Plant Height Formation in Different Cultivars of Kalanchoe

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Abstract

The control of plant height is of great importance in pot plant production. In the present work, data from greenhouse experiments and from a grower were used to evaluate plant height in several kalanchoe cultivars and to study the seasonal pattern in plant height. Plant height could be separated into a vegetative stem length, with all internodes of a similar length, and a generative stem length. The generative stem length consisted of one or two internodes, significantly longer than the vegetative internodes, and the peduncle of the top inflorescence. For 20 cultivars, varying in plant height between 10 and 32 cm, it was observed that plant height correlated with average vegetative internode length (r^2=0.86) and not with internode number (r^2=0.15). The ratio between vegetative and generative length was found to be cultivar specific and it varied between 0.4 and 3.0 for the studied cultivars. Stem elongation rate was reduced for plantings in the second half of the year and it showed a positive correlation with average temperature and average incident PAR during the short-day period. It seems likely that the light effect is mainly caused by the higher temperatures co-incident with the higher light integrals. The importance of these findings for modelling plant height in kalanchoe is discussed.

INTRODUCTION

Pot plant production in The Netherlands is strongly mechanised, but instruments for an adequate planning and quality control are still insufficient and need to be improved to face market demands. The control of plant height is particularly important since there are strict quality specifications for height. To achieve compact plants chemical growth regulators are commonly used several times during the cultivation period, which in kalanchoe can go up to ten applications (depending on the cultivar, pot size and growing season). Since these chemicals are costly and environmentally unfriendly, the need to find alternative methods to control plant height is a priority (Pearson et al., 1995). A crop growth and quality model would be a valuable tool for decision support, since this allows to generalise knowledge and to obtain quantitative information on complex systems (Challa, 1997), such as pot plant production in greenhouses. However, modelling production and product quality in pot plants is still in its infancy (Marcelis et al., 1998). Furthermore, for *Kalanchoe blossfeldiana* only very limited information is available on the effects of the growth conditions on plant height (Eveleens-Clark et al., 2004).

In a previous study a conceptual dynamic model for plant height in *Kalanchoe blossfeldiana* was developed (Eveleens-Clark et al., 2004). These authors divided plant height into its main components: vegetative length (i.e. stem length) and generative length (i.e. length of the uppermost peduncle). Furthermore, it was suggested that the vegetative length should be modelled as the number of internodes (same as number of leaf pairs) times the average internode length. In order to use this conceptual model as a basis of a year-round decision support system for controlling plant height in Kalanchoe production, it needs to be validated for different seasons and different cultivars. Therefore, information is needed about the seasonal effects on the plant height formation in different cultivars. The present work aims at being a starting point to get more insight into the complex phenomenon of plant height formation in kalanchoe. Data from two experiments and a commercial data set were used to evaluate plant height in several *Kalanchoe blossfeldiana* cultivars and to study the seasonal pattern of stem elongation rate.

MATERIALS AND METHODS

Experimental Set-up

To investigate individual internode length of two cultivars clearly differing in final plant height an experiment was conducted in one compartment (250 m^2) from a multispan Venlo-type glasshouse (Horst, The Netherlands, lat. 52 ºN) (Exp. 1). Unrooted cuttings of *Kalanchoe blossfeldiana* 'Tenorio' (Fides Goldstock Breeding, Maasland, The Netherlands) and 'Parcival' (Kwekerij Blommendale, Middelburg, The Netherlands) were planted in 10.5 cm pots filled with peat-based commercial potting compost (PG mix, EGO, Bleiswijk, The Netherlands) on the 18^{th} September 2003. During rooting the plants were placed under transparent polyethylene film at a density of 99 plants m^{-2} on ebb and flood benches (9.75m^2). Plants were initially subjected to long-day conditions (LD, i.e. vegetative phase) using assimilation lighting for 16 hours day^{-1}, including 6 hour of night-break (SON-T lamps, 40 µmol m^{-2} s^{-1} photosynthetic active radiation, PAR). For the induction of flowering, the lamps were used for 10.5 hours a day and during the remaining 13.5 hours the compartments were blacked-out completely. These short-day (SD) conditions started when the leaves of the cultivar 'Tenorio' began to overlap each other (corresponding to a leaf area index of 3 and 2 for 'Tenorio' and 'Parcival', respectively). At this moment plants from both cultivars were spaced out to 42 plants m^{-2}, and were kept under these conditions until harvest. Plants were irrigated as required with a standard nutrient solution, adjusted to the cultivation phase and no growth regulators were applied. Average daily temperature (21.0°C) and CO_2 concentration (540 ppm) were automatically recorded. Daily incident PAR was recorded at crop level (5.4 and 3.3 mol $m^{-2}d^{-1}$, respectively during LD and SD period). Final plant height, vegetative length, generative length, number of internodes and individual internode length were measured at harvest (i.e. 4 to 8 open flowers per plant: stage 11 from www.LetsGrow.com) for ten plants per cultivar.

Exp. 2 was conducted in similar conditions as described for Exp. 1, but in a different location (Heerhugowaard, The Netherlands). Unrooted cuttings from twenty kalanchoe cultivars (Pandora, Soul, Patty, Arina, Elaine, Debbie, Anatole, Bess, Amy, Mie, Red Jaqueline, Purper Jaqueline, Fame, Jane, Dicte, First star, Tenorio, Riet, Samba, Alexandra) were obtained from several breeding companies and planted on 18^{th} March 2004. These cultivars were selected for covering a wide range of plant heights but having a similar reaction time (i.e. around 65 days from start of SD until harvest). All cultivars were subjected to a LD period of 26 days. Several plant height attributes were recorded on one representative plant for each cultivar at harvest (same stage as Exp. 1).

Commercial Data Set

To have a general overview on the seasonal patterns of stem elongation and to evaluate how it relates to the growth conditions, a large data set was obtained from a Dutch grower. Dynamic measurements on plant height were conducted weekly on the cultivar 'Delia' grown in 7 cm pots. This was done for 14 planting dates distributed over the year. 'Delia' was chosen due its genetically short plant height and, therefore, absence of need for chemical growth retardants. Stem elongation rate was calculated as the slope of the linear relationship between plant height and time, during the SD period. Average daily temperature, CO_2 concentration and relative humidity as well as closure of energy and black-out screens, use of assimilation light and outside global radiation were automatically recorded. The daily incident PAR was calculated taking into account the greenhouse transmissivity and the use of assimilation lamps and screens.

RESULTS

Plant Height Formation in Different Cultivars

1. Individual Internode Length. When comparing two cultivars (Exp. 1) contrasting in terms of plant height ('Parcival': 12.0 ± 0.3 cm; 'Tenorio': 28.6 ± 0.6 cm) it was found that individual internode length was only partly influenced by its position within the main stem (Fig. 1). In general, only the two or sometimes three upper internodes, the last one being the peduncle of the top inflorescence, were much longer than the other internodes. These other internodes had a rather homogeneous length: 0.8 ± 0.1 cm in 'Parcival' (Fig. 1A) and 1.9 ± 0.1 cm in 'Tenorio' (Fig. 1B). Due to their position on the stem (lower part), their homogeneity in length and their initiation in the vegetative phase, these short internodes are grouped as vegetative internodes. In contrast, the few longer internodes located in the upper part of the main stem are entitled generative internodes.

2. Vegetative and Generative Length. In the twenty cultivars that were grown under the same conditions (Exp. 2) plant height varied between 10 cm ('Pandora') and 32 cm ('Alexandra'). The variation observed among different cultivars was explained by the variation in both vegetative and generative length as shown in Fig. 2. When excluding the most extreme cultivar 'Alexandra' these plant height components explained 57% and 61% of the variance in plant height, respectively, showing a positive linear relationship very close to the one from Fig. 2 (data not shown). Nevertheless, it was found that vegetative and generative length were not correlated (r^2 = 0.022; Fig. 3). The ratio between vegetative and generative length varied between 0.4 ('Jane') and 3.0 ('Alexandra').

When analysing the formation of the vegetative length it was found that both number of internodes and average internode length varied largely with the cultivar (Fig. 3). There were cultivars with 5 (e.g. 'Jane') and cultivars with 11 ('Bess') vegetative internodes (Fig. 4A). Since the duration of the LD period was the same for all cultivars and the initial cuttings had the same number of internodes, this shows that internode appearance rate largely differs between cultivars. Concerning the average vegetative internode length the differences between cultivars was larger, showing a minimum of 0.5 cm ('Pandora') and a maximum of 3.5 cm ('Alexandra'). The variation observed in the vegetative length was strongly related to the average length of the vegetative internodes (Fig. 4B), whereas number of vegetative internodes did not show a relationship with vegetative length (Fig. 4A). A similar result was obtained when plant height was plotted against vegetative number of internodes (r^2 = 0.15) and against average vegetative internode length (r^2 = 0.86) (data not shown). Therefore, to reduce plant height and more particularly the vegetative length the focus should be on reducing the vegetative internode length.

Seasonal Patterns for Stem Elongation

Stem elongation rate in kalanchoe was greatly influenced by the planting date (Fig. 5A). Although no clear pattern could be distinguished a maximum elongation rate was observed for crops planted in spring (e.g. May 2; 1.7 mm day^{-1}). The elongation rate of batches planted in the late summer and during autumn was much lower, dropping to values of 0.8 mm day^{-1}. The seasonal variation in the elongation rate was related to both temperature and light intensity. In Fig. 5B and 5C it is shown that a significant positive linear relationship between each of these climate factors and elongation rate exists. A variation in the average daily temperature of less than 2.5°C explained 67% of the variance in the stem elongation rate of 'Delia'. The average daily incident PAR varied enormously with the season (more than a factor four) and could explain 63% of the variation observed in the elongation rate. In addition, a significant (P < 0.001) positive relationship between temperature and light was observed (data not shown).

DISCUSSION

This work clearly shows that to model plant height specific cultivar differences have to be taken into account. For instance, the internode appearance rate, the average vegetative internode length and the ratio between vegetative and generative length are cultivar specific parameters. However, general principles that were not cultivar specific could be observed. A split could be made between internodes of a similar and shorter length (forming the vegetative stem length) and the two or three much longer internodes, of which the youngest one is the peduncle of the apical inflorescence (together forming the generative stem length). This split-up was visually observed in the 20 studied cultivars (Exp. 2), but measurements on individual internodes were only conducted for two cultivars (Fig. 1). At harvest, the first internodes are fully elongated (1 to 4 in 'Parcival'; 1 to 6 in 'Tenorio') whereas the other internodes did not reach their final size (data not shown). Despite the different stage of development, the vegetative internodes showed a rather homogeneous length at harvest stage. Hence, the vegetative internode length can be modelled individually, but based on an average elongation curve. Thus, vegetative length of the plant is the sum of the length from all individual vegetative internodes. Generative internodes appeared later and were longer, most likely due to a higher elongation rate. Therefore, similarly to the conceptual model for plant height developed by Eveleens-Clark et al. (2004), we propose to model vegetative and generative stem length separately. However, from the current research in different cultivars it becomes clear that the generative stem length is not only the length of the uppermost peduncle as previously suggested (Eveleens-Clark et al., 2004).

Another general feature, observed in the present research, is that a longer vegetative length and taller kalanchoe plants is the result of longer internodes and not of more internodes (Fig. 4). Therefore, to obtain compact plants breeders should focus on selecting cultivars with short vegetative internodes. Furthermore, since temperature has a positive effect on average vegetative internode length (Eveleens-Clark et al., 2004), shorter plants can be achieved by reducing temperature during growth.

Stem elongation rate was related to average cultivation temperature (Fig. 5B) and average daily incident PAR (Fig. 5C) during SD. For the same variation in elongation rate a much larger variation in daily incident PAR (5-20 mol m^{-2} d^{-1}) than in temperature (20.5-23°C) was necessary. This suggests that temperature has a much stronger influence on elongation rate than light intensity, which is in agreement with previous findings in other species like poinsettia and chrysanthemum (Bailey and Miller, 1991; Moe et al., 1992; Carvalho and Heuvelink, 2004). It is likely that the response to light suggested in our data is in fact mainly the result of higher temperatures that are co-incident with the higher light integrals. This assumption is supported by the significant positive relationship that was observed between temperature and light. However, our observations do not allow for a clear separation between effects of temperature and light as both factors were correlated (Fig. 5A). At present a climate room experiment, combining four temperatures with four light levels, is conducted to further elucidate the effects of temperature and light and their possible interaction on external quality parameters in kalanchoe.

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Figures

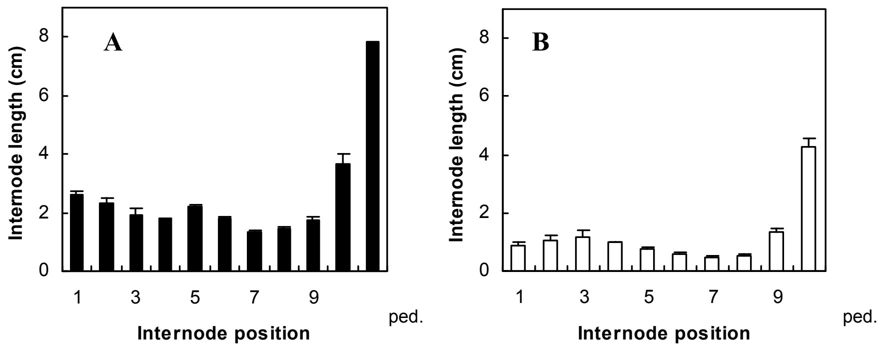

Fig. 1. Effect of internode position in the main stem (counting from the bottom of the plant and including peduncle) on individual internode length of *Kalanchoe blossfeldiana* ‘Parcical’ (A) and ‘Tenorio’ (B) at harvest of Exp. 1. Vertical bars indicate individual internode length and s.e.m. of plants with the same number of internodes: n = 5 (A) and n = 4 (B), selected from a sample of 10 plants.

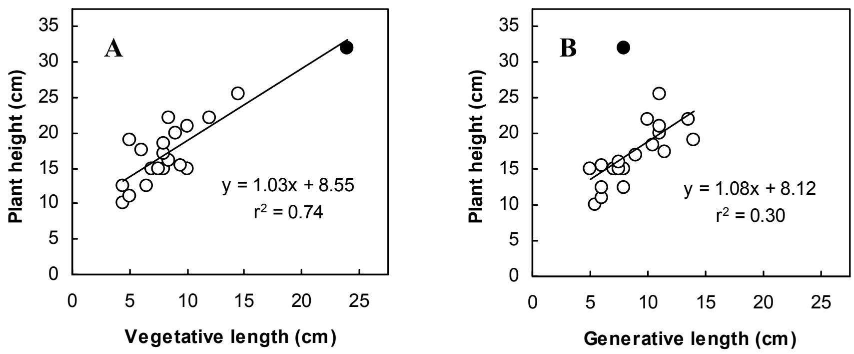

Fig. 2. Relationship between plant height and vegetative length (A) and plant height and generative length (B). Data of twenty *Kalanchoe blossfeldiana* cultivars at harvest (Exp. 2). Closed circle represents cultivar Alexandra.

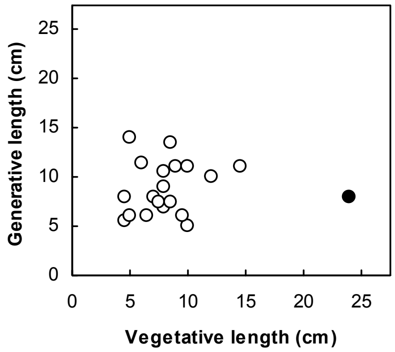

Fig. 3. Relationship between generative length and vegetative length. Data of twenty *Kalanchoe blossfeldiana* cultivars at harvest (Exp. 2). Closed circle represents cultivar Alexandra.

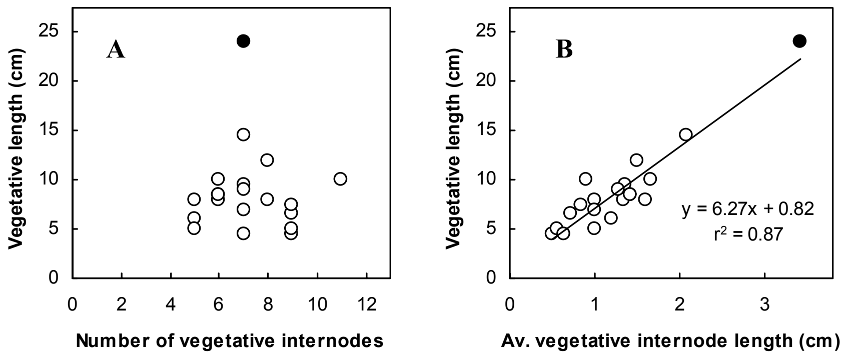

Fig. 4. Relationship between vegetative length and number of vegetative internodes (A) and vegetative length and average length of the vegetative internodes (B). Data of twenty *Kalanchoe blossfeldiana* cultivars at harvest (Exp. 2). Closed circle represents cultivar Alexandra.

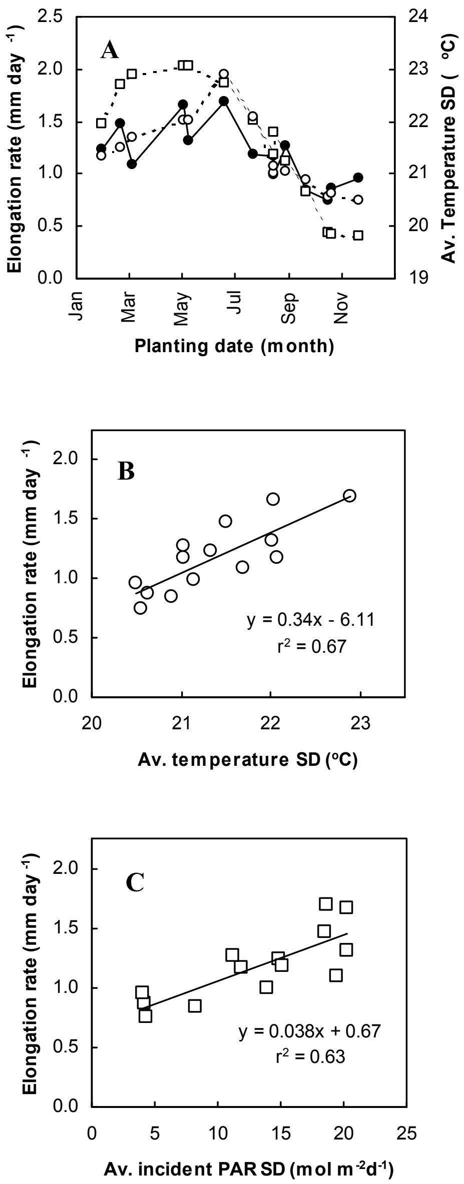

Fig. 5. (A) Seasonal patterns of stem elongation rate during SD (•), average daily temperature (○) and average daily incident PAR (□, mol $m^{-2}day^{-1}$). Values for daily incident PAR can be read from the left y-axis when multiplied by 10. Stem elongation rate as a function of average daily temperature (B) and of average daily incident PAR (C) on *Kalanchoe blossfeldiana* 'Delia'. Abbreviations: PAR = photosynthetic active radiation; SD = short-day.