flowers per node depends on the number of leaves in the whorl. Some cultivars produce several buds from each leaf axil which open in succession.

The flowers have short penducles with a 5-lobed, wide-spread calyx and a long curved sympetalous corolla. The corolla of hybrids forms a slender cylinder . The corolla is 5-lobed and zygomorphic; the lower lobe is generally longer than the others. Flower diameter is 35 to 60 mm. Flowers vary in color from white, yellow and red to pink, purple and blue (Zimmer and Junker, 1985). At the base of the corolla there are 5 stamens, 4 fertile and 1 nonfertile, and a long style terminated with a two-lobed, cup-shaped or mouth-shaped stigma. The ovary is surrounded by a cup-shaped disk (Everett, 1980).

Cultural practices

Propagation is normally by stem tip or leaf cuttings but is also possible to use rhizomes, parts or scales of rhizomes. Rhizomes develop at the base of the shoots or at the tips of underground stolons and are composed of a central axis, which is the tip of a modified underground stem, covered by fleshy triangular scales, which are modified leaves. These rhizomes reach a length of 2 to 5 cm.

After the growing period, stems die off and the rhizomes remain dormant. The sprouting of rhizomes depends on storage temperature. Low temperatures (15 °C) delay sprouting whereas higher temperature (20-25 °C) promote sprouting (Zimmer, 1976).

Achimenes is a day neutral plant. Flower development is faster at 20 °C than at lower (15 °C) or higher (25 °C) temperatures, at least in some cultivars (Zimmer and Junker, 1985). Some species and cultivars exhibit sturdy growth but in several others stems are slender and require support. These are suitable as basket plants. In the autumn flowering slows down. Feeding and watering are then reduced. When the aerial parts are dead the pots are kept at 10 to 20 °C until planting in the spring.

Rhizomes may be harvested, stored in dry sand or peat until the following season. Rhizomes can be started between February and April. For obtaining uniform plants the tips of the ensuing stems are taken and planted directly into pots 3 to 5 together. Growth retardants are applied in commercial production to produce compact potted plants.

Achimenes requires high light intensities but needs to be shaded from direct sunlight. Water colder than air temperature may cause damage to the leaves which is the reason some people call *Achimenes* the "hot water plant" (Townsend, 1984).

Plant material

It was decided to test a number of *Achimenes* cultivars, in order to be able to draw conclusions that could be generally applicable. The most popular commercial cultivars were chosen with a wide range of flower colors and growing habits. At the time the research was conducted a large assortment of cultivars was available that came from the Experiment Station at Lent in the Netherlands. Thus, the experiments involved 12 hybrids , all of them products of hybridization or mutation breeding by Michelssen of Germany , the Station at Lent and ITAL.

Cultivars used most frequently in the different experiments were 'Flamenco', 'Hilda Michelssen' (referred to as 'Hilda'), 'Rosenelfe', and 'Viola Michelssen' (referred to as 'Viola'). Of the other cultivars, rhizomes or plants were not available in the desired quantities.

Table 1. *Achimenes* cultivars used in different experiments

Cultivar	Origin	Color	Ploidy	Used in expts. of chapter							
				1	2	3	4	5	6	7	8
Blau Import	Unknown	Violet blue	2n	+							
Blauer Planet	Michelssen	Violet bleu	2n	+							
Early Arnold	ITAL-Broertjes	Dark violet	2n			+					
English Waltz	Michelssen	Pink	2n					+			
Flamenco	michelssen	Rose-red	4n		+		+		+	+	
Hilda	Michelssen	Pink	4n		+		+			+	
Linda	Lent-Evers	White	2n	+		+					
Prima Donna	Benary (Germany)	Coral red	2n	+							
Rosenelfe	Michelssen	Cardinal-red	2n		+	+	+				
Schneewitchen	Michelssen	Yellowish white	2n	+							
Tetraelfe	ITAL-Broertjes	Red	4n	+							
Vila	Michelssen	Carmin-red	2n					+	+		+

Scope of thesis

Growth and development of *Achimenes* have not been investigated thoroughly. Existing reports are contradictory, probably due to the fact that cultivars behave quite differently. The fact that *Achimenes* only rather recently has become popular as pot plants may be another reason for this lack of substantial information. Furthermore, cultivation of *Achimenes* at least in the Netherlands is limited (Table 2). The difficulty to grow *Achimenes* all year round due to the period of senescence the plant undergoes in late fall, has hindered expansion of the cultivation of *Achimenes* .The fact that the peak of production occurs in the summer months is a serious drawback for *Achimenes* . Fig.1 shows the total number of *Achimenes* plants sold in the flower auction at Alsmeer both in 1981 and 1989 .

The present work was undertaken in order to investigate the effects of environmental factors on growth and development of several commercial cultivars of *Achimenes*. Specifically, an attempt was made to answer questions like :

How do temperature and light influence growth, flower and/or rhizome development in *Achimenes*?

Can flower development and rhizome production be increased by growth regulators ?

Is it possible to break dormancy of rhizomes so that *Achimenes* can be grown all year round ?

To answer these questions a series of experiments were carried out in which temperature, light duration, light intensity and quality were tested on several cultivars. Vegetative growth, flowering and rhizome development were studied in response to the given environmental treatments in order to establish the optimum conditions for the selected cultivars.

Growth analysis studies were also carried out on several cultivars subjected to various light and temperature regimes. Exogenously applied growth regulators were used in an other series of experiments in order to investigate the possibilities of controlling growth, flowering, rhizome formation and release from dormancy in combination with environmental factors.

The present thesis deals with the results of a series of experiments conducted in the Department of Horticulture at Wageningen from September 1983 to April 1986 which are presented in parts II and III. Part II deals with the effects of light and temperature and part III with the effects of growth regulators on growth and development of *Achimenes.*

In Part II

Chapter 1 describes the effects of daylength extension on six morphologically different cultivars of *Achimenes* grown in a greenhouse.

Chapter 2 deals with the effects of temperature and irradiance on growth and development in 'Flamenco', 'Hilda' and 'Rosenelfe' grown in a controlled environment.

Chapter 3 deals with the results from a growth analysis study conducted on three different cultivars grown under three different light regimes, of the same daily light integral.

Chapter 4 investigates the response of three cultivars, the same as in chapter 2, to daylenght extension along with light quality.

In Part III

Chapter 5 describes the effect of BA and GA_3 on dormancy break of two cultivars of *Achimenes* rhizomes and the after-effects on growth and flowering of developing plants.

Chapter 6 deals with the effects of BA and GA_3 on growth and development in cultivars 'Flamenco' and 'Hilda ' under two levels of irradiance.

Chapter 7 describes the effects of BA, GA_3 and NAA on dry matter partitioning and rhizome development in two cultivars under three irradiance levels.

Chapter 8 Describes the effectiveness of growth retardants on growth flowering and rhizome formation in 'Viola '.

In part IV a general discussion is presented followed by summary. A summary in Dutch is also included.

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Table 2. Total sales of *Achimenes* in the Netherlands between 1985 and 1989 (data from the Westland and Alsmeer flower auctions).

Year	No. of plants (pots) sold	Total value in Dutch guilders
1985	131.858	273.109
1986	159.358	327557
1987	229.181	435.157
1988	119.260	300.076
1989	152.602	306.436

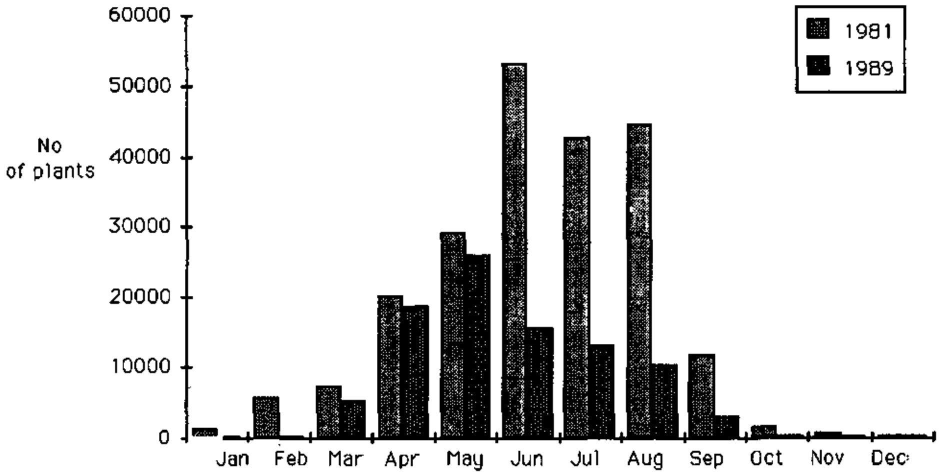

Fig. 1. Monthly sales of *Achimenes* plants (pots) sold at the Alsmeer flower auction in 1981 and 1989.

II. EFFECTS OF LIGHT AND TEMPERATURE ON GROWTH AND DEVELOPMENT OF *ACHIMENES* CULTIVARS

Chapter 1

Daylength Influences Growth and Development in *Achimenes* Cultivars

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Daylength Influences Growth and Development of *Achimenes* cultivars

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Additional index words. flowering, rhizomes, short day, long day.

Abstract. Six cultivars of Achimenes, 'Blau Import', 'Blauer Planet', 'Linda', 'Prima Donna', 'Schneewittchen', and 'Tetraelfe' were grown under short (SD, 8 hours) or long days (LD, 16 hours) at 21C in a greenhouse. LD increased plant height, shoot mass, number of flowers and accelerated time to anthesis. SD, depending on the cultivar, increased number of rhizomes. Results show differences in several characteristics of growth and development among the cultivars and that LD promote shoot growth and flowering.

Achimenes (Gesneriaceae) is indigenous from Mexico to Brazil. Many cultivars have been introduced as products of hybridization and mutation breeding, both in the United States and in Europe (Broertjes,1972). Rhode (1974) showed that flower initiation in 'Valse bleu' and 'Dornröschen' does not depend on photoperiod and that flower development is not affected by daylength. Zimmer (1976) working with four different cultivars, 'Valse bleu', 'Menuett', 'Tarantella' and 'Fritz Michelssen' found that daylengths of 8 and 16 hr did not influence the formation of rhizomes, while weight of rhizomes depended on the cultivar.

The present study was aimed at evaluating the influence of short (SD) and long (LD) days on cultivars that have not been investigated, to see if 1) there are any relationships between rhizome and shoot growth under the two daylengths, and 2) to determine which of the cultivars grow and flower satisfactorily under SD offering as an indication that they could grow during winter months when these plants are not usually produced.

Rhizomes of six, morphologically different commercial cultivars from the achimenes collection maintained at the time by the Dept of Horticulture in Wageningen were stored at 17C for 3 months and then planted in sphagnum peat in a greenhouse bench on 20 Febr. 1985. Tip cuttings taken from the sprouted rhizomes were planted in 10-cm plastic pots (0.3-liter) with a standard potting medium (pH 5.5-5.8) consisting of 6 peat mold: 4 rough peat (v/v) and placed in a greenhouse at 21/18C (day/night) temperatures for rooting and establishment. Plantlets were selected for uniformity and averaged 4.5 cm in height and had three leaf whorls (nodes). The were placed under SD and LD conditions on 15 Mar. 1985. SD were obtained using a black cloth cover from 1600 to 0800 HR. In the LD condition, the natural day was extended with the use of high- pressure sodium lamps (Philips SON/T) that provided a PAR of 48 μ mol$\cdot$s$^{-1}\cdot$m^{-2} at plant level from 1900 until 2200 HR. Due to this extension, the plants received a LD of 16 hr. Solar irridiation was recorded using a Kipp solarimeter placed near the plants. Daily counts for solar radiation in the LD treatment were calculated on a monthly basis that gave the amount of photosynthetic active radiation in $\mu\ mol{\cdot}s^{-1}{\cdot}m^{-2}$; the values were 14.6, 19.4 and 19.8 for April, May, and June, respectively.

A split-pot design with four replications was used with daylength as the main plot factor. Each replication included six cultivars, with five plants from each. Cultivars were randomized within each replicatiion. Those used were: 'Blau Import', 'Blauer Planet' (also known as 'Michelssens' Blau'), 'Linda', 'Schneewittchen', 'Prima Donna' and 'Tetraelfe'. They all belong to a new group of hybrids (Broertjes et al, 1983).

Table 1. Main effect of SD (8 hr) and LD (16 hr) on growth, flowering, and rhizome development in six cultivars of *Achimenes*[z].

Daylength	Plant ht (cm)	Internode length (cm)	Shoot fresh wt (g)	Nodes (no.)	Axillary shoots (no.)	Flowers (no.)	Days to first flower (no.)	Rhizome dry wt (mg)
SD	30.3	2.2	34	13	4	42	59	317
LD	38.0	2.8	45	14	4	62	54	317
Significance	*	*	*	NS	NS	*	*	NS

[z]Values are means of 120 plants.
NS,*Nonsignificant or significant at $P = 0.001$.

Table 2. Effects of cultivar on growth, flowering, and rhizome development in six cultivars of *Achimenes*[z].

Cultivar	Plant ht (cm)	Internode length (cm)	Shoot fresh wt (g)	Nodes (no.)	Axillary shoots (no.)	Flowers (no.)	Days to first flower (no.)	Rhizome dry wt (mg)
Tetraelfe	41.1	2.9	36.9	14	4	96	52	39
Blau Import	44.4	3.0	49.4	15	3	98	33	1490
Blauer Planet	40.4	2.8	31.0	14	1	34	53	None
Schneewittchen	27.2	1.9	34.4	14	6	38	62	32
Prima Donna	25.7	2.4	49.5	11	6	17	76	1
Linda	26.0	2.0	34.0	13	4	30	62	25
$LSD_{0.05}$	1.9	0.009	3.4	0.7	0.7	9	3	88

[z]Values are means of 40 plants.

Plants were checked daily and the date that the first flower opened was recorded for each plant. At the end of the experiment, the following data were collected: height of the main stem, number of leaf whorls, number of axillary shoots, number of flowers on the main stem and the axillar shoots. As flowers do not abort when they are old, it was possible to record the total number of flowers that developed during the 16 week period. Shoot growth (shoots and flowers) was removed for fresh and dry weight determination. Rhizomes were harvested, counted and their weights recorded. Many plants had stolons emerging from the soil. These sprouting stolons were counted to see if SD or LD treatments affected their number

Data were evaluated by analysis of variance. Cultivar effects were analysed using least significance difference at $P = 0.05$.

Regardless of cultivar, LD increased plant height, internode length, shoot fresh weight and total number of flowers. Number of days to first open flower decreased whereas number of nodes, number of axillary shoots and dry weight of rhizomes were not affected (Table 1).

There was no interaction between photoperiod and cultivar for several characteristics of growth and development. 'Blau Import' was the tallest cultivar, had more nodes, more flowers, along with 'Tetraelfe', and flowered earlier than the rest; shoot fresh weight of 'Blau Import' and 'Prima Donna' were equally high, but rhizome dry weight was highest for the former (Table 2). Fresh and dry weight per rhizome werer also highest for 'Blau Import', whereas those of the other cultivars were similar to each other (data not shown). 'Prima Donna' had the fewest nodes, the fewest flowers, and flowered last; its rhizome dry weight was the lowest.

An interaction occured between cultivar and photoperiod for number of stolons, number of rhizomes, shoot dry weight, and rhizome fresh weight (Table 3). Under both daylengths 'Blau Import' had the fewest stolons and produced more rhizomes and the highest shoot dry and rhizome fresh weights. 'Blauer Planet' had the greatest number of stolons but formed no

Table 3. Interaction of SD (8 hr) and LD (16 hr) on number of stolons, number of rhizomes, shoot fresh weight, and rhizome dry weight in six cultivars of Achimenes grown for 16 weeks in a greenhouse[z].

	Stolons (no.)		Rhizomes (no.)		Shoot dry wt (g)		Rhizome fresh wt (mg)	
Cultivar	*SD*	*LD*	*SD*	*LD*	*SD*	*LD*	*SD*	*LD*
Tetraelfe	6.8	5.8	3.2	4.2	4.1	5.5	282	217
Blau Import	None	1.3	12.4	11.8	5.7	6.7	5140	4018
Blauer Planet	10.2	8.5	None	None	3.3	4.9	None	None
Schneewittchen	4.9	7.0	5.3	1.2	2.8	5.3	335	22
Prima Donna	4.3	4.9	1.6	0.5	3.8	5.6	147	10
Linda	7.9	9.0	4.2	1.7	3.4	3.8	255	65
$LSD_{0.05}$	1.4		1.9		0.5		424	

[z]Values are means of 20 plants.

rhizomes. 'Schneewittchen' and 'Linda' had more rhizomes under SD than under LD; the other cultivars were not affected by daylength. Shoot dry weight was highest under LD in all cultivars, except in 'Linda'. SD rather than LD enhanced fresh weight of rhizomes in all cultivars; however, differences were not significant.

All cultivars flowered regardless of daylength. However duration of daylength influenced several characteristics of growth and development. Because of the supplemental irradiance provided in the LD, it was not possible to distinguish photoperiod from irradiance effects.

LD increased vegetative growth expressed as height, internode length and shoot fresh weight (Table 1). Similar results have been obtained in other species grown under LD (Boyle and Stimart, 1983; Gertsson, 1984; Janick, 1982). The increased height was due to longer internodes as number of leaf whorls was not affected by daylength; those results are analogous to those of Piringer and Cathey (1960) with petunia. Rhode (1974) found that as daylength increased, number of axillary shoots increased; our results do not agree with findings and confirm our earlier work with other cultivars, which indicates that number of axillary shoots is clearly a cultivar characteristic (Vlahos, 1985).

LD increased the number of flowers, on both main and axillary shoots. As the number of flowers depends on the number of leaf whorls (Zimmer and Junker, 1985) and considering that number of leaf whorls did not increase, the higher number of flowers in LD is attributed to the fact that more flowers developed per leaf whorl, possibly because dormant generative buds were induced to develop by an accumulation of assimilates produced by higher amounts of PAR provided under LD. Thus, although achimenes does not require a specific daylength for flower initiation, a longer photoperiod provides additional irradiance energy for more flower development.

Flower earliness was promoted by LD as has been shown for other species (Maginess and Langhans, 1961; Welander, 1984); it seems likely that the number of flowers is related to plant height (r = 0.77) and to top dry weight (r = 70). Long days promote growth and thus enhance flowering as has been reported for begonia by Fonteno and Larson (1982).

LD did not inhibit rhizome formation and development of rhizomes, contrary to what has been reported for other tuberizing species (Djurhuus, 1985; Fonteno and Larson, 1982). There was a tendency for higher rhizome fresh weight in SD, however, the difference was significant only in 'Blau Import' (Table 3). Number of rhizomes increased in SD only in 'Schneewittchen' and 'Linda'. The fact that the number of rhizomes was negatively correlated to the number of days to first open flower (r = 0.68) suggests that rhizome formation begins after flower development.

Long days, by providing the amount of energy needed for assimilate production clearly influence growth, flowering and rhizome development in *Achimenes* (Table 1). However, significant differences existed among cultivars in their pattern of growth. 'Blauer Planet' despite good growth and flowering did not form any rhizomes until the end of the experiment, suggesting that as a sink its flowers and shoots are more effective than its rhizomes. 'Prima Donna', with a high shoot weight, behaved similarly and produced the fewest rhizomes (Table 2). In contrast, 'Blau Import' produced both high shoot and rhizome weight, indicating a balanced assimilate movement.

The high number of flowers recorded for 'Tetraelfe' and 'Blau Import' could be partially attributable to the characteristics that their flowers are borne in clusters of three to nine from penducles arising from the leaf axils instead of developing singly or doubly, as in the other cultivars.

The differences observed among the cultivars tested in this study should be considered by growers in their choice of a cultivar according to the intended purpose of cultivation (flowering plants and/or rhizome production). Provided that dormancy-free rhizomes are available, if photoperiod and/or light quantity is at least of the same level as in the present experiment, it would be possible to grow and flower achimenes in winter. The critical quantity of light required for a satisfactory growth and flowering control cannot be determined from the present investigation.

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Chapter 2

Temperature and Irradiance Influence Growth and Development in Three cultivars of *Achimenes.*

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Temperature and Irradiance Influence Growth and Development of Three Cultivars of *Achimenes*

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Additional index words. flowering, light duration, rhizomes

Abstract. Three cultivars of *Achimenes*, 'Flamenco', 'Hilda' and 'Rosenelfe', were grown for 10 weeks in nine environments: 17, 21 and 25C combined with 8, 16 or 24 hours of irradiance (213 ì mol.s-1.m-2). Increase in temperature increased plant height, number of nodes, number of flowers, and shortened time to anthesis. Number of axillary shoots was enhanced at 17C. Increasing duration of illumination increased shoot dry weight and reduced plant height; a 16-hour light duration compared to 8 or 24 hours increased size and fresh and dry weight of rhizomes. 'Rosenelfe' responded differently from 'Flamenco' and 'Hilda' to the environmental treatments. Depending on cultivar, top growth and flowering were influenced by temperature and duration of illumination, whereas rhizome growth was affected mainly by the latter.

Although the genus *Achimenes* and its hybrids have been known and grown for a long time it is only recently that they have become popular as commercially grown potted plants in both the United States and Europe (Jungbauer, 1977; Moore, 1957). Rohde (1974) using 'Valse Bleu' and 'Dornröschen' showed that they are day-neutral plants, that flower development was faster at 20C than at lower or higher temperatures, and that the number of flowers depended on the number of nodes produced. Deutch (1974) indicated that rhizome formation in cuttings of 'Major' is inhibited by continuous illumination while Zimmer (1976) working with four different cultivars reported that the number of rhizomes was not affected by short (8-hr) or long (16-hr) days. The purpose of the present study was to investigate the influence of temperature and irradiance on flowering, rhizome formation and vegetative development of achimenes plants grown under controlledconditions. The effect of daylength is reported in a companion report (Vlahos, 1990).

The commercial cultivars 'Flamenco', 'Hilda Michelssen' (referred to as'Hilda') and 'Rosenelfe' were used. Young plants of the three cultivars started from rhizomes, were obtained from a commercial grower in Apr. 1985. Rooted stem cuttings, of uniform length, were selected, potted in 10-cm (0.3-liter) plastic pots and placed in a greenhouse with natural daylength, at ≈ 21C for 2 weeks before the start of the experimental treatments. At that time, the plantlets averaged 3 to 4 cm in height and had ≈ 4 nodes (leaf whorls). No flower buds were visible; only axillary shoots had emerged from the lower leaf axils.

The plants were placed at 17, 21 or 25C (constant day/night) combined with 8, 16 and 24 hr of irradiance, thus providing nine experimental conditions. The level of irradiance in each light treatment was a constant 213 μ mol·s^{-1}·m^{-2} at plant level. The illumination was provided by a combination (1:1) of high-pressure sodium (Philips SON/T) and metal halide (Philips HPI/T) lamps of 250 and 400 W. A split plot design was set up with three temperatures (main plots), three illumination periods (sub-plots) and three cultivars randomized in each subplot. There were teo replications per light treatment with four plants in each replication. The experiment involved a total of 216 plants.

The number of days until first flower opened was recorded for each plant. At the end of the experiment, the following data were collected: height of the main stem, number of axillary shoots, total number of flowers, shoot fresh and dry weight. Rhizomes were harvested, counted and their fresh and dry weights were recorded. The ratio of rhizome dry weight to total dry weight (aerial parts and rhizomes) was calculated and is referred to as rhizome weight ratio (RWR). The mean dry weight of rhizomes was divided by the number of rhizomes to obtain the dry weight per rhizome as an estimate of their size. Finally, the plants were evaluated for general quality and for flower appearence and color.

The results of the experiment were subjected to analysis of variance. From the F tests it appeared that means of cultivars, light and temperature treatments, and interactions of cultivar with treatments for all characteristics measured were significantly different ($P < 0.001$). Means were separated by least significant difference at $P = 0.05$. The confounding of the temperature effect with the chamber effect was taken into consideration. Interactions between temperature and light treatments were nonsignificant for all characteristics studied.

Temperature interacted with cultivar for stem height, number of nodes, number of flowers and days to anthesis (Table 1). In 'Flamenco' and 'Hilda' plant height and number of flowers were lower at 17 than at 21 or 25C; in 'Rosenelfe' these values were highest at 21C. Number of flowers in all cultivars was correlated to stem height ($r = 0.81$) and number of nodes ($r = 0.74$). In 'Hilda' the number of days to first open flower decreased as temperature increased whereas in 'Flamenco' and 'Rosenelfe' the difference between 21 and 25C was not significant. No interactions were evident for number of axillary shoots, number of rhizomes or rhizome dry weight (Table 2). Number of axillary shoots decreased as temperature increased; at 21C number of rhizomes was lowest, whereas dry weight per rhizome was highest.

As light duration increased, height of the main stem decreased: number of flowers was not affected in 'Flamenco', whereas for 'Hilda' most flowers developed at 24 hr and for 'Rosenelfe' at 16 hr (Table 3). There was no interaction with either cultivar or temperature treatment for tissue weights (Table 4). Dry weight of shoots was higher at 16 or 24 hr than at 8 hr; the dry weights of rhizomes and per rhizome were higher at 16 rather than at 8 or 24 hr.

There were significant differences among the three cultivars in severalcharacteristics of their growth and development under any of the treatments (Table 5). In 'Flamenco' shoot dry weight was lowest, whereas dry weight of rhizomes and per rhizome and RWR were the highest among the cultivars. In 'Hilda', the number of rhizomes, dry weight of rhizomes, and RWR were the lowest among the three cultivars. 'Rosenelfe' had more axillary shoots than the others; also flower number was correlated with axillary shoots ($r = 0.83$). Shoot dry weight and the number of rhizomes were higher for 'Rosenelfe' than for 'Flamenco' or 'Hilda'.

Plants of all cultivars, under any of the temperature treatments, were vigorous and had dark green foliage at 8 hr of light; at 16 hr, the leaves were a lighter green and plants were more compact. At 24 hr, however, leaves became chlorotic and growth of plants was stunted with evident characteristics of senescence. Furthermore, the color of the flowers changed noticeably in relation to temperature. The higher the temperature the paler the colour of the corolla. At 24 hr of light and 25C flower color had changed to a very light shade of red (in 'Flamenco' and 'Rosenelfe') or pink (in 'Hilda').

Vegetative and reproductive development in achimenes, as shown by increase in height and number of flowers, are affected by temperature. However, this effect depends on the cultivar (Table 1). It has been shown that several species flower earlier as temperature increases (Djurhuus, 1985; Maginess and Langhans, 1961; Piringer and Cathey, 1960; Rohde, 1974); the present results agree with these reports.

The number of axillary shoots was highest at 17C, as higher temperatures favored initiation of flowers instead of shoots. Relatively higher temperatures reportedly inhibit tuberization in potato (Menzel, 1983); in the present studies, where rhizome formation and development were related to tuberization, no such evidence was found. Weight of rhizomes and RWR were not significantly affected by temperature; differences existed only among cultivars. However, at 21C, dry weight per rhizome increased as a result of fewer rhizomes being formed (Table 2).

Table 1. Interaction of temperature with cultivar on growth and flowering in *Achimenes*[z].

	Ht of main stem (cm)			Nodes (no.)			Flowers (no.)			Days to first flower (no.)		
	Temperature (°C)											
Cultivar	17	21	25	17	21	25	17	21	25	17	21	25
Flamenco	14.5 a	16.6 bc	16.5 bc	7.4 a	8.7 b	10.0 c	11.0 a	15.7 b	16.6 b	22 b	9 a	8 a
Hilda	15.6 a	17.2 c	16.7 bc	9.0 b	9.5 bc	11.4 d	12.8 ab	21.7 c	23.0 c	29 c	19 b	11 a
Rosenelfe	22.8 d	24.7 c	22.0 d	10.4 d	11.3 c	10.6 dc	62.1 d	78.3 c	66.4 d	18 b	12 a	9 a

[z]Mean separation within each characteristic by LSD at $P = 0.05$. Values are means of 24 plants averaged over three irradiance treatments.

Table 2. Main effect of temperature on axillary shoot and rhizome development in *Achimenes*.[z]

Temperature (°C)	Axillary shoots (no.)	Rhizomes (no.)	Dry wt/rhizome (mg)
17	3.2 c	4.8 b	66.5 a
21	2.8 b	3.2 a	109.0 b
25	2.4 a	4.2 b	82.2 a

[z]Mean separation within columns by LSD at $P = 0.05$. Values are means of 72 plants averaged over three cultivars and three irradiances.

Table 3. The effect of light duration on height and number of flowers in three cultivars of *Achimenes*[z,y]

	Ht of main stem (cm)			Flowers (no.)		
	Hours of irradiance			Hours of irradiance		
Cultivar	8	16	24	8	16	24
Flamenco	17.9 c	15.0 ab	14.7 a	13.9 a	14.6 a	14.7 a
Hilda	19.1 cd	16.2 b	14.3 a	16.9 a	18.5 ab	22.0 b
Rosenelfe	26.7 f	22.5 c	20.3 d	65.0 c	74.3 d	67.4 c

[z]Constant irradiance level of 213 $\mu mol \cdot s^{-1} \cdot m^{-2}$.
[y]Mean separation within each characteristic by LSD at $P = 0.05$. Values are means of 24 plants averaged over three temperatures.

The effect of light treatment on plant height and the number of flowers varied with the cultivar (Table 3). It is uncertain whether these effects are due to the duration of the irradiance period or to the amount of total energy provided at plant level, as the amount of radiant energy varied proportionately with daylength. Although morphogenetic effects due to the extended light period cannot be excluded it is possible that the responses obtained are attributable to genetic factors, as cultivars differ in several growth characteristics (Table 5).

Table 4. Main effect of light duration on shoot and rhizome dry weight in *Achimenes*[z,y].

Duration of irradiance (hr)	Dry wt (g)		
	Shoots	Rhizomes	Per rhizome
8	1.5 a	0.26 a	0.063 a
16	2.1 b	0.47 b	0.114 b
24	2.3 b	0.27 a	0.078 a

[z]Constant irradiance level of 213 $\mu mol \cdot s^{-1} \cdot m^{-2}$.
[y]Mean separation within columns by LSD at $P = 0.05$. Values are means of 72 plants averaged over three cultivars and three temperatures.

The enhanced rhizome weight at 16 hr suggests an optimal amount of light energy for rhizome development (Table 4); the number of rhizomes was not affected by the light treatment. The present results are contrary to those by Deutch (1974) who found that continuous light inhibited rhizome formation,but are in agreement with those by Zimmer (1976), who reported that daylength does not influence the number of rhizomes. However, cultivars and quantities of light energy in the present experiment were different from those in the other studies. The best rhizome development and the highest RWR values were observed in 'Flamenco', signs of strong sink activity of the stolons in this cultivar. 'Rosenelfe' produced more flowers as a result not only of the increased number of axillary shoots, but also because of the many-flowered penducles that characterize the cultivar.

Table 5. Main characteristics of three cultivars of *Achimenes*[z].

Characteristic	Cultivar		
	Flamenco	Hilda	Rosenelfe
Axillary shoots (no.)	1.6 a	1.9 a	4.9 b
Dry wt of shoots (g)	1.3 a	2.0 b	2.5 c
Dry wt of rhizomes (g)	0.52 c	0.15 a	0.33 b
Dry wt per rhizome (mg)	120 b	74 a	63 a
Rhizomes (no.)	4.3 b	2.1 a	5.8 c
Rhizome weight ratio (RWR)	27.4 b	7.2 a	12.4 c

[z]Mean separation within rows by LSD at $P = 0.05$. Values are means of 72 plants averaged over three irradiances and three temperatures.

The present study demonstrates that both temperature and quantity of radiant energy influence growth and development in achimenes but responses may vary, depending on the cultivar.

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Chapter 3

A Growth Analysis Study on Three Cultivars of *Achimenes* Grown Under Three Light Regimes.

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A growth analysis study on three *Achimenes* cultivars grown under three light regimes

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ABSTRACT

The growth of three morphologically different *Achimenes* cultivars ('Early Arnold', 'Rosenelfe' and 'Linda') was studied in growth chambers for 49 days at 21/18 °C day/night temperature under three different light regimes of 60, 40 and 17 W m^{-2} PAR at the same daily light integral (300 Wh m^{-2}). Thus daylengths were 5, 7.5 and 17.5 h respectively. Growth characteristics were recorded and a growth analysis study was carried out. Mean values of growth parameters were compared over a DW interval.

No interactions between cultivar and light regime were observed in any of the parameters studied except for relative growth rate (RGR). Lower light intensity at the same daily light integral favoured growth (number of leaves, plant and leaf dry weight, leaf area) and flowering. RGR increased in all 3 cultivars (not always significantly) due to increase in net assimilation rate (NAR) whereas leaf area ratio (LAR) remained the same at decreasing light intensity at the same daily light integral. Therefore it is suggested that a better light use efficiency (mg DW J^{-1} PAR) is responsible for the increase in growth at low light intensity combined with longer days.

Linda' was the shortest cultivar with the highest number of leaves and axillary shoots after 49 days of growth. 'Rosenelfe' produced more flowers than the other 2 cultivars. Plant dry weight, leaf dry weight and leaf area were lowest for 'Linda' at the end of the experiment. This resulted from a low RGR, caused by a low NAR (small leaves, internal shading) combined with a low LAR (thick leaves).

Keywords: *Achimenes* cultivars, daily light integral, growth analysis, light intensity.

Abbreviations: A = total plant leaf area (cm^2); DW = total dry weight of the plant (mg); DW_l = total dry weight of the leaves (mg); F PR = F probability; probability of obtaining an F statistic at least as large as the present one when all treatment means are equal; LAR = leaf area ratio (A/DW; cm^2 mg^{-1}); LWR = leaf weight ratio (DW_l/DW); NAR = net assimilation rate (mg cm^2 day^{-1}); PAR = photosynthetic active radiation (400-700 nm; W m^{-2}); RGR = relative growth rate (day^{-1}); SLA = specific leaf area (A/DW_l; cm^{-2} mg^{-1}).

INTRODUCTION

Achimenes belongs to the Gesneriaceae and is cultivated as a potted plant in both the United States and Europe. It originates from Mexico and Central America (Moore, 1957). *Achimenes* is a day neutral plant and flower initiation takes place after the development of the 3rd or 4th leaf whorl in daylengths of 8 to 24 h (Zimmer and Junker, 1985). Best vegetative and generative growth is achieved at 20°C and 16 h light (Rohde, 1974).

Achimenes plants are produced mainly in spring and summer. Propagation is done by rhizomes or cuttings. Later in the season, due to a low light integral, plants become senescent, forming rhizomes in the soil. The use of additional light in the greenhouse can perhaps help to overcome this problem, making year-round production possible. It has been shown that irradiance levels are very important for growth and flowering in cultivars Flamenco' and 'Hilda Michelssen'. Increasing irradiance levels increased plant dry weight, rhizome dry weight and number of flowers (Vlahos, 1989).

Earlier work (Vlahos, 1990) with other *Achimenes* cultivars showed that growth and flowering were promoted as daylength increased (high light intensity; 35 W m^{-2}) Thus with increasing daylength, the amount of irradiance energy increased proportionately. Therefore it seems reasonable that the reported effects were due to an increase in total irradiance energy rather then daylength. Furthermore, results from previous experiments with several cultivars indicate that certain characteristics of growth and development in *Achimenes* are clearly influenced by the cultivar.

The aim of the present investigation was to use a growth analysis technique (Hunt, 1982) to explain the differences observed in growth and development in 3 cultivars under 3 light regimes at the same daily light integral.

MATERIAL AND METHODS

Experimental design. On May 21, 1985 plants of three morphologically different *Achimenes* cultivars were placed in 6 growth chambers (Controlled Environments Ltd., Winnipeg, Manitoba, Canada; length x width x height = 185x77x137 cm) at 21°/18°C day/night temperature under three different light regimes (Philips TL 33 fluorescent tubes), resulting in the same daily light integral.

The cultivars selected were: 'Early Arnold', an early flowering cultivar with sturdy, erect stems and large purple flowers, 'Rosenelfe' with good branching and small red flowers, developing in clusters of 3 to 9 arising from the leaf axils and, 'Linda' with slender stems and white flowers. The plants had been propagated by stem cuttings originating from sprouted rhizomes from the *Achimenes* collection maintained at that time by the Department of Horticulture in Wageningen. Plantlets with an average height of 4 cm and 2-3 leaf whorls were selected and potted in 10 cm plastic pots (1 plant per pot) using a standard potting medium.

The experimental layout was a split-plot design where three light regimes were applied in the whole plots (growth chamber) in duplicate. The factor cultivar was applied in the subplots. Each light regime was a combination of irradiance and daylength applied in one growth chamber to eight plants of each cultivar (in total 24 plants). The light regimes were : high irradiance,60 W m^{-2} photosynthetically active radiation (PAR) for 5 h; medium irradiance,40 W m^{-2} PAR for 7.5 h; low irradiance;17 W m^{-2} PAR for 17.5 h. Thus the total daily light integral in all 3 treatments was 300 Wh m^{-2}.

Weekly one plant per cultivar from each chamber was selected at random from each growth chamber for destructive measurements 7, 14, 21, 28, 35, 42 and 49 days after the start of the experiment. The following data were collected: number of leaves (> 5 mm), leaf area (by LI-COR Model 3100 area meter) and total dry weight (60°C, forced air oven for 6 days) of leaves, stems, flowers, roots and rhizomes (if any). Additional data were collected at the end of the experiment, i.e. plant height, number of leaf whorls, number of axillary shoots, number of flower buds and total number of flowers. As flowers do not abort when they are senescent it was possible to record the total number of flowers that developed during the 7 week period.

Growth analysis. A growth analysis was conducted according to the functional approach (Hunt, 1982). The best fitting polynomial (up to the sixth degree) relating the natural logarithms of total dry weight of the plant (DW), total dry weight of the leaves (DWl) and total plant leaf area (A) with time was calculated (Nilwik, 1981). The degree of the polynomials was chosen by using the 'stepwise' F-test ($P<0.001$) described by Draper and Smith (1966). It was found that in most cases a quadratic function provided the most satisfactory fit to the data. Therefore, a quadratic relationship was fitted to all the plots of the natural logarithms of DW, DWl and A against time.

Because growth rate is size dependent (ontogenetic effect), it is necessary to take this into account. Terry (1968) used DW as an index of ontogenetic state. This approach has also been applied here. Therefore mean values of RGR, NAR, LAR, SLA and LWR were compared on the basis of a DW interval instead of a time interval. This DW interval was 91-493 mg (lnDW = 4.51-6.20), where the lower limit equals the maximum fitted DW at the start of the experiment and the upper limit equals the minimum fitted DW at the final harvest. Thus no extrapolation of the measured data is required. Instantaneous values for RGR, NAR, LAR, SLA, and LWR were calculated by means of the polynomials described before, relating DW, DWl and A with time. Average RGR, NAR, LAR, SLA and LWR values were calculated by taking the mean of daily instantaneous values over the DW interval.

Effects of light regime and cultivar were studied in an analysis ofvariance followed by an LSD.

RESULTS AND DISCUSSION

Measured parameters..For the measured plant parameters no significant interaction ($P=0.10$) between the factors cultivar and light regime was found, so both factors can be treated seperately. DW, DWl and A were lowest for 'Linda' at the end of the experiment (Table 1). This effect was significant, except for DW_l, which did not differ significantly between 'Rosenelfe' and 'Linda'. 'Linda' was the shortest cultivar (Table 1) with the highest number of leaves and axillary shoots after 49 days of growth. 'Early Arnold' produced less leaves and axillary shoots than 'Rosenelfe', however both cultivars reached the same height.

'Rosenelfe' produced more flowers (including flower buds) than the 2 other cultivars. This high number of flowers was also reported by Vlahos (1990), comparing 'Rosenelfe' with 'Flamenco' and 'Hilda' and results from the high number of flowers (3 to 9) originating from one leaf axil in this cultivar.

The lower light intensity at the same daily light integral increased DW, DWl and A significantly (Table 2). Also number of leaves, number of leaf whorls and total number of flowers (including flower buds) were increased by lower light intensities (longer days) at the same light integral. Our results are in agreement with Gislerod et al. (1989), who reported for several ornamental plants that DW and number of flowers was higher at 20h rather than 16h at the same daily light integral. In a similar study with radish Craker et al. (1983) found also that plant weight after 25 days was higher at 16 h than at 8 h at the same daily light integral.

The fact that *Achimenes* forms flower buds regardless of daylength between 5 hr and 17.5 h) agrees with the findings of Zimmer and Junker (1985).

TABLE 1

Effect of cultivar[1] on different plant characteristics at the end of the experiment (mean of three light regimes)

Cultivar	DW (mg)	DW_1 (mg)	A (cm^2)	Plant height (cm)	Number of Leaves	Number of Axillary shoots	Total number of flowers and flower buds
'Early Arnold'	1927a	948a	286a	22.3a	29.3a	0.67a	17.3a
'Rosenelfe'	1806a	642b	261a	20.8a	79.3b	3.67b	67.0b
'Linda'	1100b	577b	177b	10.7b	126.8c	5.83c	20.2a
F PR[2]	0.005	0.001	0.001	<0.001	<0.001	<0.001	0.001

[1]Mean separation by LSD test ($P<0.05$).
[2]*F* PR = *F* probability.

TABLE 2

Effect of light regime[1] on different plant characteristics at the end of the experiment (mean of three cultivars)

Light regime	DW (mg)	DW_1 (mg)	A (cm^2)	Plant height (cm)	Number of Leaves	Number of Axillary shoots	Number of Leaf whorls	Total number of flowers and flower buds
60 W m^{-2}/5 h	793a	415a	139a	13.8	60.2a	3.5	9.2a	21.8a
40 W m^{-2}/7.5 h	1597b	715b	255b	20.2	75.2b	2.8	11.0b	35.2b
17 W m^{-2}/17.5 h	2443c	1037c	329c	19.8	102.8c	3.8	11.7b	47.5c
F PR[2]	<0.001	<0.001	0.006	0.103	0.013	0.358	0.018	0.022

[1]Mean separation by LSD test ($P<0.05$).
[2]*F* PR = *F* probability.

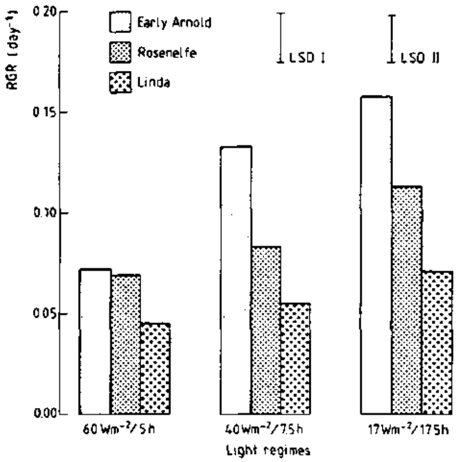

Fig. 1. Interaction effect of cultivar and light regime on mean values of RGR over the DW interval 91–493 mg. Vertical bars indicate LSD ($P=0.05$): (I) for comparisons at different light regimes; (II) for comparisons at the same light regime.

Growth analysis. **In order to explain effects of cultivar and irradiance on growth and development of *Achimenes* a growth analysis was conducted. No significant interaction (P=0.10) between the factors cultivar and irradiance was found for any of the growth characteristics, except for RGR (Fig. 1). A lower light intensity at the same daily light integral increased RGR for all 3 cultivars, although this increase was not always significant. RGR was highest for 'Early Arnold', although at 60 W**

m^{-2}/ 5h there was no significant difference with 'Rosenelfe'. 'Linda' had the lowest RGR, although only at 17 W m^{-2}/17.5 h RGR differed significantly from 'Rosenelfe'.

Separating RGR into an assimilatory component (NAR) and a morphological component (LAR), led to the conclusion that cultivar differences in RGR were caused both by NAR and LAR (Table 3). The high RGR found for 'Early Arnold' was the result of a higher NAR and LAR, compared with the other 2 cultivars. These differences were significant except for the difference in LAR between 'Early Arnold' and 'Rosenelfe'. 'Linda', with a low RGR, had a significantly lower NAR than the other 2 cultivars, whereas LAR was also lower than for 'Early Arnold' ($P < 0.05$) and for 'Rosenelfe' (not significant). LAR can be considered as the product of SLA and LWR. Table 3 shows that the above mentioned differences in LAR between the 3 cultivars resulted from differences in SLA. LWR was the same for the 3 cultivars.

TABLE 3

Effect of cultivar[1] on mean values of NAR, LAR, SLA and LWR over the DW interval 91–493 mg (mean of three light regimes)

Cultivar	NAR (mg cm^{-2} day^{-1})	LAR (cm^2 mg^{-1})	SLA (cm^2 mg^{-1})	LWR
'Early Arnold'	0.484a	0.251a	0.354a	0.711
'Rosenelfe'	0.389b	0.231ab	0.356a	0.652
'Linda'	0.279c	0.203b	0.306b	0.673
F PR[2]	0.001	0.038	0.021	0.80

[1]Mean separation by LSD test ($P < 0.05$).
[2]*F* PR = *F* probability.

TABLE 4

Effect of light regime[1] on mean values of NAR, LAR, SLA and LWR over the DW interval 91–493 mg (mean of three cultivars)

Light regime	NAR (mg cm^{-2} day^{-1})	LAR (cm^2 mg^{-1})	SLA (cm^2 mg^{-1})	LWR
60 W m^{-2}/5 h	0.282a	0.220	0.332	0.664
40 W m^{-2}/7.5 h	0.365a	0.242	0.362	0.672
17 W m^{-2}/17.5 h	0.505b	0.224	0.322	0.700
F PR[2]	0.026	0.353	0.356	0.502

[1]Mean separation by LSD test ($P < 0.05$).
[2]*F* PR = *F* probability.

Effects of light intensity at the same daily light integral on RGR could be fully explained by effects on NAR (Table 4). Lowering light intensity combined with increasing daylength increased NAR, whereas LAR remained the same. This increase in NAR is probably partly a result of the saturation type relationship between light intensity and photosynthesis. This can play a role even at the rather low light intensities used in our experiment,,because *Achimenes* is a shade plant (van Raalte, 1969). Another explanation could be the smaller leaf size (cm^2 $leaf^{-1}$) at the highest light intensity resulting in more internal shading (calculated from Table 2).

CONCLUSIONS.

Combining measured plant characteristics with the results of growth analysis, it is concluded that the low values of DW, DW_l and A for 'Linda' at the end of the experiment (Table 1) resulted from a low NAR and SLA (thicker leaves). For young plants, as in this experiment, thicker leaves led to less light interception per unit leaf weight and thus to growth reduction. The low NAR can be a result of unfavourable photosynthesis characteristics for 'Linda' (e.g. low light use efficiency; μg CO_2 J^{-1} absorped PAR), but it can also be a result of the large number of small leaves produced by this cultivar (calculated from Table 1). Small leaves result in more internal shading than larger leaves at the same total plant leaf area, which leads to a lower NAR. High values of DW, DWl and A for 'Early Arnold' at the end of the experiment (Table 1) resulted mainly from a high NAR, probably a result of its large thin leaves. Leaf size (cm^2 $leaf^{-1}$) in 'Early Arnold' was 3 times as high as in 'Rosenelfe' and 7 times as high as in 'Linda' (calculated from Table 1).

Increase in daylength at the same daily light integral favoured growth in *Achimenes* (Table 2). This could be explained by an increase in NAR (Table 4), whereas LAR remained unaffected. Therefore it is suggested that a better light use efficiency (mg DW J^{-1} PAR) is responsible for the increase in growth at low light intensity combined with longer days.

The use of supplementary lighting in *Achimenes* production will be more profitable (better growth, lower investment costs) if low intensities are provided during a longer period compared to high intensities at the same light integral.

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Chapter 4

Influence of Daylength, Light quality and Temperature on Growth and Development in Three Cultivars of *Achimenes*.

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Influence of Daylength, Light quality and Temperature on Growth and Development in 3 cultivars of *Achimenes*.

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Additional index words. daylength extension, incandescent light, fluorescent light, growth analysis

Abstract. The effects of supplementary irradiance (20 μ mol·s^{-1}·m^{-2} for 6 h) with incandescent light (GLS) or fluorescent compact gas-discharge lamps (SL) vs a basic irradiance (96 μ mol·s^{-1}·m^{-2} for 12 h) with fluorescent (TL) light under 17 or 25oC was studied for *Achimenes* hybrids 'Flamenco', 'Hilda' and 'Rosenelfe'. The additional GLS light (low R/ FR ratio) compared to the control irradiance (TL) increased leaf area (A), leaf dry weight (DWl) and plant dry weight (DW) in 'Hilda' and 'Rosenelfe', and promoted stem elongation in all 3 cultivars. Additional SL light (high R/ FR ratio) had no effect on DW compared to TL. However, depending on cultivar, responses for A, DWl or rhizome dry weight (DWrh) varied. Number of flowers or axillary shoots were not influenced by the light regimes, except in 'Rosenelfe' where axillary branching was suppressed by supplementary GLS light and number of flowers was promoted by both GLS and SL compared to the control. In all cultivars, the supplementary fluorescent light (SL) when compared to the incandescent light (GLS) reduced A, DWl, DW and increased DWrh in 'Flamenco' only. A, DWl and DW were significantly higher at higher temperature, except for 'Rosenelfe'; DW and DWl were not influenced in this cultivar, A was lower at the higher temperaturer. All 3 cultivars produced a longer stem, more leaf whorls and more flowers at the higher temperature. Calculated growth parameters were influenced by light regime and temperature. Daylength extension by either GLS or SL lowered specific leaf area (SLA) (15 respectively 22%) and leaf area ratio (LAR) (19 respectively 25%) and increased net assimilation rate (NAR) (27 respectively 43%). As a result relative growth rate (RGR) increased. Higher temperature resulted in a lower leaf weight ratio (LWR) for 'Hilda' and 'Rosenelfe' (5 respectively 13%). However, due to a larger increase in NAR (51 respectively 37%), RGR increased with increasing temperature (53 respectively 12%). For 'Flamenco' LWR increased (8%) and NAR decreased (16%) with increasing temperature.

Hybrids of the genus *Achimenes*, Gesneriaceae, are cultivated as potted plants in both the United States and Europe. *Achimenes* flowers regardless of daylength after the development of the 3rd or 4th leaf whorl (Zimmer and Junker, 1985). Best vegetative and generative growth is achieved at 20°C and 16 h light (Rohde, 1974). Recently the influence of light and temperature on growth and development of several *Achimenes* cultivars was quantified. Higher temperatures (21 or 25°C rather than 17°C) increased number of leaf whorls and favoured flowering. However, responses varied among cultivars (Vlahos, 1990a). Extending natural daylength with high pressure sodium lamps increased growth and flowering (Vlahos, 1989, 1990b). Low light intensities combined with long days (at the same daily light integral) increased growth and flowering in 3 cultivars of *Achimenes* due to increase in RGR and NAR, due to a more efficient light use at lower light intensity (Vlahos et al, 1991).

Apart from light intensity and light integral, it is well known that also light quality (spectral distribution of light perceived by a particular kind of colour vision; Bjorn, 1986) influences plant growth and mprphogenesis (Healy et al., 1980; Smith, 1982).

Most research on light quality refers to the use of different light sources combined with different irradiance levels or photoperiods on growth and development of several species. Incandescent light increases stem height reducing plant quality in several pot plants. The fluorescent lamp although it does not increase stem height as much as incandescent light is not commonly used in commercial plant production. (Andersen, 1986, Grimstad, 1987; Mortensen and Stromme, 1987; Knight and Mitchell, 1988; Kristiansen, 1988). Red light promoted whereas far red light supressed rhizome formation in leaf or stem cuttings of *Achimenes* 'Major' (Deutch, 1974). Other effects of light quality have not been reported in *Achimenes.* The present experiment was designed to investigate the effect of supplementary lighting of different quality on growth and development in 3 Achimenes cultivars at 2 temperatures.

Material and Methods

Experimental design. Cultivars Flamenco, Hilda Michelssen (referred to as Hilda) and Rosenelfe were obtained from a commercial grower in March 1985 and grown in 10 cm plastic pots (volume 300 cm^3) in a commercial potting soil (pH 5.5-5.8) consisting of 60 peat mold: 40 rough peat (by volume). Plants were grown for 10 days in a greenhouse at 21°C day and 18°C night temperature under natural daylength in order to establish.

On April 3 the plants were placed in 6 growth chambers (Controlled Environments Ltd., Winnipeg, Manitoba, Canada; length x width x height = 185 x 77 x 137 cm) and grown for 9 weeks at 17 and 25°C (constant day/ night) each combined with 3 light regimes. At the start of the experiment plants had an average height of 4 cm with 3 - 4 leaf whorls (nodes) with no flower buds visible and only axillary shoots emerging from the lower leaf axils.

The light regime treatments were :

TL : 12 h irradiance provided with fluorescent Philips TL33 tubes (96 μ mol· s^{-1}· m^{-2} PAR; high R/ FR ratio)

GLS : 12 h irradiance (same as TL), extended for 6 h with incandescent Philips GLS lamps (20 μ mol· s^{-1}· m^{-2} PAR; low R/ FR ratio)

SL : 12 h irradiance (same as TL), extended for 6 h with Philips SL compact gas-discharge lamps (20 μ mol· s^{-1}· m^{-2} PAR; high R/ FR ratio)

The SL lamp (miniature fluorescent) has the same spectrum as the TL, but is a more practical and energy saving type of lamp.
R/FR ratio= The ratio of the number of photons in the 655-665 nm band (red) to that in the 725-735 nm band (far-red) (Bjorn, 1986).
PAR = *photosynthetic active radiation* (400-700 nm) (μ mol$\cdot$ $s^{-1}\cdot$ m^{-2})

The R/FR ratio of the 3 lamp types was not measured, but according to Hart (1988) this ratio might be as much as 20 times higher in fluorescent light compared to incandescent light. The experimental layout was a split-plot design, where the six combinations of temperature and light regime have been applied in the whole plots (growth chambers) with cultivar as sub-plots (16 plants per cultivar in each growth chamber). The experiment involved a total of 288 plants.

Leaf area (LI-COR Model 3100 Area Meter), leaf, stem, root and rhizome fresh and dry weight (60°C; forced air oven for at least 5 days) were determined on 4 plants for each cultivar at 0, 21, 42 and 63 days after the start of the experiment. At the final harvest, plant height, number of leaf whorls and number of axillary shoots were also measured. The number of days to first flower was recorded by daily observations. Data were subjected to an analysis of variance with LSD mean seperation.

Growth analysis. Growth analysis was conducted according to the functional approach (Hunt, 1982). The best fitting polynomial (up to the sixth degree) relating the natural logarithms of DW, DW_l and A with time was calculated (Nilwik, 1981). The degree of the polynomials was chosen by using the 'stepwise' F-test ($P < 0.001$) described by Draper and Smith (1981). It was found that in most cases a quadratic function provided the most satisfactory fit to the data. Therefore, a quadratic relationship was fitted to all the plots of the natural logarithms of DW, DW_l and A against time.

Because growth rate is size dependent (ontogenetic effect), it is necessary to take this into account. Terry (1968) used DW as an index of ontogenetic state. This approach has also been applied here. Therefore mean values of RGR (day^{-1}), NAR (mg cm^{-2} day^{-1}), LAR (A/ DW; cm^2 mg^{-1}) SLA (A/ DW_l; cm^{-2} mg^{-1}) and LWR (DW_l/ DW) were compared on the basis of a DW interval instead of a time interval. This DW interval was 107-508 mg (lnDW = 4.68 - 6.23), where the lower limit equals the maximum fitted DW at the first harvest and the upper limit equals the minimum fitted DW at the last harvest. Thus no extrapolation of the measured data is required.

Instantaneous values for RGR, NAR, LAR, SLA and LWR were calculated by means of the polynomials described before, relating DW, DW_l and A with time. Average RGR, NAR, LAR, SLA and LWR values were calculated by taking the mean of daily instantaneous values over the DW interval. Results were statistically analysed with analysis of variance followed by an LSD test.

Results and Discussion

Light regime.. The experimental design (split plot; where the interaction between light regime and temperature was confounded with the growth chamber effect) did not provide for a test on interaction between light regime and temperature. Significant interactions between light regime and cultivar were found for plant height, number of axillary shoots and number of flowers (Fig. 1 and 2) and A, DW, DW_l, and DW_{rh} (Fig.3). Additional lighting for 6 h with GLS lamps increased plant height in all 3 cultivars, however this effect was significant only in 'Flamenco' and 'Rosenelfe'. Number of leaf whorls was not different (data not shown), which means that

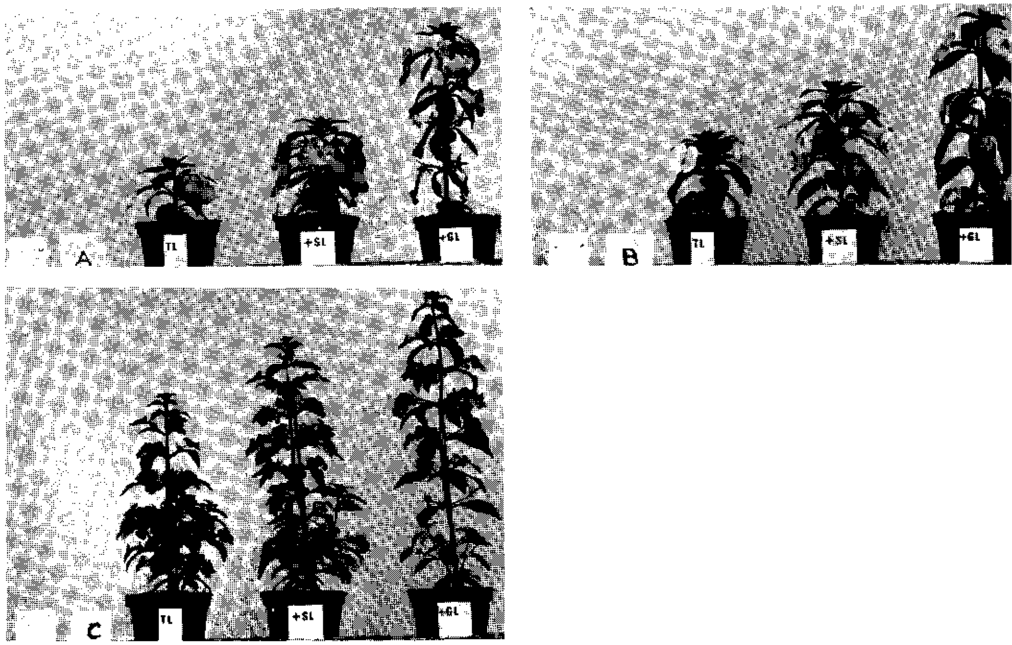

Fig. 1. The effect of 3 light regimes on growth and flowering in 'Flamenco'(A), ' Hilda' (B) and 'Rosenelfe' (C), kept in growth chambers at 25°C. Photo taken 8 weeks after start of treatment.

increased plant height was a result of elongation (longer internodes). This elongation reduces plant quality. A low R/ FR ratio (incandescent light) is known to promote stem elongation compared to high R/ FR ratio (fluorescent light) in a wide range of ornamental plants (Vince-Prue, 1975; Cathey and Campbell, 1975; Smith, 1986). Additional SL light (high R/ FR ratio) had no significant effect on plant height (Fig.2). Kristiansen (1988) reported similar results for *Campanula*. Incandescent light is known to retard or inhibit lateral branching in several plants (Vince-Prue, 1977; Cathey and Campbell, 1975; Tucker, 1975; Hagen and Moe, 1981; Grimstad, 1987). In the present investigation only 'Rosenelfe' responded with reduced branching to the low R/FR ratio of incandescent light (Fig. 1) possibly a result of the low level of branching in the other two cultivars.

Wilkins (1985) and Grimstad (1987) reported for *Fuchsia* and *Gloxinia* that flower development was not influenced by different light sources or photoperiod. Results in 'Flamenco' and 'Hilda' are similar to these findings, as total number of flowers was not significantly affected by the light regime. In 'Rosenelfe' however, supplementary lighting with SL increased number of flowers compared to the TL light regime (Fig. 2).

Flower development in several day neutral plants is strongly influenced by the light integral (Kinet and Sachs, 1984). In the present study it is suggested that in 'Rosenelfe' also the increased light integral (by 10%) promoted flowering as daylength extension with GLS had also a positive effect on the number of flowers, although not significant. Number of days to anthesis was not significantly affected by light regime (data not shown) for any of the cultivars studied.

Lighting by either GLS or SL reduced A in 'Flamenco' and increased it in

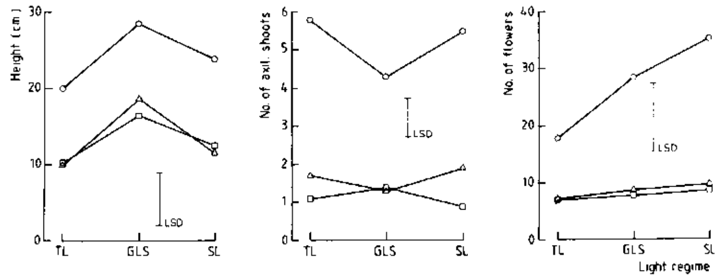

Fig. 2. Interaction effect of light regime and cultivar (Δ:'Flamenco', :□'Hilda', 0 :'Rosenelfe') on plant height , number of axillary shoots and total number of flowers after 63 days. Points represent the means of 2 temperature regimes .

'Hilda'. In 'Rosenelfe' A was reduced only by SL. Additional GLS light significantly increased A in all cultivars when compared to SL (Fig. 3). In 'Hilda' and 'Rosenelfe' both DW and DW_l were increased by additional incandescent light (GLS) compared to the other light regimes (Fig.3). DW and DW_l in 'Flamenco' was not affected by the light regime. Generally, similar trends were found for the fresh weight parameters (data not shown).

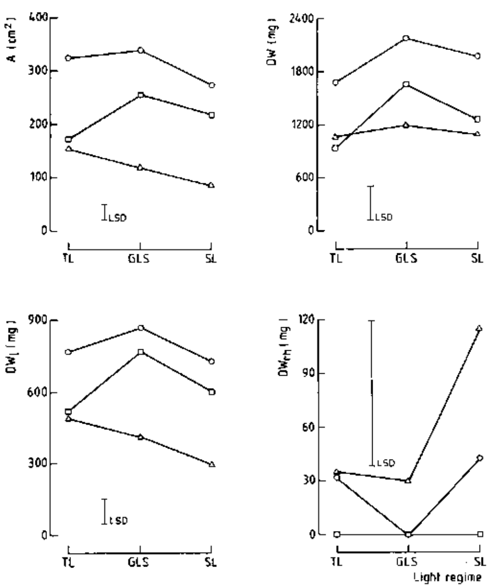

Fig. 3. Interaction effect of light regime and cultivar (Δ:'Flamenco', □Hilda', O:'Rosenelfe') on A, DW, DW_l and DW_{rh} after 63 days. Points represent the means of 2 temperatures regimes .

Dry weight in several species increased with incandescent irradiance, supplementing fluorescent irradiance (Dijak and Ormrod,1985; Knight and Mitchel,1988). Our results for 'Hilda' and 'Rosenelfe' agree with these findings. Mortensen and Stromme (1987) reported that blue light, containing a high R/ FR ratio, reduced dry weight and leaf area in several plant species. Results for 'Hilda' are in agreement with the above findings as under both TL and SL light (high R/ FR ratio) A, DW and DW_l decreased compared to GLS. The other cultivars varied in their response. Considering that equal PAR (400-700 nm) was maintained in both GLS and SL light regimes the differences observed are due to light quality. Light regimes had no significant effect on the number of rhizomes (data not shown); Deutch (1974) found that far red light suppressed whereas red light promoted rhizome formation in leaf cuttings in *Achimenes* 'Major'. Results with 'Flamenco' indicate a similar trend (Fig. 3) as DW_{rh} was lower in GLS (higher proportion of far red) compared to SL (higher proportion of red) suggesting that rhizome dry weight is likely to be promoted by a high R/FR ratio. 'Hilda' formed no rhizomes till the end of the experiment.

Temperature. Significant interactions between temperature and cultivar existed for plant height, number of leaf whorls and number of flowers (Fig.4). Higher temperature promoted plant height and number of leaf whorls in all cultivars. Time to anthesis was shortened in 'Rosenelfe' and 'Hilda' (data not shown). At 25°C number of flowers was higher than at

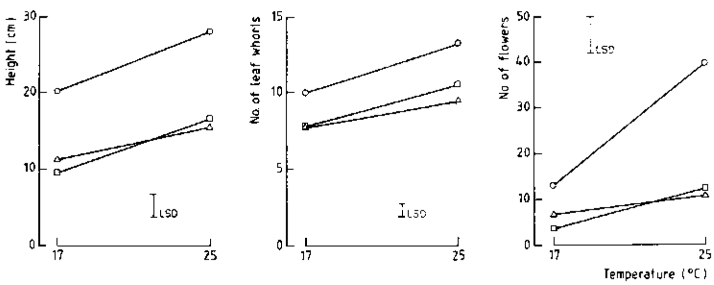

Fig. 4. Interaction effect of temperature and cultivar (Δ:'Flamenco', :'Hilda', O:'Rosenelfe') on plant height , number of leaf whorls and number of flowers after 63 days. Points represent the means of 3 light regimes.

17°C in all 3 cultivars although this effect was significant only in 'Rosenelfe'. Higher temperature is known to promote growth and flowering in many species (Gertsson, 1984; Djurhuus, 1985; Kristiansen, 1988). ' Rosenelfe' produced more flowers than the other two cultivars (Fig. 4), as 3 to 9 flowers may develop from one leaf axil (Vlahos, 1990a).

The interaction effect (significant at 5% level) of temperature and cultivar on A, DW, DW_l and DW_{rh} is shown in Fig.5 . Both 'Flamenco' and 'Hilda' showed a significantly higher A, DW and DW_l at 25 compared to 17°C. However, for 'Rosenelfe' A was reduced at 25°C whereas DW_l and DW were not significantly affected by temperature in this cultivar (Fig. 5). DW_{rh} was not significantly affected by temperature in any of the 3 cultivars. 'Hilda' developed no rhizomes until the end of the experiment (Fig.5).

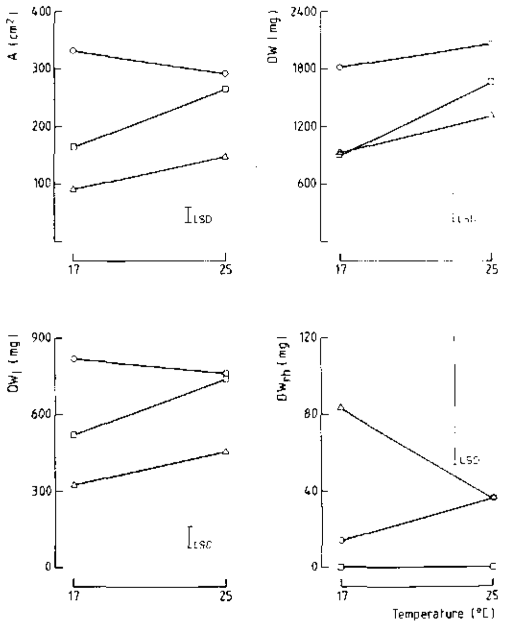

Fig. 5. Interaction effect of temperature and cultivar (Δ:'Flamenco', :'Hilda', O:'Rosenelfe') on A, DW, DW_l and DW_{rh} after 63 days. Points represent the means of 3 light regimes.

Growth analysis. No significant interaction between light regime and cultivar was found for any of the calculated growth parameters. Light regime influenced RGR, NAR, LAR and SLA (Table 1). However, due to the few degrees of freedom for the residual (r=2), means were not significantly different at 5% level. Daylength extension by either GLS or SL lowered SLA

Table 1. Effects of light regime on mean values of RGR, NAR, LAR, SLA and LWR over the DW interval 107-508 mg[z] .

Light Regime	RGR (day^{-1})	NAR (mg cm^{-2} day^{-1})	LAR (cm^2 mg^{-1})	SLA (cm^2 mg^{-1})	LWR
TL	0.0564	0.318	0.203	0.333	0.609
GLS	0.0642	0.403	0.165	0.282	0.585
SL	0.0640	0.456	0.152	0.259	0.587
FPR [y]	0.537	0.107	0.088	0.258	0.723

[z]Values are means of 3 cultivars and 2 temperature regimes

[y] F probability; probability of obtaining an F statistic at least as large as the present one when all treatment means are equal.

(15 and 22% respectively) and LAR (19% and 25% respectively). The lower SLA might be mainly a result of a higher light integral. GLS or SL increased NAR by 27 and 43%, respectively (Table 1). As a result RGR increased by 14%. Supplementary lighting provided with GLS or SL (20 μ mol s^{-1} m^{-2}) for 6 h per day appeared to be high enough to give higher photosynthesis (higher NAR). This is as expected, because *Achimenes* is a 'shade-plant' (van Raalte, 1969) and therefore is adapted to utilize low light intensity. The lower SLA under both GLS or SL supplementary lighting indicates a morphological effect (thicker leaves) on *Achimenes*.

Table 2. Temperature and cultivar interaction effect on mean values of RGR, NAR, LAR, SLA and LWR over the DW interval 107-508 mg[z]

	RGR (day^{-1})		NAR ($mg.cm^{-2}.day^{-1}$)		LAR ($cm^{-2}.mg^{-1}$)		SLA ($cm^{-2}.mg^{-1}$)		LWR	
Cultivar	17C	25C	17C	25C	17C	25C	17C	25C	17C	25C
Flamenco	0.0633	0.0653	0.532	0.449	0.121	0.166	0.228	0.288	0.529	0.571
Hilda	0.0406	0.0622	0.228	0.345	0.182	0.183	0.269	0.286	0.677	0.644
Rosenelfe	0.0651	0.0728	0.338	0.463	0.223	0.167	0.365	0.314	0.611	0.530
F PR[y]	0.039		0.069		0.185		0.459		0.030	
LSD 5%	0.017		0.14		0.076		0.148		0.083	

[z] Values are means of 3 light regimes
[y] F probability;;probability of obtaining an F statistic at least as large as the present one when all treatment means are equal.

Significant interactions (P<0.10) between temperature and cultivar were found for RGR, NAR and LWR (Table 2). Cultivar differences were greater at 17 than at 25°C. RGR was lowest for 'Hilda' and increased 53% with temperature; for 'Flamenco' and 'Rosenelfe' this increase with temperature was smaller (3 and 12% respectively). NAR decreased (16%) in 'Flamenco' at the higher temperature whereas in 'Hilda' and 'Rosenelfe' there was a 51% and 37% increase respectively. LWR for 'Hilda' and 'Rosenelfe' was lower (5 and 13%) at 25 compared to 17°C. LWR in 'Flamenco' increased with temperature (8%).

The low RGR for 'Hilda' was the result of the lowest value for NAR compared to the other two cultivars, combined with an intermediate value for LAR. The high RGR for 'Rosenelfe' resulted from the highest LAR and intermediate NAR. Therefore, both NAR, the photosynthetic component of growth, and LAR, the morphological component, appeared to be important factors in determining the differences in growth between the cultivars.

Results indicate that depending on cultivar a 6h daylength extension providing a quantity of light energy as low as 20 μ mol s^{-1} m^{-2} from either fluorescent or incandescent lamps affects growth and development in *Achimenes* . However, the SL lamp is to be preferred as it does not cause stem elongation.

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III. EFFECTS OF GROWTH REGULATORS ON GROWTH AND DEVELOPMENT OF ACHIMENES CULTIVARS

Chapter 5

Effects of BA and GA_3 on Sprouting of *Achimenes* Rhizomes.

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Presented at the Second Symposium on Growth Regulators in Floriculture
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Effects of BA and GA_3 on Sprouting of *Achimenes* rhizomes

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Abstract

Apical and basal halves of *Achimenes* rhizomes, cv English Waltz, were soaked in four different concentrations of benzyladenine solution for 8, 16 and 24 h. Kept at 25°C in a dark chamber for two weeks, the higher BA concentrations (50 and 100 mg l^{-1}) broke dormancy and enhanced sprouting in both rhizomes halves.

In an other trial, rhizomes of cv Viola Michelssen were similarly treated in 50 mg l^{-1} GA_3 and placed at four different temperatures under continuos light and/or darkness for 3 weeks. Dormancy was broken by GA_3 at 21°C in the dark. In both experiments the apical halves sprouted earlier than the basal ones. GA_3 and temperature pretreatment significantly influenced height, number of leaf whorls and flowers in plants developed from treated rhizomes, growing at 21°C and 16 h light, for 22 weeks (5 months).

1. Introduction

Commercial production of *Achimenes* starts in late January by sowing rhizomes, produced from plants or leaf cuttings in the previous season. Starting in March, cuttings are taken at successive intervals for plant production until August. The cultivation stops in September or October because plants do not grow in the winter, entering a period of senescence (Rhode, 1973). During the growing period, underground rhizomes are formed that must undergo a period of rest before they sprout for new plant production in the following season. Thus cultivation is limited to one crop per year.

Zimmer (1976) has investigated dormancy break and sprouting in several *Achimenes* cultivars. Results varied greatly depending on cultivar and environmental conditions under which rhizomes were formed and stored. It was concluded that the longer the rhizomes were stored the sooner they woulfd sprout and that dormancy was broken at high temperatures (20 to 30°C) after dry storage for 10 to 15 weeks.This is a rathe rlong period and it would be ineresting to know if release from dormancy and sprouting can be controlled. This would allow not only a better timing in production but also it would make it possible to have 2 crops in a year, provided that the factors that cause senescence of plants would also be known.

Breaking dormancy of *Achimenes* rhizomes with growth regulators has not been investigated before. Gibberellin and benzyladenine were selected for these experiments because they have been used with success in breaking dormancy in several bulbous plants. Potato tubers have been induced to sprouting with GA_3 (Tsukamoto et al., 1960; Rappaport et al., 1965; Bruinsma and Swart, 1970). Also cytokinins and especially benzykadenine were most effective in releasing potato tubers from dormancy (Tsukamoti and Yazawa, 1972) and a combination of BA and GA_3 has broken dormancy of gladiolus corms (Tsukamoto, 1974).

Concentrations and method of application of substances used in these trials were based on previously reported research on other tuberous plants.

The purpose of the experiments reported here was to investigate the possibility of breaking dormancy and enhancing sprouting of *Achimenes* rhizomes and to observe if there is a carry-over effect on plants developed from treated rhizomes.

2. Material and Methods

Rhizomes if cultivar English Waltz (EW) and Viola Michelssen (VM) were used because they were available at the required quantities for the trials. The rhizomes were collected from senescing plants of a cultivar assortment grown in the summer of 1983 at the Experimetn station at Lent in the Netherlands. After harvesting, the rhizomes were cleaned, washed with tap water and those with a uniform size were selected and were broken by hand in two halves, the apical (A) and the basal (B). The rhizomes to be treated were soaked in freshly made growth regulator solutions while controls were soaked in water, at room temperature (20±1°C). All rhizomes were sprayed with Preficure (2 ml/l) to prevent fungal infestation. Treatments contained 10 halves (A and B) and each lot was placed on moistened with paper, double filter paper in a covered Petri dish, before being put under incubation conditions. The rhizomes were checked weekly and data were collected after 2 or 3 weeks. The length of emerging sprouts were recorded within 1 mm. If sprout length was 3 mm or more the rhizome was recorded as sprouted.

2.1. Experiment I

On September 26, 1983 freshly harvested rhizomes of EW were treated in 1, 25, 50 and 100 mg l^{-1} BA solution for 8, 16 and 24 h and then placed at 25 °C in a dark chamber. Sprouting was recorded after 2 weeks.

2.2 Experiment II

Rhizomes of cv VM harcested on October 20, 1983 were stored dry in the dark, at room temperature, for 4 weeks. On November 17 they were treated in 50 mg l^{-1} GA_3 solution for 16 h and then placed in growth rooms at 13, 17, 21 and 25 °C under two light regimes; continous dark (CD) and continous light (CL) of 35 W m^{-2} (phase 1). Sprouting was recorded after 3 weeks. The lots were then placed at 21 °C in CD, because sprouting was observed to be enhanced under these conditions (phase 2). 3 weeks later, on December 30, 1983, sprouting was recorded again and all rhjizome halves of CD regime were planted individually in 7 ½ pots in a standard potting soil and were kept at 21 °C and 16 h light in a growth room for 5 months. Data on plant growth and flowering were collected every 4 weeks. On June 5, 1984 the experiment was terminated and plants were checked for rhizomes. Data were processed with an analysis of variance test.

3. Results

3.1 Experiment I

The effect of benzyladenine on the sprouting percentage of both rhizome halves of 'English Waltz' is shown in Fig.1. The highest sprouting percentage was achieved at 50 mg l^{-1} BA, while the highest mean sprout length of both A and B was observed at 100 mg l^{-1} BA (6 mm). It was also observed that mean sprout length of apical halves was significantly different from that of the basal ones (4.3 mm vs. 1.5 mm).

Fig. 2 shows that the mean sprout length was significantly influenced by a linear interaction of BA treatment and rhizome part. The 3 soaking time periods had no effect on sprouting, but at 16 h sprout length was slightly increased.

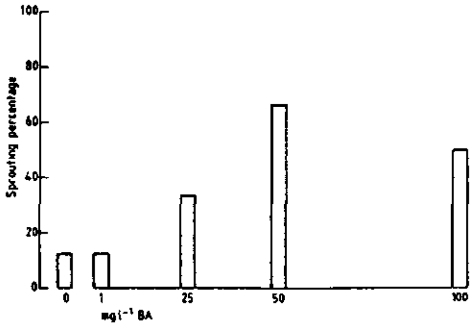

Fig. 1. Sprouting percentage of rhizomes cv English Waltz treated with 4 different concentrations of BA and kept at 25°C in the dark for 2 weeks.

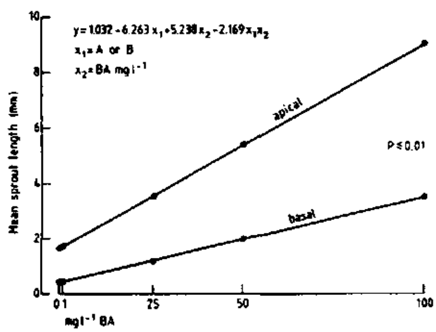

Fig. 2. Mean sprout length of apical (A) and basal (B) halves of rhizomes cv English Waltz treated with 4 different concentrations of BA and kept at 25°C in the dark.

Table 1. Effect of GA_3 on sprouting percentage of *Achimenes* rhizome halves cv Viola Michelssen, after 3 weeks at 4 temperatures in CL and CD (Phase I) followed by 3 weeks at 21°C and CD (Phase II).

Treatment		Temperature (°C)	Phase I A	Phase I B	Phase II A	Phase II B
CL	Control	13			0	0
		17			0	0
		21			20	0
		25			40	0
GA_3	50 mg l⁻¹	13	NONE	NONE	80	0
		17			60	0
		21			100	0
		25			100	0
CD	Control	13	0	0	0	0
		17	0	0	0	0
		21	20	0	30	0
		25	0	0	40	0
GA_3	50 mg l⁻¹	13	0	0	60	20
		17	0	0	60	60
		21	100	30	100	80
		25	100	0	100	80

3.2 Experiment II

Phase 1. Under CL none of the rhizome parts sprouted. Under CD, dormancy of controls (A) was broken only at 21°C, while GA_3 treated rhizomes sprouted in both 21°C (A and B) and at 25°C (A). Sprouting percentages are shown in Table 1. Fig. 3 shows that the mean sprout length of both rhizome halves under CD exhibits a quadratic response to temperature levels with maximum at 19.8°C and no sprouting below 13.2°C.

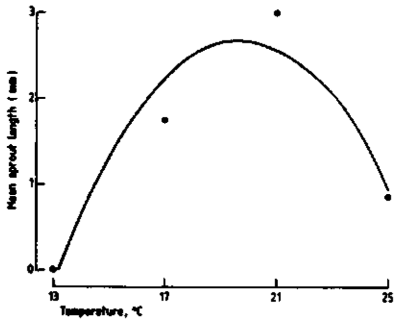

Fig. 3. Mean sprout length of both apical and basal halves of rhizomes cv Viola Michelssen treated with 50 mg l^{-1} GA_3 for 16 h and kept at 4 different temperatures in the dark for 3 weeks (Phase 1).

Phase 2. Irradiance, temperature and GA_3 treatments during phase 1, influenced the response of both rhizome halves, after 3 weeks under CD and 21°C. Table 1 (phase 1) indicates that apical halves of untreated rhizomes kept during phase 1 at 21 and 25°C in the light (CL) or in the dark (CD) sprouted for 20-40 percent. No basal halves sprouted. Apical halves ofGA_3 treated rhizomes sprouted for 60-100 percent irrespective of CL or CD pretreatment, basal halves however, sprouted only if kept in CD and for a lower percentage. Fig.4 shows that mean sprout length of rhizomes was influenced by an interaction between GA_3 treatment and temperature levels given during phase 1. Maximum mean sprout length was recorded at 21°C in GA_3 treated rhizomes.

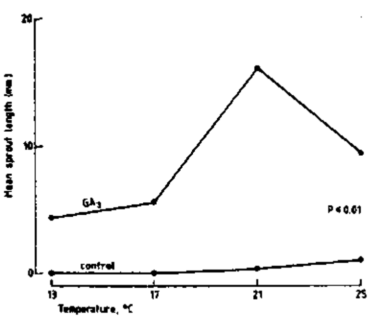

Fig. 4. Mean sprout length of rhizomes cv Viola Michelssen, after 3 weeks at 21°C in CD (Phase 2) following treatment with GA_3 at 50 mg l^{-1} for 16 h and kept at 4 different temperatures either in CL or CD for 3 weeks (Phase 1). Interaction of GA_3 and temperature treatment.

Table 2. Influence of GA_3 treatment of rhizomes 'Viola Michelssen', during Phase I, on growth and flowering of produced plants. Numbers on same horizontal row are significant at P = 0.05.

	Control	50 mg l^{-1}
Height of plants (cm)	13.0	19.0
No. of leaf whorls	6.7	9.5
Total no. of flowers	32.5	43.5
No. of axill. shoots	3.1	4.8 NS

Phase 3. Table 2 shows that plant height, number of leaf whorls and total number of flowers per plant were significantly increased in plants whose rhizomes had been treated with gibberellic acid. Fig. 5 indicates the significant linear effect of the 4 temperature levles given at phase 1, on the number of flowers produced. It was also recorded that the first lot of plants to flower, 8 weeks after planting, were those produced from basal halves treated with GA_3 at 21°C. Plants whose rhizomes had been treated with GA_3 flowered 2 to 3 weeks earlier than those not treated. When the experiment was terminated all plants were in fairly good condition with no signs of senescence. No rhizomes were formed by any of the plants.

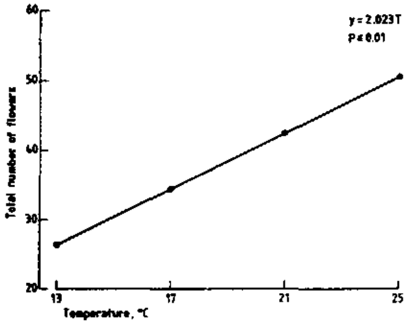

Fig. 5. Total number of flowers of *Achimenes* in 'Viola Michelssen' grown at 21°C and 16 h light for 22 weeks, in response to temerature pretreatment of rhizomes. Rhizomes were kept at 13, 17, 21 and 25°C for 3 weeks and then for another 3 weeks at 21oC in CD before planting.

4. Discussion

Benzyladenine promoted sprouting, expressed as a percentage or mean length of sprout, in both apical and basal halves of rhizomes of cv English Waltz (Fig. 6). Similar findings have been reported with gladiolus corms (Tsukamoto, 1974) and potato tubers (Tsukamoto and Yazawa, 1972). Masuda and Asashira (1978) have shown that high temperature increase endogenous cytokinins and decrease inhibitor levels resulting in breaking of dormancy of Freesia corms. It is suggested that by soaking rhizomes in BA and storing at 25°C for 2 weeks a similar activity takes

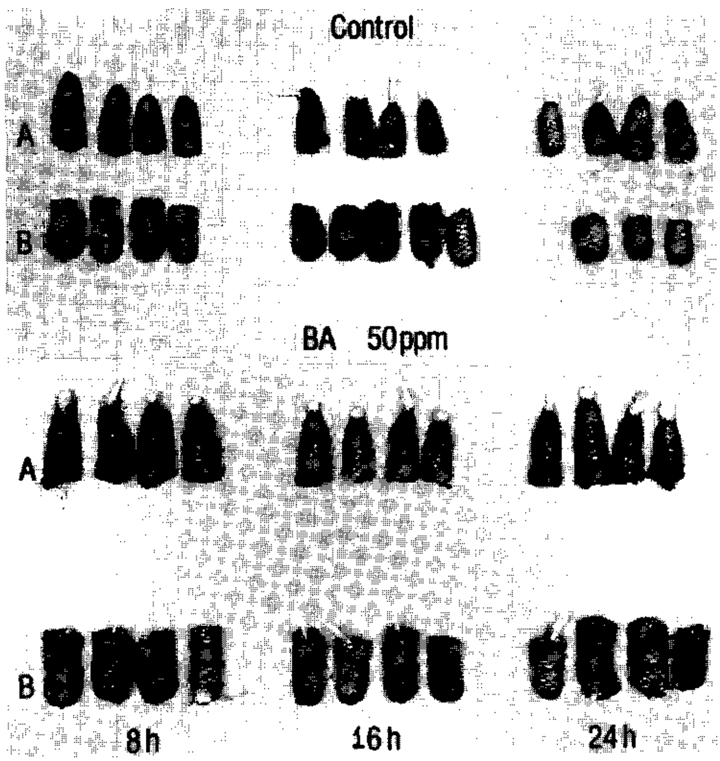

Fig. 6. Sprouting of *Achimenes* rhizomes cv English Waltz in response to treatment with BA at 50 mg l^{-1} for 8, 16b and 24 h, then kept at 25°C in the dark for 2 weeks. A = apical half, B = basal half.

place (Fig. 6). In the trial with cv Viola Michelssen, the inhibitory role of light was clearly demonstrated which indicates that rhizomes seem to have a dark requirement for breaking dormancy (Fig. 7). It is known that seeds of several species do not germinate in light (Wareing and Phillips, 1975) and that sprouting of potato buds in the dark is highly promoted as compared with growth in the light (Burton, 1966).

The importance of high temperature during storage of rhizomes has been demonstrated by Carow (1980) and Zimmer (1976). Burton (1966) has reported that increasing storage temperature increased sprout growth in the potato up to an optimum temperature above which growth was decreased. Similar results were observed in this experiment where sprout length showed a quadratic relationship to the 4 temperature treatments. The delay of sprouting at the lower temperatures was temporary as rhizomes kept at 13 and 17°C, when planted at 21°C eventually sprouted and produced plants (Fig. 8). Yamaguchi et al (1964) also reported delayed stem emergence when seed potato sprouted at lower temperatures and were then planted at higher ones.

Gibberellin treated rhizomes kept either in ligh tor dark showed a marked increase in sprout growth 6 weeks after treatment. Numerous reports show that GA_3 can overcome dormancy in buds and shorten the rest period in underground organs (Vegis, 1964), while high endogenous gibberellin levels hav ebeen found in

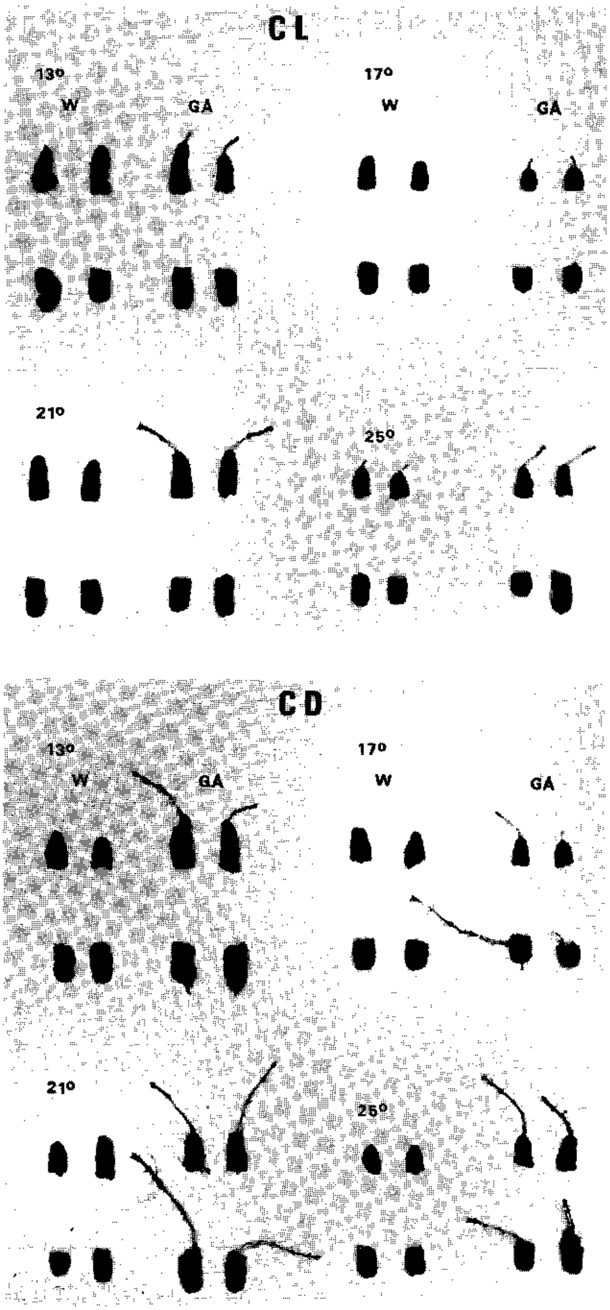

Fig. 7. Sprouting of *Achimenes* rhizomes cv Viola Michelssen treated with GA_3 at 50 mg l^{-1} for 16 h and kept either in dark (CD) or in light (CL) at 13, 17, 21 and 25°C for 3 weeks. Controls labeled W(water).

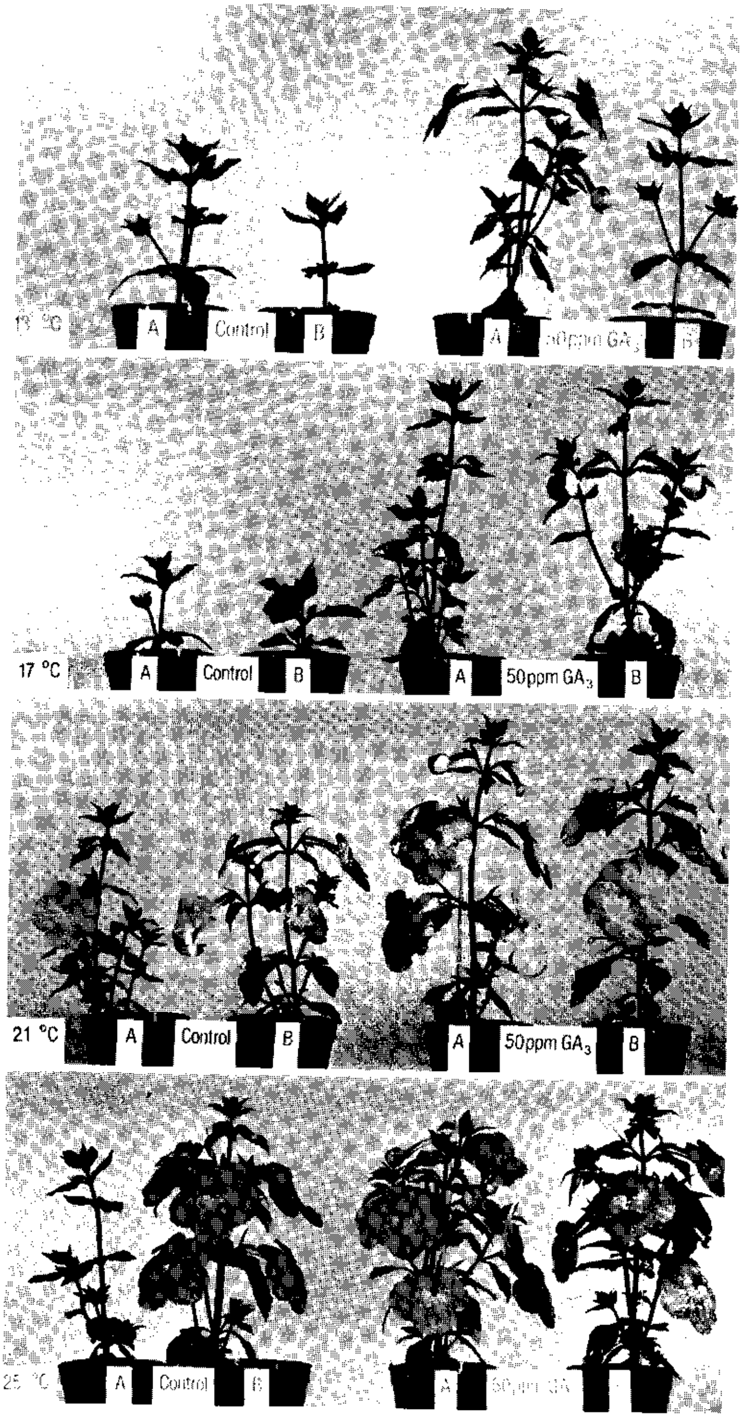

Fig. 8. Growth and flowering of *Achimenes* cv Viola Michelssen, at 21°C and 16 h light, after pretreatment of rhizomes. Rhizomes were treated with GA_3 at 50 mg l^{-1} for 16 h and then kept in the dark at 13, 17, 21 and 25°C for 3 weeks. They were then kept for another 3 weeks at 21°C in darkness, before planting. Photo taken 10 weeks after planting.

potatoes towards the end of dormant phase (Smith and Rappaport, 1961), but it has been questioned if GA_3 can actually break true dormancy or simply promotes elongation when dormancy has already largely dissapeared (Doorenbos, 1958).

The observed mean sprout length and the increased sprouting percentage of rhizomes 100% at higher temperatures compared to 0% at lower temperatures agrees with Vegis's (1964) suggestion that the effect of gibberellin maybe highly dependent on the temperature before and after treatment. Most interesting was the finding that GA_3-treated rhizomes produced plants with significant differences in growth and flowering in comparison to the controls (Fig. 8). The fact that gibberellins influence flowering in several plants by promoting earliness has been shown before (Wellensiek, 1972; Van Bragt and Van Gelder, 1979). The interaction between GA_3 and temperature and their effect on sprout growth is probably the result of an accelerated cell division and increased cell enlargement. The influence of temperature preteatment on the numbe rof flowers can be explained by assuming that the temperatures given before planting, influence the rate of sprout growth. Higher temperatures promote sprouting and subsequently affect flowering. Earlier sprouting, earlier flowering. Similar observations in iris bulbs have been reported by Le Nard (1980).

In both trials, apical halves of treated or untreated rhizomes always sprouted first. Apical dominance could explain this as younger buds in the apex usually start growing first while buds in the basal end remain dormant (Burton, 1966). The injury caused by breaking the rhizome would have increased the rate of respiration, as reported for potato tuber by Timm et al (1965), and promoted sprouting in the basal half. Hemberg and Overlid (1967) have offered evidence that a difference in sprouting between apical and basal potato halves was the result of difference in the amount of an inhibitor, depending on the stage of the dormant period. This experiment does not allow such an explanation, but it would be interesting to investigate the possibility.

Total absence of rhizomes was not expected. It could be accounted for in the GA_3treated plants, since it is a fact that GA_3 treated plants, since it is a fact that gibberellin inhibits tuberization (Menzel, 1983). It can nly be implied that conditions given during phase 2 (21°C and CD for 3 weeks) had some effect on the general metabolism of the plant parts in mobilizing assimilates to the above ground parts thus inhibiting tuberization. The influence of 21°C and 16 h photoperiod under which the plants grew has to be taken into account.

5.Conclusions

The findings reported in this paper, although preliminary, establish significant relationships among storage temperature, growth regulators and light and give some information on how these factors may influence dormancy in *Achimenes* rhizomes. Further investigations on the role of both endogenous and exogenous factors that influence release from dormancy and subsequent plant growth are necessary.

Acknowledgement

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Chapter 6

Effects of GA_3 and BA on Two Cultivars of *Achimenes longiflora* Under Two levels of Irradiance.

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Effects of BA and GA_3 on Two cultivars of *Achimenes longiflora* Under Two Levels of Irradiance

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Publication 491

Abstract

Two cultivars of *Achimenes longiflora* were placed at 21°C and 16 h light of two irradiance levels, 22 and 35 W m^{-2} for 12 weeks, after being sprayed with gibberellic acid (GA_3) and benzyladenine (BA). Number of axillary shoots, fresh weight, and number of rhizomes were higher in cultivar Flamenco than in Viola Michelssen. The higher irradiance level increased number of leaf whorls, number of flowers and number of leaf axils that developed more than one flower. Number and fresh weight of rhizomes were also increased at 35 W m^{-2}. The number of leaf whorls was increased by 100 mg l^{-1} alone and in combination with 25 mg l^{-1} BA. Neither GA_3 nor BA influenced the total number of flowers while the number of atrophic flowers was increased by high GA_3 or BA concentrations. Growth regulator treatments had no carry-over effect on the dormancy and/or sprouting of produced rhizomes.

1. Introduction

Achimenes originates from Mexico, Brazil and Jamaica (moore, 1975). Cultivated as a potted plant, it is propagated by rhizomes or stem cuttings in early spring and flowers until late fall before it becomes senescent, forming rhizomes in the soil which remain dormant until next spring (Jungbauer, 1977). Flower initiation of *Achimenes* cultivars usually occurs after the development of the 3rd or 4th leafwhorl in daylengths of 8 to 24 h and temperatures ranging from 15 to 25°C (Rohde, 1973). Leaf whorls are composed of 3 or 4 leaves and flowers are borne single or paired in the axils of the leaves (Broertjes, 1980). The lower 4 leaf whorls develop mainly axillary shoots from their axils. Research by Rohde (1974) with 2 *Achimenes* cultivars has indicated that plants are day neutral, and that best vegetative and generatuve growth is achieved at 20°C and 16 h light. Optimal ligh tintensity for *Achimenes* is not known. The factors that cause senescence of the aerial parts and formation of dormant underground rhizomes have not been investigated, but it has been suggested that short days and low temperatures stimulate ABA synthesis which could be responsible for reduction of plant growth (Rohde, 1973).
The growth regulators gibberellic acid and benzyladenine were selected for this first investigation, to be applied to 2 cultivars of *Achimenes* to study their effects on flowering and rhizome formation. It is well established that both GA_3 and BA can influence the flowering process in many ornamental plants (Sachs and Hackett, 1977; Lyons and Mayer, 1983) and that cytokinins promote while gibberellins suppress tuberization (Smith and Palmer, 1970; Deutch, 1974; Melis and Van

Staden, 1984). Two commercial cultivars, morphologically similar, were selected for this experiment in order to investigate if they would respond differently to the given experimental conditions. They were cultivars Flamenco and Viola Michelssen, both hybrids of Michelssen (Hannover), described as vigorous and well branched plants with large red flowers (Pouwer end Evers, 1983)

The aim of this work was to investigate if a difference in irradiance levels and/or application of growth regulators could influence growth, flowering and rhizome formation in two *Achimenes* cultivars.

2. Materials and methods

Achimenes plants of cultivars "Flamenco' and 'Viola M' propagated by stem cuttings originating from sprouted rhizomes were obtained from a commercial grower in September 1983. Plants were uniform in height (10 cm) and had 5 to 6 leaf whorls. 'Viola M' had already formed visible flower buds in the upper two leaf axils.

On 21 September 1983, 80 plants from each cultivar were individually potted in 10 cm plastic pots with a standard potting medium and were sprayed to run off with the following concentrations of GA_3 and BA.

1. Control (only water)		5. GA_3	100 mg l^{-1} + BA 25 mg l^{-1}
2. GA_3	1 mg l^{-1}	6. BA	25 mg l^{-1}
3. GA_3	10 mg l^{-1}	7. BA	50 mg l^{-1}
4. GA_3	100 mg l^{-1}	8. BA	100 mg l^{-1}

Two weeks later the same applications were repeated. The solutions were made on the day of application and forGA_3. Berelex 90% tablets were used. The pH of the solution was brought to 7 and Tween 20 was added as a surfactant at the rate of 0.1 ml l^{-1}. Each plant was sprayed with approximately 15 ml of solution. The treated plants were placed in a growth room at 21°C day and night temperature and 16 h light. Plant density was 60 plants/m2. Sodium (SON/T) and Mercury (HPI/T) lamps of 250 and 400 W provided illumination. The higher irradiance (hI) consisted of 35 W m^{-2} while the lower irradiance (lI) of 22 W m^{-2} at plant level. This 35% reduction of light intensity was achieved by covering the plants with a single layer of white cheese cloth. The experimental lay out was a randomized complete block design with 2 cultivars, 2 levels of irradiance and 8 treatments in 5 blocks, with a total of 160 plants. All plants received fertilization twice and were sprayed 3 times for spider mites with the insecticide Vydate L. Height of the main stem was recorded every two weeks and at the end of the 10th week (30 November, 1983) the following data were taken: Number of leaf whorls, number of leaf axils with more than one flower (MFLA for Multiple Flower Leaf Axils) and their position on the stem, number of atrophic flowers, number of open and dead flowers on both the main and the axillary shoots and number of axillary shoots developed from the ower 4 leaf whorls. In *Achimenes* only the corolla is shed while the pedicel with the lobed calyx and the pistil remain intact. It was therefore possible to estimate the total number of flowers produced during the 10 week period by counting separately the old (dead) flowers and the open ones on both main and axillary shoots. Atrophic flowers were also observed and counted similarly.

The plants were left in the growth room for another 2 weeks before they were destroyed and the rhizomes in the soil were removed, counted, weighed and then stored dry at room temperature in the dark for 10 weeks (from 15 December to 10 February, 1984). The rhizomes from each treatment were then planted (sown) in a mixture of peat and sand, covered with a layer of 1.5 - 2 cm, and were placed in the greenhouse at temperatures of 18-20°C. On April 6, (8 weeks later) they were checked for sprouting.

3. Results

3.1. Effects of cultivar

Table 1 indicates that both cultivars developed an equal number of axillary shoots from the first leaf whorl while 'Flamenco' formed more side shoots from the 2nd to the 4th leaf whorl than 'Viola M'. It should be mentioned that both in 'Flamenco' and in 'Viola M' the leaf whorls are composed of 3 leaves. Only the basal whorl usually has 2 leaves. From the leaf axils of the lower leaf whorls axillary shoots develop while flowers begin to appear mostly after the 4th leaf whorl. The present results are in agreement with observations by Rohde (1974) that the number of side shoots in each whorl is influenced by the number of shoots developed in the previous lower whorls and by the onset of flower initiation. Although the number of flowers is not different between the two cultivars, the number of old (dead) flowers on the main stem is higher in 'Viola M' because as it forms less side shoots, flower formation started earlier on the main stem. The number of open and dead flowers

Table 1. Main characteristics of two cultivars of *Achimenes* grown under two levels of irradiance at 21°C and 16 h light. All values are means of 80 plants. Numbers on the same horizontal row are different at P = 0.001. Those marked with * are not significant.

	cv. Flamenco	cv. Viola Michelssen
No. of axil. shoots on		
1st leaf whorl	1.6 *	1.6*
2nd leaf whorl	2.0	1.4
3rd leaf whorl	2.0	0.5
4th leaf whorl	0.9	0
Total no. of axil. shoots	6.6	3.7
No. of atrophic flowers on		
a. main stem	2.3	1.5
b. axil. shoots	3.2	1.2
No. of atrophic flowers	5.3	2.9
Percentage of atrophic flowers	18.6	11.2
No. of open flowers on		
a. main stem	3.5*	4.0*
b. axil. shoots	6.0	2.9
Total no. of flowers	29.7*	25.7*
No. of rhizomes	7.8	5.1
Fresh weight of rhizomes (g)	2.3	1.6

Table 2. Main effects of two irradiance levels on two cultivars of *Achimenes* grown for 12 weeks at 21°C and 16 h light. All values are means of 80 plants. Numbers on the same horizontal row are different at P = 0.001. Those marked with * are not significant.

	Level of Irradiance	
	22 W m^{-2}	35 W m^{-2}
No. of leaf whorls	12.8	13.8
No. of MFLA	1.6	6.8
No. of atrophic flowers	2.8	5.6
Percentage of atrophic flowers	14.5*	15.5*
Total no. of lfowers	19.5	35.8
No. of rhizomes	5.7	7.2
Fresh wt. of rhizomes (g)	1.3	2.5
Fresh wt. per rhizome (g)	0.2	0.4

Table 3. Main effects of foliar spray with GA_3 and BA on two *Achimenes* cultivars at 21°C and 16 h light. All values are means of 20 plants. Numbers in one column followed by the same letter are not different at P = 0.05.

Treatments	Height increase (cm)	No. of leaf whorls	No. of atrophic fls	Percentage atrophic fls	Fresh wt. of rhizome (g)
1. Control	14.5a	12.3a	1.4a	4.9a	2.2ab
2. GA_3 1 mg l^{-1}	14.4a	12.7ab	2.3	7.7ab	1.9ab
3. 10 mg l^{-1}	18.1a	13.9bc	3.6ab	11.6ab	2.0ab
100 mg l^{-1}	30.8b	14.6cd	5.3bc	19.3bc	1.6a
GA_3 100 mg l^{-1} +					
BA 25 mg l^{-1}	28.6b	14.6cd	7.1c	25.7c	1.3a
BA 25 mg l^{-1}	15.4a	12.4a	2.1ab	8.3ab	1.9ab
50 mg l^{-1}	14.6a	12.5a	4.6abc	17.5abc	1.9ab
100 mg l^{-1}	15.8a	12.9a	7.1c	27.6c	2.6b

on side shoots was greater in 'Flamenco' as it develops more side shoots. The number and percentage of atrophic flowers on both main and side shoots were higher in 'Flamenco'. Total number of flowers was not different between the two cultivars. Number and fresh weight of rhizomes were greater in 'Flamenco'.

3.2. Effects of Irradiance levels

The effects of two irradiance levels are given in Table 2. An irradiance of 35 W m^{-2} for 16 h significantly increased the number of leaf whorls and the total number of flowers as compared to 22 W m^{-2}. The number of leaf axils that formed more than one flower (MFLA) was also increased under hI. These MFLA developed usually 2 or 3 flower buds that were brought to anthesis at successive stages (Fig. 3). The number of atrophic flowers was higher in the hI regime but when expressed as a percentage of the total number of flowers there was no difference. Number and total fresh weight of rhizomes as well as fresh weight of each rhizome were significantly increased under hI. The rhizomes produced under lI were also of a smaller size than those under hI.

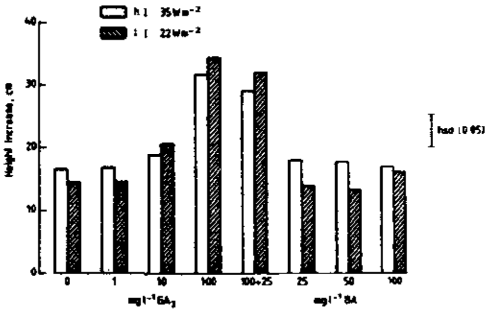

Fig. 1. Height increase (cm) of main stem in *Achimenes* cultivars. Interaction of irradiance levels and treatment with GA_3 and BA.

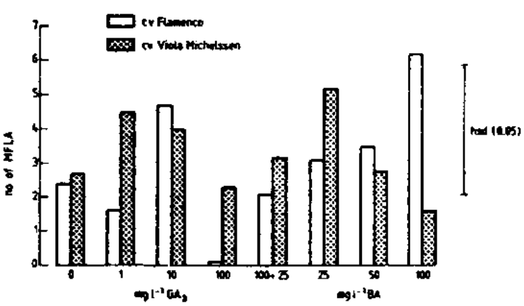

Fig. 2. Number of leaf axils with more than one flower (MFLA). Interaction of *Achimenes* cultivar and treatment with GA_3 and BA.

3.3. Effects ofGA_3 and BA treatments.

Effects of treatment with 3 different concentrations of GA_3 and BA, one combination of 100 mg l^{-1} GA_3 + 25 mg l^{-1} BA are presented in Table 3. Concentrations of 10, 100 mg l^{-1} GA_3 alone or in combination with 25 mg l^{-1} BA increased the number of leaf whorls. Height of the main stem wa ssignificantly increased by 100 mg l^{-1} GA_3 alonwe and in combination with 25 mg l^{-1} BA. The number of atrophic flowers was increased by the highest concentrations of both GA_3 and BA and the combination 100 mg l^{-1} GA_3 + 25 mg l^{-1} BA (atrophic flowers are shown in Fig. 4). The fresh weigh tof rhizomes was highest after 100 mg l^{-1} BA and lowest after 100 mg l^{-1} GA_3, but the difference with the control wa snot significant.

3.4. Interaction effects

Fig. 1 shows the interaction between GA_3 treatments and irradiance on the height increase of plants. Under hI control plants and those treated with 1 mg l^{-1} GA_3 and all concentrations of BA showed a higher increase of height, than those under lI, while those treated with 10, 100 mg l^{-1} GA_3, and 100 mg $l^{-1}$$GA_3$ + 25 mg l^{-1} BA had a higher height increase under lI than those treated under hI.

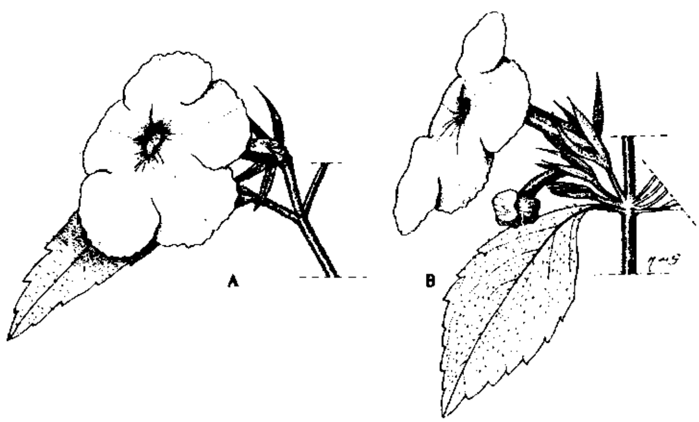

Fig. 3. A. One flower per leaf axil

B. More than one flower per leaf axil (MFLA).

Fig. 2 shows there was an interaction effect between BA treatment and cultivar on the number of leaf axils that produced more than one flower (MFLA). Increasing concentrations of BA increased the number of MFLA in 'Flamenco' from 2.4 (control) to 6.2 while GA_3 was stimulating only at 10 mg l^{-1} (4.7) and at 100 mg l^{-1} there was a sharp decrease (0.08). 'Viola M' responded differently. The lowest concentration of BA and GA3 increased MFLA while increasing concentrations decreased MFLA. Collected data also showed that 80% of the observed MFLA were located between the 5th and the 10th leaf whorl in both cultivars. There was no effect of the BA and/or GA_3 treatments on the plants on dormancy or sprouting of rhizomes (data not shown).

4. Discussion

Results from this experiment show that irradiance levels are very important for growth, flowering and rhizome development in *Achimenes* . Low irradiance (lI) might have promoted height of the main stem as reported in an other Gesneriad, gloxinia, by Sydnor et al (1972). Instead, only the number of leaf whorls was decreased in comparison to h I which indicates that internode length was increased since there was no difference in the overall height of the plants under the two irradiances. The greater number of flowers under hI can be partially attributed to the increase in leaf whorls since flowers develop in the axils of the leaves. The occurence of more flowers per leaf axil (Fig. 3) in a greater number of cases under hI can be explained by assuming that higher energy levels activated already existing dormant buds to develop into flowers. Similar results were reported by Berghoef (1979) in begonia where hI also increased the number of flowers in the nflorescences. The greater number and fresh weight of rhizomes produced under hI may also be explained by higher assimilate levels, as it has also been mentioned in studies on tuberization (Park, 1984).

Gibberellin (GA_3) did not influence the total number of flowers but increased the number of atrophic flowers (Fig.4). These results can be related to findings where GA_3caused poor quality flowers in cyclamen (Thomas et al, 1983) and retarded normal flower development in Cosmos (Molder and Owens, 1974). Increased plant height and number of leaf whorls by treating plants with GA_3 can be explained by assuming that GA_3 influences assimilate distribution, diverting movement of assimilates away from flowers to shoot apices. The decrease of fresh weight of rhizomes by gibberellin is in accordance with results reported by Okazawa (1960) and Menzel (1983) where gibberellins inhibited tuberization in potatoes.

The increased number of atrophic flowers and increased fresh weight of rhizomes caused by the highest concentration of BA can be explained by assuming that flowers and rhizomes compete for assimilates when the supply is limited. Cytokinins have been regarded as an important stimulus for rhizome development (Smith and Palmer, 1970). BA could have triggered a flow of assimilates to the active meristematic areas of the stolon tips where high endogenous cytokinin levels already exist (Melvin and Van Staden, 1984) establishing a storage "sink" attracting metabolites. This does not mean that BA alone is responsible for rhizome formation as tuberization processes involve an integrated action of several hormones in the plant. BA had no effect on growth of the aerial parts, except that many leaves showed wilting and became curly after application of BA.

Interaction effects between cultivar and treatment on the number of MFLA indicated that cultivars react very differently when treated with the same concentrations of growth substances exhibiting an optimal and suboptimal reaction. Treatment and irradiance also ineract on the expression of height increase and it is evident that GA_3 is promoting cell division and elongation more under lI than under hI. Controls and BA treated plants are slightly taller under hI.

Investigations on the effect of gibberellins and benzyladenine on *Achimenes* rhizomes showed that both substances can break dormancy and promote sprouting (Vlahos, 1985). It could therefore be expected that treatment of mother plants with

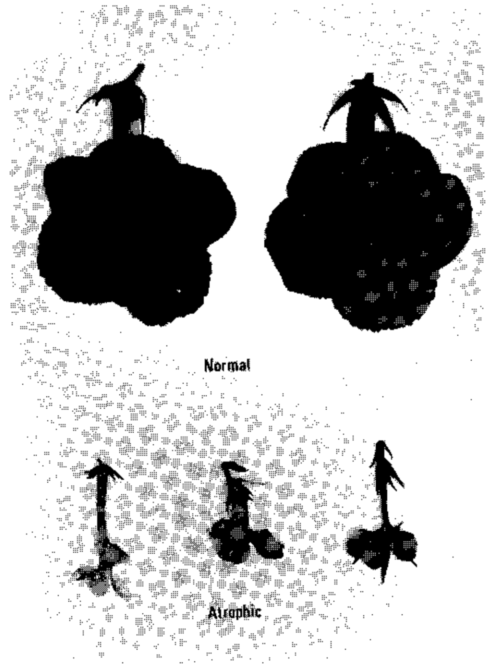

Fig. 4. Normal and atrophic flowers of *Achimenes* .

these substances should affect sprouting of the rhizomes produced as reported in a similar study with potato tubers by Tsukamoto et al (1960). However, such a carry-over effect was not found. It is possible though that storage temperature or incubation conditions were not optimal for expression of such an influence. Further studies will investigate this posibility. It was also observed that irradiance levels, under which the plants were kept, had a profound effect on sprouting and subsequent formation of secondary rhizomes (puppation). These results are not discussed here as they would be further investigated and reported in a future publication.

5. Conclusion

The present study and the results obtained indicate the complexity of interplay among various environmental factors and growth regulators involved in growth, flowering and tuberization processes in *Achimenes* . Only a few of these factors have been studied in this experiment and the need arises to extend the investigations into several other areas involving photoperiod, temperature, nutrition and a greater spectrum of growth regulators in several combinations.

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Chapter 7

Effects of GA_3 , BA and NAA on Dry Matter Partitioning and Rhizome Development in Two Cultivars of *Achimenes longiflora* DC Under Three Levels of Irradiance.

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EFFECTS OF GA_3, BA AND NAA ON DRY MATTER PARTITIONING AND RHIZOME DEVELOPMENT IN TWO CULTIVARS OF *ACHIMENES LONGIFLORA* DC, UNDER THREE LEVELS OF IRRADIANCE.

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Publication 556

Abstract

Two cultivars of *Achimenes longiflora* DC., 'Flamenco' and 'Hilda' were placed at 21°C and 16 h light of 3 irradiance levels 35, 18 and 10 W m^{-2} for 16 weeks after being sprayed with gibberellic acid (GA_3), benzyladenine (BA) or a-napthalenacetic acid (NAA), alone and in combination. Increasing irradiance levels increased dry weight of aerial parts and number and dry weight of rhizomes. GA_3 increased plant height; the elongation effect was more prominent at lower irradiances. The combination of GA_3 with BA or/and NAA increased weight of aerial parts and lowered the percentage of dry matter incorporated in the rhizomes (RWR). BA combined with NAA increased dry weight and number of rhizomes; however responses to growth regulator treatments depended on the cultivar; 'Flamenco' was more responsive than 'Hilda'.

1. Introduction

Earlier work demonstrated that rhizome development in *Achimenes* is enhanced by a higher level of irradiance. Application of 100 mg l^{-1} BA compared to 100 mg l^{-1} GA_3 increased fresh weight of rhizomes (Vlahos, 1985). The last conclusion is in agreement with Deutch (1974) who found that cytokinin promoted and gibberellin suppressed tuberization of leaf and stem cuttings in *Achimenes*.

It is well established that plant growth and development are affected by several growth substances or their combinations; endogenous auxins are known to interact with cytokinins and gibberellins in the promotion of transport of assimilates and also influence uptake of assimilates by sink tissue (Wareing, 1978). Furthermore, environmental factors and or treatments with growth regulators can induce changes in the ratio of root or tubers to shoot weights or influence sink-source relationships in several plants (Thomas, 1978; Menzel, 1980; Melis and v.Staden, 1984). It seems likely that growth substances would affect the distribution of assimilates in Achimenes. Thus a study was carried out to determine if exogenously applied growth regulators influence the formation and development of rhizomes in two cultivars under different levels of irradiance. The cultivars used, although morphologically similar, are known to differ considerably in the development of their aerial parts and rhizomes (Vlahos, unpublished). The growth regulators gibberellic acid (GA_3), benzyladenine (BA) and a-naphthalenacetic acid (NAA) were used in this investigation; the first two were also used in a previous study and NAA was preferred to IAA because the latter caused epinasty in the plants during preliminary experiments.

2. Material and methods.

2.1. Plant material.

Two commercial cultivars were used, 'Flamenco' and 'Hilda Michelssen' (referred to as 'Hilda'). Stem cuttings from sprouted rhizomes were obtained from a commercial grower in April 1984. They were placed in a greenhouse to root and become established. Plantlets with an average height of 10 cm and 5 to 6 leaf whorls were selected and potted in 10 cm plastic pots using a standard potting medium on May 8, 1984. Flower buds were already visible in the axils of the upper leaf whorls in both cultivars.

2.2. Light and growth regulator treatments.

Plants were placed in a growth room at 21°C day and night temperature and 16 h light. Illumination was provided by Philips sodium (SON/T) and mercury (HPI/T) lamps of 250 and 400 W respectively. Three light regimes were provided: the high irradiance (h I) of 35 W. m^{-2} , the reduced irradiance (r I) of 18 W m^{-2} and the low irradiance (l I) of 10 W m^{-2} . The 50% and 70% reduction in light intensity was achieved by shading the rI group with a double layer of white cheese cloth and the lI group with 4 single layers of the same material. Plants, under each irradiance level, were sprayed to run off with 7.10^{-5} M GA_3, 14.10^{-5} M NAA, 21.10^{-5} M BA and their combinations; the concentrations used were determined from earlier and preliminary experiments. Controls were sprayed with water. Two weeks later the same applications were repeated. Solutions were made on the day of application, pH was brought to 7 and Tween 20 was added as a surfactant at the rate of 0.1 ml l^{-1}. The experimental design was a split-plot with two replications, 3 irradiance levels (main plots) and 2 cultivars (sub-plots).

There were 8 growth regulator treatments randomized within each sub-plot. 2 plants per replication were the experimental unit. Plants were fertilized regularly and sprayed with Vydate-L four times during the experimental period.

2.3. Recording of data.

At the end of the 16 week period, on September 4, 1984 plant heigh tand fresh weight of the aerial plant parts were recorded. Rhizomes were harvested, counted and both their fresh and dry weight were recorded. Dry weights were determined after the plant parts had been dried at 70°C for 48 h. The weight of rhizomes was divided by the number of rhizomes to determine the weight per rhizome which was related to their size. The ratio of rhizome dry weight to the total dry weight (aerial parts and rhizomes) was estimated in order to find out if treatments influenced the amount of dry matter incorporated into rhizomes. This ratio will be referred to as rhizome weigh ratio, RWR. Data were analysed according to analysis of variance and Tukey's (1953) honestly signifiant difference (HSD) was used to evaluate differences among means of the various treatments at the 1% level of significance.

3. Results

Results indicated that cultivars responded differently to the growth regulator treatments and that there were interactions between irradiance and growth regulator treatments. All comparisons are with the control, unless stated otherwise.

3.1. Effects of cultivar

Table 1 shows those characteristics of each cultivar that were independent from either irradiance or growth regulator treatments. Fresh and dry weight of rhizomes, RWR and fresh weight per rhizome were significantly higher in 'Flamenco'. Height, fresh and dry weight of aerial parts were greater in 'Hilda'.

3.2. Effects of irradiance

Table 2 shows the main effects of irradiannce on the two cultivars, averaged over the 8 growth regulator treatments since irradiance and growth regulator treatments were independent. As irradiance levels increased, dry weight of aerial parts and rhizomes increased in both cultivars.

3.3. Interaction effects

Table 3 shows the interaction effects between cultivar and growth regulators. Dry weight of aerial parts in 'Flamenco' increased with GA_3 alone or in combination with BA and /or NAA and BA alone; in 'Hilda' only the combination BA+GA_3 increased dry weight whereas NAA or BA alone or combined decreased it. Dry weight of rhizomes was enhanced by the application of GA_3 or the combination BA+NAA in 'Flamenco' and was supressed by NAA alone in 'Hilda'. Data for fresh weights were similar to those of dry weight thus are not shown in Table 3. Percentage of dry matter incorporated into rhizomes (RWR) was not influenced by any of the treatments in 'Hilda', in 'Flamenco' however, NAA alone increased RWR whereas the combinations GA_3+NAA, BA+GA_3 and BA+NAA+GA_3 decreased it (Fig.1).

Table 1. Main characteristics of two cultivars of *Achimenes* treated with GA_3, NAA and BA and grown under three levels of irradiance at 21°C and 16 h light. Values are means of 96^{Z} plants. numbers on the same horizontal row are different at the 1% level of significance (HSD).

	cv Flamenco	cv Hilda
Height of main stem (cm)	31.2	41.0
Top fresh weight (g)	20.5	34.2
Top dry weight (g)	2.6	4.2
Rhizome dry weight (mg)	848	387
Fresh weight per rhizome (g)	0.50	0.25
Rhizome weight ratio (RWR)	26	7

^{Z} 2 replications, 3 irradiance levels, 8 chemical treatments and a 2-plant experimental unit.

Table 2. Effect of 3 levels of irradiance on dry weight of aerial parts and rhizomes in 2 cultivars of *Achimenes* grown at 21°C and 16 h ligh tfor 16 weeks. Values are means of 32 plants[x]. Numbers on the same row followed by different letters are significantly different at 1% level (HSD).

	Levels of irradiance (W m^{-2})		
Dry wt. of	l I (10)	r I (18)	h I (35)
aerial parts (g)			
'Flamenco'	1.70 a	2.50 b	3.74 c
'Hilda'	2.76 a	3.90 b	4.99 c
rhizomes (mg)			
'Flamenco'	396 a	491 b	1658 c
'Hilda'	141 a	313 b	707 c

[x] 2 replications, 8 treatments and a 2-plant experimental unit.

Table 3. The effect of GA_3, NAA and BA alone or in combination on dry weight of aerial parts and rhizomes in 2 cultivars of *Achimenes* grown at 3 irradiance levels at 21°C and 16 h light for 16 weeks. Values are means of 12 plants[y]. Numbers on the same row marked with an * are significantly different from control at the 1% level (HSD).

	Top dry wt (g)		Rhizome dry wt (mg)	
Treatment	'Flamenco'	'Hilda'	'Flamenco'	'Hilda'
control	1.65	4.54	706	487
GA_3	3.64 *	5.28	1165 *	352
NAA	1.37	2.65 *	839	218 *
GA_3+NAA	3.43 *	4.95	766	248
BA	2.72 *	3.40	764	461
BA+GA	2.98 *	5.71 *	653	431
BA+NAA	1.95	2.98	980 *	587
BA+GA_3+NAA	3.42 *	3.87	916	313
x	2.64	4.17	848	387

[y] 2 replicants, 3 irradiance levels and a 2-plant experimental unit.

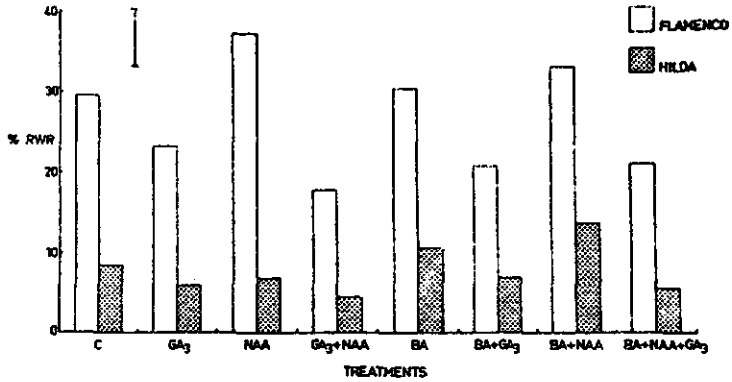

Fig. 1. The effect of GA_3, BA, NAA and their combinations on percentage of dry matter incorporated into rhizomes (RWR) on two cultivars of *Achimenes*. The vertical bars represent HSD (0.01).

Table 4. Interaction effect of growth regulators and irradiance on plant height in 2 cultivars of *Achimenes* grown at 21°C and 16 h light for 16 weeks. Values are means of 8 plants.[W] Numbers on the same column marked with an * are significantly different from control at the 1% level (HSD).

	Plant height (cm)		
	lI (10 W m^{-2})	rI (18 W m^{-2})	hI (35 W m^{-2})
control	21.0	31.0	27.0
GA_3	54.6*	45.7 *	37.9 *
NAA	22.0	24.6	31.6
GA_3+NAA	49.5 *	48.9 *	40.2 *
BA	24.1	29.6	28.7
BA+GA_3	49.4 *	44.7 *	35.0 *
BA+NAA	27.7	29.2	30.9
BA+GA_3+NAA	49.4 *	47.1 *	36.5 *
X	37.2	37.6	33.5

[W] 2 replications, 2 cultivars and a 2-plant experimental unit.

Table 4 shows the interaction effects between irradiance and growth regulators averaged over the two cultivars as they did not influence the interaction. Plant height increased, under any of the 3 irradiances, by treating plants with GA_3 alone or in combination with BA and/or NAA. Among the 3 irradiance levels, the difference in plant height was more pronounced when plants were sprayed with GA_3 alone. Number of rhizomes was influenced by a three way interaction (Table 5). Under hI, the combinations BA+NAA anf GA_3+NAA increased number of rhizomes in 'Flamenco'. In 'Hilda', GA3 alone or in combination with NAA and/or BA and NAA alone decreased it. Treatments under rI or lI had no effect on the number of rhizomes. As the average of means (x) indicates, number of rhizomes in both cultivars increased as levels of irradiance increased. The size of rhizomes, as it was related to the dry weight per rhizome, was also affected by a three way interaction. 'Hilda' had bigger rhizomes when treated with NAA alone under hI (551 mg compared to 96 mg of control) whereas under lI had the smallest rhizomes (31 mg). 'Flamenco' was not affected. These data are not shown in tables.

4. Discussion and conclusions

Results indicate that partitioning of assimilates differed in the two cultivars. Vegetative and generative growth is limited whereas rhizome development is enhanced in 'Flamenco' in comparison to 'Hilda'. Differences in the levels of endogenous hormones may be responsible for this difference. Gibberellins are known to supress and cytokinins to promote tuberization (Deutch, 1974; Esashi and Leopold, 1968). It could be that 'Flamenco' produces higher levels of endogenous hormones cytokinins or that the ratio of cytokinins to gibberellins is higher than in 'Hilda'. Increased levels of endogenous gibberellins could be responsible for increased top growth, at the expense of rhizome production in 'Hilda' as compared to 'Flamenco'. An

Table 5. Interactions of growth regulator treatments and irradiance on number of rhizomes in two cultivars of *Achimenes* grown at 21°C and 16 h light for 16 weeks. Values are means of 4 plants[z]. Numbers on the same column ,arked with an * are significantly different from the control at the 1% level (HSD)

	Number of rhizomes					
	l I (10 W m-2)		r I (18 W m-2)		h I (35 W m-2)	
control	3.2	2.5	4.0	4.7	4.5	10.0
GA_3	2.7	2.2	6.0	5.2	6.5	5.2 *
NAA	1.7	2.2	3.7	4.0	6.2	3.2 *
GA_3+NAA	3.7	2.2	3.7	3.5	8.7 *	4.2 *
BA	4.2	2.5	5.7	3.2	6.0	10.7
BA+GA_3	3.7	3.2	4.2	5.5	4.5	6.0 *
BA+NAA	3.5	3.7	3.7	4.5	8.5 *	12.3
BA+GA_3+NAA	4.7	2.2	4.2	4.0	6.2	5.7 *
X	3.4	2.6	4.4	4.4	6.4	7.2

[z] 2 replications and a 2-plant experimental unit.

investigation on the endogenous hormone levels would have answered these assumptions but such a study was not undertaken in this experiment.

It has been shown that irradiance influences number of rhizomes (Vlahos, 1985). Data from this study confirm these finding and further indicate that when level of irradiance decreases dry weight of aerial parts and rhizomes also decreases. Mortensen and Ulsaker (1985) reported similar effects of irradiance on growth of begonia. It is a fact that at higher light intensities photosynthesis is enhanced and production of assimilates increases; accumulation of assimilates in the aerial and the underground parts of the plant account for increased top growth and flowering (Thijn, 1954) and tuber development in the potato (Bodlaender, 1963).

The present results in *Achimenes* are in agreement with those findings as the higher the level of irradiance the higher the dry weight of the top and the rhizomes (Table 2). The effect of growth regulators depended on cultivar and/or irradiance. Application of solutions with GA_3 and its combinations increased dry weight of aerial parts and reduced RWR in 'Flamenco' (Table 3, Fig.1). These results are in agreement with reports that GA_3 inhibits tuberization and increases haulm weight in potato (Menzel, 1983) and that sink strength of the tuber is reduced (Mares et al, 1981). The increased rhizome dry weight in 'Flamenco' treated with GA_3 alone can be explained as an indirect effect resulting from translocation of increased assimilates from the highly developed aerial parts. However, when NAA or BA was combined with GA_3 even though it enhanced top growth, rhizome weight was not affected. This could be an indication that the aerial sink was strengthened in relation to that of rhizomes when BA or NAA was used, as auxins and cytokinins are known to attract metabolites at the site of application (Luckwill, 1981; Wareing and Patrick,1975). In 'Flamenco' the combination of BA with NAA increased dry weight of rhizomes and NAA alone increased RWR (Fig.1). Furthermore the combinations GA3+NAA and BA+NAA significantly increased number of rhizomes under the hI regime (Table 5).

One may speculate that as NAA is known to induce endogenous ethylene production (Luckwill, 1981) and given that ehtylene was reported to increase rhizome number and weight in Achimenes (Runger, 1984) it seems then probable that NAA combined with either BA or GA_3 resulted in increased rhizome formation and development. Vreugdenhil et al (1984) reported a similar effect of IAA with BA increasing radial growth and ethylene production in tubers of radish resulting in increased dry weight of tubers. Gibberellic acid relates almost exclusively to stem elongation (Leopold and Krieseman, 1975); in both cultivars height of the main stem increased significantly under any of the irradiance regimes when plants were sprayed with a solution containing GA_3. However, a high irradiance level (hI) was antagonistic to the effect of GA_3 as under either lI or rI elongation was more pronounced. Furthermore, under lI, the marked elongation effect of GA_3 alone was reduced when either NAA or/ and BA were incorporated in the mixture (Table 4).

'Hilda' was affected quite differently from 'Flamenco' by the growth regulator treatments. Application of NAA alone was not favourable as numbe rof rhizomes and dry weight of both aerial parts and rhizomes decreased (Tables 3 and 5); GA_3 alone or combined with NAA and/ or BA decreased number of rhizomes only under the h I regime (Table 5).It is clear that 'Flamenco' and 'Hilda' differ in their pattern of growth and assimilate partitioning suggesting possible differences in the levels of endogenous hormones. High light intensities are needed for satisfactory growth and development of both aerial and underground plant parts of *Achimenes*. The use if gibberellins alone or in combination with auxin and cytokinin is not recommended as plants obtain an undesirable elongation of the main stem. However, in 'Flamenco', the combination of NAA with either GA_3 or BA can increase number of rhizomes under high light intensities, which can be useful to growers of *Achimenes* rhizomes.

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Chapter 8

Effects of Ancymidol, Paclobutrazol and S-3307 on Growth and Flowering of *Achimenes* 'Viola Michelssen' Under Two Light Levels.

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Effects of Ancymidol, Paclobutrazol and S-3307 on growth and flowering of *Achimenes* 'Viola Michelssen' under two light levels.

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Abstract. Plants of *Achimenes* 'Viola Michelssen', were treated with foliar sprays of Ancymidol, Paclobutrazol and S-3307 at 3 different concentrations each, and were placed in a greenhouse at 21°C under 2 light levels (0 and 40% light exclusion) for 12 weeks. Reduced light level decreased plant height,number of axillary shoots and flowers.The 3 growth retardants in any concentration, supressed development of axillary shoots and flowers.Ancymidol at 25 and 50 mg.l^{-1}, S-3307 at 5 mg.l^{-1} and paclobutrazol at 25, 50 or 100 mg.l-1 decreased plant height and number of leaf whorls.Number of rhizomes was reduced by the 3 chemicals at the highest concentration only. Paclobutrazol was more effective than the other 2 growth retardants. Effects of treatments were more pronounced under shade rather than in full sunlight. Days to anthesis was not affected by any of the treatments except by Paclobutrazol at 100 mg.l^{-1}.

However, use of these growth retardants is not recommended for 'Viola Michelssen' because height reduction goes along with significant reduction in number of flowers .

Chemical names used: cyclopropyl - (4-methoxyphenyl) 5-pyrimidinemethanol. (ancymidol); beta-((4-chlorophenyl) methyl)---(1,1 dimethylethyl)-1 H -1,2,4 triazole-1-ethanol (PP-333) (paclobutrazol); (E)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)-1-penten-3-ol (S-3307).

Achimenes is cultivated as a potted plant both in the United States and Europe. Most commercial cultivars have erect stems and develop lateral branching from the lower leaf whorls. However, low light conditions due to shadowing caused by high planting density in the greenhouse may cause elongation of the main stem and thus reduce plant quality. Spraying with CCC or B-9 for obtaining a well branched plant has been suggested (Rohde,1973).

In the Netherlands some growers of *Achimenes* apply Alar (daminozide) as a foliar spray at the rate of 1500 mg.l^{-1} when plants are about 8-10 cm tall for a satisfactory height reduction and development of axillary shoots in order to get a more compact plant (Anonymous,1983).

The growth retardants ancymidol , paclobutrazol (PP-333), already used in a wide range of ornamental plants for controlling height (Lewis and Warrington,1988; Tija and Sheehan,1986,Barret,1982), and S-3307, also known as XE-1019 (Barret et al, 1987) a new experimental growth retarding chemical were used in this experiment. Application of these growth retardants has not been previously reported on *Achimenes*.

The objectives of the present study were to determine how these growth retardants may affect height, branching or flowering in *Achimenes*. Furthermore, a hypothesis that by reducing growth of the aerial parts formation of more and/or bigger rhizomes might be induced, is investigated. Cultivar Viola Michelssen, also used in other experiments, was selected for this study. The effects of the growth retardants treatments were studied in combination with two light levels as irradiance levels influence vegetative growth and rhizome production in *Achimenes* (Vlahos, 1985; 1989)

Achimenes plants, cv Viola Michelssen, referred to as 'Viola', propagated by stem cuttings, obtained from sprouted rhizomes originating from plants maintained at the Department of Horticulture at Wageningen were used in this experiment. Uniform rooted plantlets were selected averaging 3 to 4 cm in height with 4 leaf whorls and were potted in 10-cm (0.3-liter) plastic pots with a standard potting medium. On April 7,1985 all the plants were sprayed once with one of the following 3 growth retardants, each in 3 different concentrations :

Ancymidol at 12.5, 25 and 50 $mg.l^{-1}$, Paclobutrazol at 25, 50 and 100 $mg.l^{-1}$

S-3307 at 0.05, 0.5 and 5 $mg.l^{-1}$

Spraying was carried out with a handled compressed air sprayer and the solution was applied until runoff. There were two application treatments,once or twice. Therefore half of the plants were sprayed a second time 4 weeks later. On the first application all plants were sprayed with 5 ml of solution each; Those sprayed for a second time received 10 ml of the above solutions. Controls were also sprayed once or twice with water. In all solutions 0.1% Tween 20 was used as a surfactant. Plants were kept in a greenhouse at 21^{o}C either under full sunlight (0% light exclusion) or under a shading cloth (40% light exclusion) for 12 weeks. Solar irradiation was recorded using using a Kipp solarimeter placed along with the plants in the full sunlight treatment. Daily counts for solar radiation were calculated on a monthly basis giving the amount of photosynthetic active radiation (PAR) in mol $day^{-1}m^{-2}$. PAR was for April 14.6, for May 19.4 and for June 19.8 mol $day^{-1}m^{-2}$. The experimental layout was a split-plot design with 4 replications, two light regimes(main plots) and two application frequencies (subplots0. there were 10 growth retardant treatments (control included) randomized within each sub-plot 4 plants per replication were the experimental unit. Halfway (6th week) and at the end of the experiment (12th week) height of the main stem , number of leaf whorls, axillary shoots and flowers were recorded. At the end of the experimental period the following data were also collected: number of rhizomes, fresh and dry weight of both aerial parts and rhizomes (70^{O}C forced air oven for 48 h). The number of days to first flower was also observed. Data recorded at 6 weeks were analysed separately for those parameters. All data were subjected to analysis of variance and means were seperated by least significant difference at $P = 0.05$

The analysis of data collected on the 6th week showed that results for height,number of leaf whorls and flowers were analogous to those obtained from the analysis of the final data. Therefore only data from the 12th week are presented and comparisons refer to contol unless otherwise stated. Furthermore data on fresh weight were similar to those of dry weight, therefore only the latter are presented here.

Shading the plants (40% light exclusion) influenced several parameters of growth and development in Achimenes. Table 1 shows the main effects of the two light levels as they were not influenced by the type of chemical used, concentration or number of applications. Plants under shade were shorter and developed fewer axillary shoots and flowers; number of leaf whorls, days to anthesis and rhizomes were not affected. It is noted here that number of flowers on the 6th week were not different under the 2 light levels(data not shown)

Spraying the plants with Ancymidol, Paclobutrazol and S-3307 at 3 different concentrations each, under any of the two light levels, decreased plant height, number of axillary shoots, leaf whorls and flowering (Table 2).
Ancymidol at 25 or 50 $mg.l^{-1}$ and S-3307 at 5 $mg.l^{-1}$ reduced height and number of leaf whorls; lower concentrations were not effective.

Number of axillary shoots and flowers was reduced by all treatments except the lowest concentration (0.05 $mg.l^{-1}$) of S-3307. Paclobutrazol, in all concentrations applied, reduced plant height, number of leaf whorls, axillary shoots and flowers, the reduction increasing with increasing concentrations. Anthesis was delayed only by the two higher concentrations of Paclobutrazol. In all treatments, except the lowest (12.5 $mg.l^{-1}$) of Ancymidol, two sprays were more effective than one in reducing plant height and number of leaf whorls. (data not shown). Table 3 shows that number of rhizomes was reduced, at the higher concentrations of any of the three growth retardants. Dry weight of rhizomes had a tendency to decrease as concentrations of applied chemicals increased however only Paclobutrazol at 100 $mg.l^{-1}$significantly reduced rhizome dry weight.

Dry weight of the aerial plant parts was influenced by the interaction of chemical treatment, concentration and light level (Table 4). All plants under full sunlight (0% light exclusion) had a greater dry weight compared to those under shade (40% light exclusion). Under both light levels, Paclobutrazol at any concentration, reduced dry weight whereas application of Ancymidol and S-3307 were effective only at the highest concentrations. Number of applications of the growth retardants influenced independently number of flowers and total plant dry weight. Spraying the plants for a second time after 4 weeks with any of the three growth retardants decreased number of flowers and dry weight of plants (data not shown). No symptoms of phytotoxicity were observed in any of the treatments with the chemicals.

Results show that levels of irradiance are very important for growth and flowering in *Achimenes* . Contrary to reports for *Achimenes* and other species that low light levels increase plant height(Rohde,1973; Williams and Lewis,1983; Albrecht,1987), plants kept under shade (40% light exclusion) were shorter than those under full sunlight (Table 1). As number of leaf whorls was not affected height reduction is attributed to shorter internodes. This finding, combined with the observation that under shade development of axillary shoots and flowers is supressed, suggests that the lower energy level provided under shade inhibit both cell elongation and bud activation. Similar findings were reported by Berghoef (1979), Mortensen and Ulsaker (1985) in begonia and by Koranski et al (1987) in clerodendrum receiving less than 60% of full sunlight.

Furthermore, dry weight of aerial parts decreased at the low light level whereas number of rhizomes (Table 1) and rhizome dry weight (data not shown) were not affected. In earlier studies with 'Flamenco', 'Hilda' or 'Viola' lower light levels decreased not only number of

Table1.Effects of 2 light levels on growth and development in *Achimenes* 'Viola Michelssen' sprayed once or twice with 3 different concentrations of Ancymidol, Paclobutrazol and S-3307. Plants were kept in a greenhouse at 21°C for 12 weeks.[z]

				Number of		
Light level (% light exclusion)	Plant ht (cm)	leaf whorls	axil. shoots	flowers	rhizomes	days to flower
0	23.5	9.8	2.2	28.4	8.0	51.8
40	20.6	9.2	0.7	18.4	6.9	51.5
Significance[y]	***	NS	***	***	NS	NS

[z] Values are means of 320 plants
[y] NS,***. Nonsignificant or significant at the 0.1% level.

Table 2. Effect of 3 growth retardants applied at 3 different concentrations on growth and flowering in *Achimenes* 'Viola Michelssen'. Plants were sprayed once or twice and kept in a greenhouse at 21°C ,under 2 light levels for 12 weeks.[z]

				Number of		
Growth retardant	Concentration ($mg.l^{-1}$)	Plant ht (cm)	leaf whorls	axil. shoots	flowers	days to flower
control	0	28.0	10.1	2.2	28.0	50.5
Ancymidol	12.5	26.4	10.0	1.5	25.0	51.6
	25.0	22.4	9.5	1.7	24.5	51.4
	50.0	17.8	9.3	1.4	23.3	51.2
Paclobutrazol	25.0	20.1	9.2	1.2	22.8	51.1
	50.0	14.5	8.5	0.9	17.6	54.5
	100.0	11.3	8.0	0.7	14.9	55.5
S-3307	0.05	27.3	10.2	1.9	26.0	50.8
	0.5	26.6	10.1	1.4	24.9	48.6
	5.0	14.6	8.6	0.7	18.0	50.5
LSD(0.05)		1.7	0.4	0.5	2.7	3.4

[z] Values are means of 64 plants

Table 3. Effect of 3 growth retardants each applied at 3 different concentrations on number and dry weight of rhizomes in *Achimenes* 'Viola Michelssen'. Plants were sprayed once or twice and kept in a greenhouse at 21°C under 2 light levels for 12 weeks.[z]

Growth retardant	Concentration ($mg.l^{-1}$)	Number of rhizomes	Dry weight of rhizomes (g)
control	0	8.0	0.103
Ancymidol	12.5	9.1	0.104
	25.0	7.9	0.095
	50.0	6.6	0.088
Paclobutrazol	25.0	7.7	0.108
	50.0	7.0	0.085
	100.0	5.0	0.057
S-3307	0.05	8.4	0.105
	0.5	8.3	0.111
	5.0	6.1	0.081
LSD (0.05)		1.3	0.025

[z]Values are means of 64 plants

Table 4. Interaction effect of 2 light levels and 3 growth regulators applied each at 3 different concentrations on dry weight (g) of aerial parts in *Achimenes* 'Viola Michelssen'. Plants were sprayed once or twice and kept in a greenhouse at 21°C for 12 weeks.[z]

Growth retardant	Concentration ($mg.l^{-1}$)	Light level (% light exclusion) 0	40
control	0	3.9	2.5
Ancymidol	12.5	4.0	1.7
	25.0	3.4	1.5
	50.0	2.9	1.3
Paclobutrazol	25.0	2.9	1.3
	50.0	1.8	1.2
	100.0	1.9	0.7
S-3307	0.05	3.7	1.8
	0.5	3.5	1.7
	5.0	2.1	0.9
LSD (0.05)		0.9	

[z]Values are means of 32 plants.

flowers and shoot dry weight, as found in this investigation, but also number and dry weight of rhizomes and had no effect on number of axillary shoots (Vlahos, 1985; 1989) which is contrary to the present findings. It should be noted however, that those experiments were carried out in growth rooms where different light levels were applied. Those differences may further be explained by the fact that different cultivars were used in those studies and it has been established that the factor cultivar has a main effect on several parameters of growth and development (Vlahos,1990) .

There were significant interactions between chemical treatment and concentration for plant height and number of leaf whorls,axillary shoots and flowers (Table 2). The low concentration of Ancymidol (25 $mg.l^{-1}$) was not effective in reducing height or leaf whorls however it reduced number of axillary shoots and flowers. Increasing concentration of Ancymidol decreased the parameters studied. The highest concentration (50 $mg.l^{-1}$) reduced height by 36%. The effect of Ancymidol on number of flowers is contrary to reports that it either promotes or has no effect on flowering in other ornamental plants (Williams and Lewis, 1983; Mor et al, 1986; Tija and Sheehan,1986; Koranski et al,1987; Armitage,1988). Two sprays of Ancymidol were more effective than one in in reducing height,number of axillary shoots and leaf whorls (data not shown); the efficiency of two sprays compared to one was reported for Gerbera by Armitage et al (1984).

Number of days to anthesis is not affected by Ancymidol as reported by Albrecht (1986) for other tuberous plants. Our results agree with these findings as only paclobutrazol at 100 $mg.l^{-1}$delayed anthesis. Alar and CCC were also reported to delay flowering in *Achimenes* by a few days (Zimmer and Junker,1985). Number of rhizomes but not dry weight of rhizomes was reduced at 50 $mg.l^{-1}$(Table 3). Dry weight of aerial parts decreased under full synlight at the highest concentration whereas under shade the two higher concentrations were effective (Table 4). Other chemical retardants are also known to reduce dry weight of plants (Sanderson et al,1987; Lewis and Warrington,1988) Paclobutrazol at any of the three concentrations applied, was the most effective growth retardant among the 3 chemicals.All parameters tested (Table 2) were reduced; the reduction being greater as concentration increased.All means were different when compared among the concentration treatments.The number of rhizomes however and their dry weight were reduced only by the higher concentration (100 $mg.l^{-1}$).Its effect on dry weight of aerial parts was more prominent under shade (Table 4).

Paclobutrazol is known to retard growth in many ornamentals and to produce very compact plants decreasing dry weight (Lamont,1986; Arthur and Eaton,1987; McDaniel,1987). In our study, the higher concentrations of 50 and 100 $mg.l^{-1}$ reduced height by 48 and 60% respectively. Growth was severely stunted producing unattractive plants with very few flowers (Fig.1). S-3307, the new growth retardant tested ,was effective in the higher concentration (5 $mg.l^{-1}$) in reducing height,number of leaf whorls, flowers and rhizomes (Tables 2 and 3) whereas the lower concentrations were not effective. The dwarfing effects of S-3307 were tested on rice (Izumi et al,1984) where at 0.064 $mg.l^{-1}$ plant height was reduced by 50%. In 'Viola' a similar reduction (48%) was achieved at the higher concentration (5 $mg.l^{-1}$) All chemical treatments reduced number of flowers. As flowers develop from the leaf axils of the leaf whorls (Zimmer and Junker,1985) a decrease in height and number of leaf whorls consequently reduces flower production. Furthermore a subsequent development of axillary shoots following height reduction is not promoted by any of the chemical treatments,thus further reducing the potentiality of developing flowers.

Fig.1. The effect of 3 concentrations of paclobutrazol (applied twice) on growth of *Achimenes* cv Viola Michelssen. Plants were grown under shade (40% light exclusion) for 12 weeks.

Application of the growth retardants did not promote rhizome development. Runger (1985) reported that Ethrel increased rhizome production in *Achimenes*. Bodlaender and Agra (1966) also found that the growth retardant Alar reduced growth of aerial parts in the potato thus increasing tuber production. In *Achimenes* where tubers are related to rhizomes no such evidence was found. The assumption that growth retardation may lead to increased rhizome production was not thus verified.The present results are in agreement with earlier findings on two different *Achimenes* cultivars treated with other growth regulators under three levels of irradiance (Vlahos,1989).

It can be stated therefore that a vigorous growth of the aerial parts under sufficient light level provides the plant with greater amounts of assimilates which are needed for a sartisfactory flower production which are then transported to the underground stolons and stimulate rhizome formation and development.

It is concluded that all 3 growth retardants used in this study at higher concentrations were effective in reducing plant height and suppressed development of axillary shoots and flowers which are both desirable characteristics in a flowering pot plant like *Achimenes*. Except Paclobutrazol, the effect of the other two chemicals at lower concentrations on height and other parameters was negligible. Therefore their use in 'Viola', in concentrations and mode of application similar to those used in this study, would not be recommended because,depending on concentration, they either produce unmarketable plants or they do not have any significant effect.

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IV. GENERAL DISCUSSION

Introduction

In the series of experiments described in this thesis the effects of environmental factors and exogenously applied growth regulators on growth and development on several cultivars of *Achimenes* were studied.

Vegetative and generative growth expressed as height, leaf whorls, flowers and rhizomes were measured combined with results from a growth analysis study. Light along with temperature affected several growth and developmental processes. Growth regulators affected sprouting of rhizomes and dry matter distribution. Furthermore cultivars responded differently to the various treatments. The effects of those factors studied in each of the experiments described in this thesis, are discussed separately.

Effects of light duration, level of irradiance, and light quality.

Achimenes flowers regardless of daylength and number of flowers depends on the number of leaf whorls (Zimmer and Junker, 1985). It was established that longer photoperiods by providing additional irradiance energy promote flower development. Long days (16 h) obtained by extending natural daylength with a PAR of 48 μ mol $s^{-1} \cdot m^{-2}$increased vegetative growth (expressed as plant height and shoot fresh weight) and number of flowers (Chapter 1, Table 1). A 16 or 24 h irradiance of 213 μ mol $s^{-1} \cdot m^{-2}$, compared to 8 h, increased both shoot and rhizome weight (Chapter 2, Table 4). Higher irradiance levels increased number of leaf whorls, flowers, rhizomes and their fresh weight (Chapter 6, Table 2) and dry weight of both shoots and rhizomes (Chapter 7, Table 2). It is evident that at higher light intensities photosynthesis is enhanced. Shoots and rhizomes both profit from the higher production of assimilates . Furthermore, higher energy levels activate existing dormant buds that develop into flowers, thus more than one flower may develop from each leaf axil (Chapter 6, Table 2). Berghoef (1979) reported similar findings with the inflorescence in Begonia.

When the same daily light integral was maintained and intensity varied with daylength, it was shown that growth and flowering were favoured when lower light intensities were combined with longer photoperiods . Total dry weight of the plant, total dry weight of the leaves and total plant leaf area increased along with number of leaf whorls and flowers (Chapter 3, Table 2). These results are in agreement with those of Craker et al. (1983) and Gislerod et al (1989), who reported similar findings for several ornamental plants. A growth analysis study showed that these results were related to the increased relative growth rate which was due to increased net assimilation rate whereas leaf area ratio remained the same(Chapter 3, Fig.1; Table 4). Similar results were obtained in Chapter 4 where daylength extension by incandescent or fluorescent lamps increased net assimilation rate and lowered leaf area ratio (Chapter 4, Table 1).

From the above chapters it becomes clear that irradiance energy is important for growth and development of *Achimenes* , however it should be provided over a long photoperiod rather than a short one so that a better light use efficiency is achieved thus assuring an increase in the net assimilation rate . This increase is probably a result of the saturation type relationship between light intensity and photosynthesis. Considering that *Achimenes* is a shade plant (van Raalte, 1969) this increase can play a significant role in the growth of the plant even at a low light intensity.

In Chapter IV, the effects of light quality on plant growth were evaluated. Daylength was extended for 6 h with supplementary low irradiance (20 mol $s^{-1} m^{-2}$) provided with either incandescent or fluorescent light. Incandescent light is known to have a low R/ FR ratio which promotes stem elongation, compared to the fluorescent light (high R/FR ratio), in many plants (Vince-Prue, 1975, Smith ,1986). Incandescent light increased plant dry weight and caused stem elongation (Chapter 4, Fig. 2). Incandescent light is known to retard or inhibit lateral branching in several plants (Vince-Prue, 1977; Cathey and Campbell, 1975; Hagen and Moe, 1981; Grimstad, 1987).

In the present study only 'Rosenelfe' responded with reduced branching to the low R/FR ratio of incandescent light (Chapter 4, Fig.1) whereas 'Flamenco' and 'Hilda' did not respond possibly because they already had few axillary shoots. 'Rosenelfe' also responded to the supplementary lighting by the SL lamp (fluorescent) by increased number of flowers. The other cultivars were not significantly affected as light quality regime did not influence flower development. Similar findings were reported by Wilkins (1985) and Grimstad (1987) for *Fuchsia* and *Gloxinia* respectively.

Additional incandescent light significantly increased total leaf area in all cultivars when compared to the fluorescent light. Total dry weight and leaf dry weight were similarly increased in 'Hilda' and 'Rosenelfe'. In several species dry weight increased with incandescent irradiance supplementing fluorescent irradiance (Dijak and Ormrod, 1985; Knight and Mitchel, 1988). Results from Chapter 4 for 'Hilda' and 'Rosenelfe' agree with these findings. Axillary branching and number of flowers were not affected by light quality (lamp type), except in 'Rosenelfe' where more flowers developed under fluorescent light (Chapter 4, Fig.1). Considering that equal photosynthetic active radiation (400-700 nm) was maintained in both incandescent and fluorescent light regimes, the difference observed was due to light quality.

Light quality regimes had no significant effect on the number of rhizomes. Deutch (1974) found that far red light suppressed whereas red light promoted rhizome formation in leaf cuttings of Achimenes. Results with 'Flamenco' indicate a similar trend as dry weight of rhizomes was lower in incandescent light (higher proportion of far red) suggesting that rhizome dry weight is likely to be promoted by a high R/ FR ratio.

Effects of temperature

Vegetative and reproductive development in *Achimenes* are affected by temperature as shown in Chapters 2 and 4. Temperature is known to affect growth and flowering in many species (Gertsson, 1984, Djurhuus, 1985, Kristiansen, 1988). Increase in temperature increased plant height, number of leaf whorls and flowers, however this effect depends on the cultivar (Chapter 2, Table 1). Several species flower earlier as temperature increases (Maginess and Langhans, 1961; Rohde, 1974; Djurhuus, 1985). It was shown that also in *Achimenes* time to anthesis is shortened as temperature increased. Furthermore, the color of flowers changed to lighter shades as temperature increased. The higher the temperature the paler the corolla.

At temperatures ranging from 15 to 25°C flower initiation in *Achimenes* cultivars usually occurs after the development of the 3rd or 4th leaf whorl (Rohde, 1973). Axillary shoots develop mainly from the lower leaf axils. In the present investigation (Chapter 2) it was found that at 17°C development of axillary shoots increased from the lower leaf axils at the expense of flower initiation. Total plant leaf area, total dry weight of the leaves and total dry weight of the plant also increased at 25°C compared to 17°C, (Chapter 4, Fig.4). There was an interaction effect, however, between temperature and cultivar on the above parameters. Furthermore, the growth analysis study showed that significant interactions existed between temperature and cultivar on relative growth rate, net assimilation rate and leaf weight ratio. Relative growth rate always increased with temperature; however in 'Hilda' there was a 53% increase at 25°C compared to 17°C, whereas in 'Flamenco' and 'Rosenelfe' this increase was 3% and 12% respectively (Chapter 4, Table 2).

Dry weight of rhizomes and rhizome weight ratio (percentage of dry matter incorporated into rhizomes) were not affected by temperature in any of the three cultivars (Chapter 2, Table 2) contrary to reports that at high temperatures tuberization is inhibited (Menzel, 1980). Zimmer (1976) and Carow (1980) had already shown that higher temperatures during storage of rhizomes favour sprouting. In the present research sprouting of rhizomes was greatly affected by temperature during storage (Chapter 5). The length of sprouts showed a quadratic response to the four temperature treatments, 21°C for three weeks being the optimum (Chapter 5, Fig.3). These results may be paralleled to those of Burton (1966) who had reported that increasing storage temperature increased sprout growth in the potato up to an optimum temperature above which growth decreased. It was further shown that the temperature given to rhizomes before planting influences the rate of sprout growth and thus indirectly affects flowering. In Chapter 5, Fig 5 shows that there is a linear relationship between temperature pretreatment and number of flowers. It is evident that temperature pretreatment indirectly affects flowering since more nodes means more flowers as in Chapter 1 a correlation was found to exist between those two characteristics (r= 0.77). Thus earlier sprouting means earlier flowering. Similar observations were reported in iris bulbs by Le Nard (1980).

Effects of growth regulators on rhizomes

Cytokinins and gibberellins have been used in breaking dormancy of several bulbous and tuberous plants (Tsukamoto et al, 1960; Rappaport et al, 1965; Bruinsma and Swart, 1970). Cytokinins and especially benzyladenine were most effective in releasing potato tubers from dormancy (Tsukamoto and Yazawa, 1972) and a combination of BA and GA_3 has broken dormancy of gladiolus corms (Tsukamoto, 1974). In Chapter 5, it was shown that soaking rhizomes in benzyladenine solutions and storing at 25°C in the dark resulted in sprouting in two weeks. It is known that high temperature increase endogenous cytokinins and decrease inhibitor levels resulting in breaking of dormancy of freesia corms (Masuda and Asashira, 1978). It is suggested that the combination of high temperature and cytokinin activated a similar mechanism in *Achimenes* which resulted in the sprouting of rhizomes.

Gibberellin treated rhizomes kept either in light or dark showed a marked increase in sprout growth . GA_3 has been reported to overcome dormancy in buds in underground organs (Vegis, 1964) but it has been questioned whether GA_3 can actually break true dormancy or simply promotes sprout growth when dormancy has already disappeared (Doorenbos, 1958). In the present investigation where freshly harvested rhizomes were used, it seems rather certain that dormancy was broken as 100% sprouting was recorded after 3 weeks combined with a higher temperature (25°C). It is thus shown that the gibberellin effect depends on the temperature during treatment. Vegis (1964) made a similar observation.

Most interesting was the finding that GA_3 treated rhizomes produced plants which differed significantly in growth and flowering compared to controls (Chapter 5, Fig.8). Gibberellins influence flowering in several plants by promoting earliness (Wellensiek, 1972; Van Bragt and Van Gelder, 1979). The present results are brought about by an interaction between GA_3 and temperature which presumably accelarated cell division and increased cell enlargement.

Effect of growth regulators on plants

It is well established that plant growth and development are affected by several growth regulators or their combinations. GA_3 and BA influence the flowering process in several ornamental plants (Sachs and Hackett, 1977; Lyons and Meyer, 1983). Cytokinins promote while gibberellins supress tuberization (Smith and Palmer, 1970; Deutch, 1974; Melis and Van Staden, 1984). Endogenous auxins are known to interact with cytokinins and gibberellins influencing transport and uptake of assimilates by sink tissues (Wareing, 1978).

Spraying whole plants with GA_3 alone or in combination with BA or/ and NAA resulted in taller plants with more leaf whorls; however, number of flowers was not affected and quality of flowers was poor (Chapter 6 and 7). Similar findings have been reported for other pot plants (Molder and Owen, 1974; Thomas et al, 1983). These results can be explained by assuming that GA_3 influences assimilate distribution diverting movements of assimilates away from flowers to shoot apices hence the increased plant height and number of leaf whorls.

BA or NAA had no effect on growth of the aerial plant parts except that many leaves wilted and became curly. It is clear that spraying achimenes with any of the above mentioned growth regulators does not promote any desirable characteristics in the above ground plant parts. However, the underground parts and the distribution of dry matter into rhizomes are clearly affected. Gibberellin alone or in combination with BA or/ and NAA increased dry weight of aerial parts and reduced fresh weight of rhizomes (Chapter 6) or rhizome weigh ratio (Chapter 7). The decrease in fresh weight of rhizomes is in accordance with results reported by Okazawa (1960) and Menzel (1983) where gibberellin inhibited tuberization and increased haulm weight in potatoes. The sink strength of the rhizomes is definitely reduced. These results however depended on the cultivar. The increased dry weight of rhizomes in 'Flamenco' when treated with GA_3 alone was not expected. It can be explained however, as an indirect effect resulting from translocation of assimilates from the highly developed aerial parts (Chapter 7, Table 3)

Cytokinins have been regarded as an important stimulus for rhizome development (Smith and Palmer, 1970). When BA was used alone or in combination with NAA, dry weight of rhizomes increased and NAA alone increased rhizome weight ratio in 'Flamenco' (Chapter 7, Fig.1). Luckwill (1981) reported that NAA induced endogenous ethylene production and Runger (1984) found that ethylene increases rhizome number and weight. This may explain why NAA combined with either BA or GA_3 increases rhizome formation and development.

Achimenes growers apply the commercial growth retardants Alar (daminozide) and Cycocel (chlormequat) in order to obtain well branched plants (Rohde, 1973; Anonymous, 1983). The growth retardants ancymidol, paclobutrazol and S-3307 (a new growth retardant) have been used with success in several other ornamental plants for controlling height (Lewis and Warrington, 1988; Tija and Sheehan, 1986; Barret, 1982; Izumi et al., 1984; Barret et al, 1987). In Chapter 8, Table 2 shows that application of Ancymidol, Paclobutrazol and S-3307 suppressed height and development of axillary shoots and flowers. Ancymidol is reported to either promote or have no effect on flowering in several ornamental plants (Williams and Lewis,1983; Mor et al,1986; Koranski et al 1987; Armitage, 1988). *Achimenes* appears to belong to the plants in which it has no effect. Paclobutrazol was the most effective in reducing plant height, however, the higher concentrations produced stunted plants. Application of growth retardants did not promote rhizome development (chapter 8, Table 3) contrary to reports by Runger (1985) that Ethrel increased rhizome production Bodlaender and Agra (1966) also found that Alar reduced growth of the aerial parts in the potato and simultaneously increasing tuber production. In *Achimenes* where rhizomes take the place of tubers no such evidence was found. The assumption made that growth retardation may lead to increased rhizome production was not verified. It is thus suggested that a vigorous top growth is related to a good flower production and greater amounts of assimilates produce more rhizomes. The use of the tested growth retardants is not recommended, at least for cultivar Viola, as they do not produce any desirable effect but they produce unmarketable plants (Chapter 8, Fig.1).

Cultivar characteristics and Interactions

Results from all the experiments described in this thesis involving several cultivars under different environmental and growth regulator treatments, indicate that the factor cultivar either exhibits a main effect or interacts with the other treatments. Several of the cultivars tested, presumably due to genetic factors, developed more axillary shoots, were taller with more leaf whorls and flowers or had a lower shoot and rhizome weight than others (Chapter 1, Table 2). 'Tetraelfe', 'Blau Import' and 'Rosenelfe' characteristically bear flowers in clusters of 3 to 9 from the leaf axils instead of developing one or two flowers as in other cultivars.

In Chapter 2 (Table 5) it was shown that in 'Flamenco' shoot weight is low whereas rhizome weight and rhizome weight ratio high, compared to either 'Hilda' or 'Viola ' (Chapters 6 and 7). Partinioning of assimilates is definetely different between 'Flamenco' and the other two cultivars. Differences in the levels of endogenous hormones may be responsible for these differences as gibberellins are known to supress and cytokinins to promote tuberization (Deutch, 1974; Esashi and Leopold, 1968). Increased levels of endogenous gibberellins could be responsible for higher shoot growth at the expense of rhizome production in 'Hilda' or 'Viola' as compared to 'Flamenco' which probably produces higher levels of endogenous cytokinins. Several culivars were slow in forming rhizomes. 'Blauer Planet' and 'Viola' did not form any rhizomes during the period of the experiments (Chapter 1 and 5). 'Prima Donna' and 'Hilda' also formed very few rhizomes. This observation, coupled with the finding for 'Hilda' that rhizome weight ratio (Chapter 7) is low, suggests that their shoots and flowers are more effective as 'sink' than their rhizomes.

Cultivars differed in the calculated parameters as shown by the growth analyses described in Chapters 3 and 4. It is evident that differences in relative growth rate were caused by both net assimilation rate and leaf area ratio. (Chapter 3, Table 3). 'Linda' with a low relative growth rate had also a low net assimilation rate, LAR and specific leaf area (thicker leaves) explaining thus the low values of total dry weigh of the plant, total dry weight of leaves and total leaf area (Chapter 3, Table 1) . Thicker leaves lead to less light interception per unit leaf weight and thus to growth reduction, whereas the low net assimilation rate can be a result of unfavourable photosynthesis characteristics (low light use efficiency, or smaller leaves) Small leaves result in more internal shading than larger leaves at the same total plant leaf area which lead to lower net assimilation rate.

'Early Arnold' had the greatest relative growth rate as a result of higher net assimilation rate and leaf area ratio resulting also in high values for total plant and leaf dry weight and total plant leaf area. The high net assimilation rate being probably a result of its large thin leaves. Leaf size in 'Early Arnold' was 3 times as high as in 'Rosenelfe' and 7 times as high as in 'Linda'. In Chapter 4 where extension lighting was provided with different light quality lamps only 'Rosenelfe' responded to the fluorescent light (high R/ FR ratio) treatment and produced more flowers compared to the other cultivars. Significant interactions also existed between the three cultivars and light quality or temperature regime, on total plant leaf area, total leaf and plant dry weight as well as on total dry weight of rhizomes (Chapter 4, Fig. 2 and 4).

Furthermore, significant interactions were found on the calculated growth parameters between cultivar and temperature (but not with light) regime (Chapter 4, Table 2). At lower temperatures the differences among the cultivars in the two temperatures were more pronounced. 'Hilda' and 'Rosenelfe' due to genetic factors, respond favourably to higher temperature (25 °C) as the increase in relative growth rate is due to increased net assimilation rate. 'Hilda ' had a lower relative growth rate , compared to the other two cultivars, as a result of a low net assimilation rate; in 'Rosenelfe' the higher relative growth rate resulted from the highest leaf area ratio and intermediate net assimilation rate. Therefore, both net assimilation rate, the photosynthetic component, and leaf area ratio appeared to be important factors in determining the differences between the cultivars.

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SUMMARY

Achimenes is a herbaceous perennial of the Gesneriaceae family. Its origin is Central and South America. It has been cultivated as a pot plant since the Victorian era. Extensive hybridization has produced many attractive cultivars which have been introduced in commercial floriculture both in the United States and Europe. Commercial *Achimenes* cultivars have short erect stems bearing flowers in the axils of the leaves and form rhizomes at the tips of underground stolons. At the end of the growing period, in late summer, the plants enter a period of senescence and rhizomes undergo a period of dormancy before they sprout for a new plant production in early spring . Thus cultivation of *Achimenes* is limited to one crop per year.

The aim of the present study was to describe the effect of the environment, mainly light and temperature, on plant growth and development in order to realize optimum flower and / or rhizome production . Moreover the possibilities to manipulate plant development and release of rhizomes from dormancy by means of growth regulators are indicated.

Vegetative growth and flower development

Growth and flowering were strongly affected by treatments involving duration, intensity and quality of light (Chapters 1 through 4). Longer photoperiods increase vegetative growth in most *Achimenes* cultivars. LD (16 h) increased plant height, shoot weight and number of flowers compared to SD (8 h). Increased duration of illumination, of the same light level, increased shoot dry weight and reduced plant height (Chapter 2). When the same daily light integral was maintained, long day i.e. low light intensity favoured growth and flowering and increased relative growth rate (Chapter 3). This is due to increase in net assimilation rate but not in leaf area ratio suggesting a better light use efficiency when a low light intensity is combined with longer days. When daylength was extended with low intensity incandescent light (low R/ FR ratio) total leaf area , total dry weight of the plant and leaves increased . Fluorescent light (high R/ FR ratio) had no effect on total dry weight of the plant. Number of flowers was not influenced by light quality except in 'Rosenelfe' where number of axillary shoots was suppressed by incandescent light and flowering was promoted by fluorescent light . Furthermore, light duration and quality influenced calculated parameters of growth. Daylength extension by either incandescent or fluorescent low intensity light increased relative growth rate , net assimilation rate and lowered leaf area ratio (Chapter 4).

Vegetative and generative growth were influenced by the temperature treatments. Higher temperatures increased plant height, number of leaf whorls and flowers and reduced time to anthesis (Chapters 2 and 4). At 25 °C , total leaf area and total dry weight of the plant increased compared to 17 °C. Application of gibberellic acid (GA_3) alone or in combination with benzyladenine (BA) and / or naphthalenacetic acid (NAA) increased plant height and weight of aerial plant parts but number of flowers was not affected (Chapters 6 and 7). The growth retardants Ancymidol, Paclobutrazol and S-3307 suppressed plant height and development of axillary shoots and flowers in 'Viola'. The effects of the growth retardant treatments were more pronounced under shade rather under full sunlight. The growth regulators used in this study do not cause any desirable effects in *Achimenes* as plants become either too tall (GA_3) or stunted (retardants) with subsequent adverse effects on flowering (Chapter 8).

Rhizome formation and development

In general rhizome development seemed to be correlated to shoot growth. Daylength hardly influences number of rhizomes, however, in some cultivars number and fresh weight of rhizomes increase in SD (Chapter 1). LD or continous ligh tdid not inhibit rhizome formation and development (Chapter 2). Higher irradiance levels, increased number and dry weight of rhizomes, along with increases in dry weight of the aerial parts, indicating that rhizome development depends largely on the accumulation of metabolites provided by increased assimilation of the above ground parts. Light quality (incandescent vs. fluorescent light) affected dry weight of rhizomes depending on the cultivar. Fluorescent light increased dry weight of rhizomes in 'Flamenco' only. Number of rhizomes was not affected by light quality. Temperature had no effect on rhizome development or on rhizome weight ratio (percentage of dry matter incorporated into rhizomes) as shown in Chapters 2 and 4.

Application of GA_3 reduced rhizome weight ratio whereas the combination of BA and NAA increased dry weight of rhizomes (Chapter 7). BA also increased fresh weight of rhizomes whereas GA_3 reduced it (Chapter 3). The use of growth retardants, however, did not promote rhizome development but in some cases even reduced it. This finding confirms that rhizome development depends on good shoot growth .

Sprouting of rhizomes

Freshly harvested rhizomes are released from dormancy with either benzyladenine (BA) or giberrellic acid (GA_3). Soaking rhizomes of 'English Waltz' in a BA solution (50 $mg.l^{-1}$) and keeping them at 25 °C in the dark for two weeks resulted in the highest percentage of sprouting . Soaking rhizomes of 'Viola' in GA_3 (50 $mg.l^{-1}$) for 16 h also promoted sprouting depending on subsequent storage treatment. Continous light during storage inhibited sprouting whereas in continous darkness at 21 or 25 °C resulted in 100% sprouting in three weeks. When rhizomes were cut in half the apical halves always sprouted first and more than the basal ones. Rhizomes which had been treated with GA_3 produced taller plants with more leaf whorls, flowering earlier with more flowers. High temperature pretreatment of rhizomes increases the number of flowers produced. This is the result of the promotive effect of temperature on sprouting which subsequently affects flowering. Earlier sprouting ensures earlier flowering.

Varietal differences

Several cultivars were studied. Plant height, number of axillary shoots, flowers , earliness , number and dry weight of rhizomes are clearly cultivar characteristics usually not influenced by environmental factors. Certain cultivars are slow in forming rhizomes. During the period of the experiments 'Blauer Planet' did not form any rhizomes at all. 'Prima Donna' , 'Viola ' and 'Hilda' formed very few. In 'Hilda' the relative growth rate was lower than in in 'Flamenco ' or 'Rosenelfe'. Responses to temperature also varied among cultivars. 'Rosenelfe' and 'Hilda' were the most responsive and this was due to increased net assimilation rate at higher temperatures (Chapter 4).Leaf morphology was responsible for some of the differences observed. 'Early Arnold' had greater total leaf area and total dry weight of leaves and plant due to a high net assimilation rate which was attributed to its large thin leaves, 'Linda' on the other hand, had a low net assimilation rate because of its many and small leaves which caused more internal shading. It is concluded that differences in the mean values for net assimilation rate and leaf area ratio are responsible for the differences observed among cultivars.

Levels of endogenous hormones may be responsible for some differences among cultivars. 'Flamenco' had a low shoot weight whereas rhizome dry weight was high. It also responded to the far red light treatment by decreasing the dry weight of rhizomes. Relative growth rate and fresh weight per rhizome were greater in 'Flamenco' rather than in 'Hilda' or 'Viola'. It was shown that the number of flowers is correlated to height of the main stem and number of leaf whorls. Furthermore, 'Rosenelfe', 'Blau Import' and 'Tetraelfe' had a higher number of flowers per plant as they bear flowers in clusters of 3 to 9 from the leaf axils where the other cultivars bear only one or two. All cultivars tested flowered regardless of daylength thus confirming that *Achimenes* is a day neutral plant.

It is concluded that it is possible to control growth and flowering in *Achimenes* through temperature and light, the latter being the more crucial factor . Dormancy of rhizomes can be broken and sprouting enhanced with the use of growth substances. Thus the time interval between two growing seasons can be shortened. However, additional light, at least of the same levels and/or duration as in the present experiments, should be given during winter months. The right choice of cultivar, depending on the intended purpose of cultivation (flower or rhizome production) is also an important factor to consider. Growth regulators are not recommended for application to whole plants except for the purpose of increasing rhizome production.

SAMENVATTING

Achimenes is een kruidachtige, overblijvende plant uit de familie der Gesneriaceae, verspreid in Midden en Zuid-Amerika. Het gewas is in cultuur als potplant sinds de Victoriaanse tijd. Uitgebreide hybridisatie heeft vele aantrekkelijke cultivars opgeleverd, die in de commerciële sierteelt zijn opgenomen, zowel in de Verenigde Staten als in Europa. Commerciële *Achimenes* cultivars hebben korte rechtopgaande stengels, bloemen in de oksels van de bladeren en rizomen aan de uiteinden van ondergrondse stolonen. Aan het eind van de groeiperiode in de nazomer sterven de bovengrondse plantedelen af en gaan de rizomen een rustperiode in. In het voorjaar lopen ze uit en vormen nieuwe planten. Hierdoor is de teelt van Achimenes beperkt tot één gewas per jaar.

Het doel van dit onderzoek was het beschrijven van de invloed van milieufactoren, voornamelijk licht en temperatuur, op de groei en ontwikkeling, om een optimale bloem-en/of rizoomproduktie te realiseren. Bovendien zijn de mogelijkheden om door middel van groeiregulatoren de plantontwikkeling te beïvloeden en de rizomen uit de rustperiode op te wekken bestudeerd.

Vegetatieve groei en bloemontwikkeling

Groei en bloei bleken sterk beïvloed door duur, intensiteit en kwaliteit van het licht (Hoofdstukken I tot en met IV). Onder langere fotoperiodes nam de vegetatieve groei van de meeste Achimenes cultivars toe. Plantlengte, scheutgewicht en aantal bloemen waren groter onder LD (16 h) dan in KD (8 h). Bij een langere belichtingsduur van hetzelfde lichtniveau nam het droge-stof gewicht van de scheut toe en de plantlengte af (Hoofdstuk II). Bij dezelfde dagelijkse lichtsom bevorderde lange dag, i.e. lage lichtintensiteit, groei en bloei en deed de de relatieve groeisnelheid toenemen (Hoofdstuk III). Dit is toe te schrijven aan een toename van de netto assimilatiesnelheid, maar niet van de bladoppervlakte per eenheid drooggewicht, hetgeen wijst op een efficiënter lichtgebruik wanneer een lage lichtintensiteit wordt gecombineerd met lange dagen.

Wanneer de dag werd verlengd met gloeilampenlicht met een lage intensiteit (lage R/FR verhouding) namen de totale bladoppervlakte en het totale drooggewicht van plant en bladeren toe. TL-licht (hoge R/FR verhouding) had geen invloed op het totale drooggewicht van de plant. Het aantal bloemen werd niet beïnvloed door de lichtkwaliteit, behalve bij 'Rosenelfe', waar het aantal axillaire scheuten verminderde door gloeilampenlicht en de bloei werd bevorderd door TL-licht. Verder beïnvloedden duur en kwaliteit van het licht de berekende groeiparameters. Wanneer de dag verlengd werd door middel van gloeilampenlicht of TL-licht met een lage lichtintensiteit namen de relatieve groeisnelheid en netto assimilatiesnelheid toe nam het bladoppervlakte per eenheid drooggewicht af (Hoofdstuk IV).

Temperatuurbehandelingen beïnvloedden de vegetatieve en generatieve groei. Plantlengte en aantallen bladparen en bloemen waren groter bij hogere temperaturen, en de tijd tot bloei was korter (Hoofdstukken II en IV). Bij 25 °C waren de totale bladoppervlakte en het totale drooggewicht van de plant groter dan bij 17 °C.

De plantlengte en het gewicht van de bovengrondse delen namen toe bij toepassing van gibbereline (GA_3), alleen of in combinatie met benzyladenine (BA) en/of naftylazijnzuur (NAA), maar het aantal bloemen werd hierdoor niet beïnvloed (Hoofdstukken VI en VII). De groeiremmers Ancymidol, Paclobutrazol en S-3307 remden de plantlengte en de ontwikkeling van axillaire scheuten en bloemen van 'Viola'. De effecten van de behandelingen met groeiremmers waren duidelijker in de schaduw dan onder vol zonlicht. De onderzochte groeiregulatoren hebben geen enkel gewenst effect op *Achimenes;* planten worden `of te lang ($GA_3$) `of blijven achter in groei (groeiremmers) met de bijbehorende negatieve effecten op de bloei (Hoofdstuk VIII).

Rizoomvorming en ontwikkeling

In het algemeen leek de rizoomontwikkeling gecorreleerd met scheutgroei. Daglengte is nauwelijks van invloed op het aantal rizomen, hoewel in sommige cultivars aantal en versgewicht van rizomen toenemen onder KD (Hoofdstuk I). LD of continu licht onderdrukte de vorming enontwikkeling van rizomen niet (Hoofdstuk II). Aantal en drooggewicht van de rizomen namen toe bij hogere lichtintensiteiten, evenals het drooggewicht van de bovengrondse delen. Dit gaf aan dat rizoomontwikkeling grotendeels afhangt van de ophoping van metabolieten, veroorzaakt door een toegenomen assimilatie door de bovengrondse delen. Lichtkwaliteit (gloeilampen-vs. TL-licht)beïnvloedde het droge-stofgewicht van de rizomen afhankelijk van de cultivar. Alleen bij 'Flamenco' nam het drogestofgewicht van de rizomen toe door TL-licht. Het aantal rizomen werd niet beïnvloed door de lichtkwaliteit.

Temperatuur had geen invloed op de rizoomontwikkeling of de rizoomgewicht-ratio (percentage droge stof vastgelegd in rizomen) zoals te zien is in de hoofdstukken II en IV.

De rizoomgewicht-ratio nam af bij toepassing van GA_3, terwijl de combinatie van BA en NAA het drogestofgewicht van rizomen deed toenemen (Hoofdstuk VII). Het versgewicht van rizomen nam ook toe door de toepassing van BA, terwijl het afnam door GA_3 (Hoofdstuk III). Het gebruik van groeiremmers bevorderde de rizoomontwikkeling evenwel niet, maar vertraagde het in sommige gevallen zelfs. Dit resultaat bevestigt dat de rizoomontwikkeling afhangt van een goede scheutgroei.

Uitloop van rizomen

Vers geoogste rizomen worden uit hun rust gewekt door benzyladenine (BA) of gibberellinezuur (GA_3). Het hoogste uitlooppercentage werd gevonden wanneer rizomen van 'English Waltz' gedrenkt werden in een BA oplossing (50 $mg.l^{-1}$) en gedurende twee weken bij 25 °C in het donker bewaard. Drenken van rizomen van 'Viola' in GA_3 (50 $mg.l^{-1}$) gedurende 16 h bevorderde eveneens de uitloop, afhankelijk van de daaropvolgende bewaring. Continu licht gedurende de bewaring remde de uitloop, terwijl continu donker bij 21 of 25°C resulteerde in 100% uitloop in drie weken. Wanneer rizomen door de helft werden gesneden, liepen de apicale helften altijd eerder en meer uit dan de basale helften. Rizomen die waren behandeld met GA_3 vormden langere planten met meer bladparen, die eerder met meer bloemen bloeiden. Het aantal gevormde bloemen nam toe door voorbehandeling met hoge temperaturen. Dit is het gevolg van het stimulerende effect van de temperatuur op de uitloop die op zijn beurt bloei beïnvloedt. Vroegere uitloop verzekert eerdere bloei.

Cultivar verschillen

Verscheiden cultivars zijn bestudeerd. Plantlengte, aantal axillaire scheuten, bloemen, vroegheid, aantal en drooggewicht van rizomen zijn duidelijk cultivareigenschappen, die weinig beïnvloed worden door de omgevingsfactoren. Sommige cultivars zijn traag in het vormen van rizomen. Gedurende de duur van de experimenten vormde 'Blauer Planet' in het geheel geen rizomen. 'Prima Donna', 'Viola' en 'Hilda' vormden er erg weinig. De relatieve groeisnelheid van 'Hilda' was lager dan die van 'Flamenco' of 'Rosenelfe'. De cultivars verschilden ook in hun reacties op temperatuur. 'Rosenelfe' en 'Hilda' waren het meest gevoelig, wat werd veroorzaakt door de hogere netto assimilatiesnelheid bij hogere temperaturen (Hoofdstuk IV). De morfologie van het blad wasverantwoordelijk voor een gedeelte van de geconstateerde verschillen. 'Early Arnold' had een groter bladoppervlak en totaal drooggewicht van bladeren en plant dankzij een hogere netto assimilatiesnelheid, die was toe te schrijven aan zijn grote dunne bladeren. 'Linda' daarentegen had een lage netto assimilatiesnelheid door zijn vele en kleine bladeren die elkaar onderling meer beschaduwden. Geconcludeerd kan worden dat verschillen in de gemiddelde waarden voor de netto assimilatieΣsnelheid en de bladoppervlakte per eenheid drooggewicht verantwoordelijk zijn voor de verschillen tussen de cultivars.

Endogene hormoonniveaux kunnen verantwoordelijk zijn voor sommige verschillen tussen cultivars. 'Flamenco' had een laag scheutgewicht, terwijl het drooggewicht van de rizomen hoog was. Dit ras reageerde ook op het ver-rood licht door een lager drogestofgewicht van de rizomen. Relatieve groeisnelheid en versgewicht per rizoom waren groter in 'Flamenco' dan in 'Hilda' of 'Viola'. Aangetoond werd dat het aantal bloemen gecorreleerd is met de lengte van de stengel en het aantal bladparen. Verder hadden 'Rosenelfe', 'Blau Import' en 'Tetraelfe' een groter aantal bloemen per plant daar de bloemen in groepen van 3 tot 9 bijeenstaan in de bladoksels, waar andere cultivars er maar één of twee dragen. Alle geteste cultivars bloeiden onafhankelijk van de daglengte, hiermee bevestigend dat *Achimenes* een daglengte-neutrale plant is.

Geconcludeerd kan worden dat het mogelijk is groei en bloei in Achimenes te sturen door middel van temperatuur en licht, waarbij het laatste de meest cruciale factor is. Door het gebruik van groeiregulatoren kan de rust van rizomen verbroken worden en de uitloop bevorderd. Hierdoor kan het tijdsinterval tussen twee groeiseizoenen verkort worden. Gedurende de wintermaanden zou men echter bijbelichting van tenminste hetzelfde niveau en/of duur als in de huidige experimenten moeten geven. De juiste cultivarkeuze, afhankelijk van het beoogde doel van de teelt (bloem-of rizoomproduktie) is ook een belangrijke factor van overweging. Toediening van groeiregulatoren aan de gehele plant wordt niet aanbevolen, behalve wanneer het doel is de rizoomproduktie te vergroten.

Curriculum Vitae

Joannis C. Vlahos was born on March 15, 1947 in Athens, Greece. He attended primary and secondary school in Iraklion, Crete . In 1964 he received a scholarship as an exchange student for one year of highschool studies in the United States He attended the Agricultural University of Athens where he received a BSc degree in 1971. He continued his education as a graduate student at Cornell University in the United States and was awarded a MSc degree in 1973. Since 1976 he is teaching Plant Morphology and Physiology in the School of Agricultural Technology at the Technological Education Institute of Iraklion, Crete . In 1983 he received a grant from the State Scholarships Foundation of Greece (IKY) and was accepted by the Agricultural University of Wageningen in the Netherlands to do research leading to a PhD degree.

He is married to Eva Astrinaki and they have one son Constantine, 10 years old , and two daughters Maria, 8 and Kallia 6 who was born in the Netherlands.