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# Growth and Flowering of *Antirrhinum majus* L. under Varying Temperatures

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## ABSTRACT

Plants of an early flowering cultivar 'Chimes White' of *Antirrhinum* were subjected to three temperature regimes (0, 10 and 20°C) at 6-leaf pair stage to observe their effects on the flowering time and plant quality. Plants at higher temperature (20°C) flowered earlier (86 days) than the lower ones i.e. 109 days (10°C) and 145 days (0°C). However, maximum flower numbers (33) were counted in plants at 10°C followed by 20°C (29). Plants at 0°C produced only seven flower buds. The quality of plants was improved at 10°C temperature; whereas, it was poor at 0°C.

**Key Words:** *Antirrhinum majus*; Flowering; Temperature

## INTRODUCTION

Temperature has a direct influence on the rate of many chemical reactions, including respiration that is the process responsible for growth and development of plants and photosynthesis. For most species, biological activity stops below 0°C and above 50°C, and proteins are irreversibly destroyed and plants die as a result. The different temperature requirements of a cultivar, not only determine the climate in which they are best produced, but also the season most suited to the crop.

Although controlling the temperature of a greenhouse by heaters and coolers is one of the major costs for commercial ornamental producers, is crucial for producing quality crops. Optimum temperature for horticultural crops refers to best productivity or quality plants and not necessarily the largest or fastest growing plants. By understanding the relationship between plant growth rate and temperature, a grower can often increase or slow crop growth, in order for the crop to be ready at the desired time.

Temperature has been shown to have different effects on the flowering and bedding time of genotypically different inbred lines of *Antirrhinum*. For most cultivars, a temperature of 25°C almost halved the flowering time compared to a 12°C temperature (Edwards & Goldenberg, 1976). However, different plant sizes or plant stages were also shown to have different optimum temperatures. Miller (1962) showed that as the size of snapdragons increased, the optimum temperature for dry weight accumulation decreased. A possible explanation is that as the size of plant increased, the ratio of tissue capable of carrying photosynthesis to tissue capable of respiring decreased. Thus, lower optimum temperatures in higher plants decreased respiration and the already limiting food supply was conserved. In the small plants, with a relatively large leaf surface in relation to the size of the plant, higher optimum temperatures were required, as photosynthesis was the dominant process (Miller, 1962).

Flowering time in *Antirrhinum* was shown to be controlled by adjusting night temperatures in relation to light intensity during the day. Earlier flowering resulted, after adjusting night temperatures upward during the growing period after bright winter days. This was explained in terms of efficiently using the excessive carbohydrates of a bright day, by causing higher respiration rates during the night, with the higher night temperatures. Reducing night temperatures after dark throughout the growing season did not give in increased size or apparently higher quality (Miller, 1962).

Snapdragons are known to be 'cool season' or 'low temperature' crops (Miller, 1962). However, lowering temperature from 25 to 5°C increased the flowering time in snapdragons (Maginnes & Langhans, 1961; Miller, 1962; Sanderson & Link, 1966; Edwards & Goldenberg, 1976). Plants at 21°C required 84 days for initiation and 109 days for the anthesis, whereas plants at 4.5°C required 124 days for initiation and 148 days for the anthesis (Maginnes & Langhans, 1961). Though fresh weight, number of flowers, number of leaves, stem and inflorescence length increased as the temperature was lowered from 25 to 10°C (Maginnes & Langhans, 1961; Sanderson & Link, 1966).

Similar results were obtained for other ornamental species. A temperature of 29°C caused seedlings of *Platycodon grandiflorus* to flower much earlier than lower temperatures, but lower temperatures produced higher plants with greater branch number, fresh and dry weight and leaf area (Park *et al.*, 1998). In chrysanthemum, rate of progress to flowering increased linearly with temperature to an optimum of 21°C and after that began to decline linearly with temperature (Pearson *et al.*, 1993).

The time at which a particular temperature is applied to snapdragons was shown to be critical for the flower

development. Transferring plants of snapdragons to 4.5°C during flower development, caused flower bud development to be completely arrested, producing 'skips' within the inflorescence (Langhans & Maginnes, 1962). Applying the correct temperature at the correct plant stage may help to produce the desired plant quality at the desired time. This experiment was designed to investigate the effect of three different temperatures (0, 10 & 20°C) on the flowering and plant development of *Antirrhinum*, applied late at 6-leaf pair stage.

## MATERIALS AND METHODS

The objective of the experiment was to determine the effect of temperature on the developmental parameters of *Antirrhinum majus* L. cultivar Chimes White. Seeds were obtained from Colegrave Seeds Ltd., Banbury, U.K., and were sown on 2nd February 2000 into module trays (P135, volume of each cell, 20 mL; Plantpak Ltd., Maldon, U.K.) containing a peat-based modular compost (SHL, William Sinclair Horticulture Ltd., Lincoln, U.K.). Seed trays were watered and held for germination at 20 ± 1°C in a growth room providing a photosynthetic photon flux density of 72 µmol $m^{-2}$ $s^{-1}$ at approx. one meter above tray height from a mixture of white fluorescent and tungsten bulbs (6.3% tungsten by nominal wattage), with a 16 h $day^{-1}$ photoperiod.

After 70% seed germination, plants were transplanted into 9cm pots (volume 370 mL) containing a mixture of peat-based compost (SHL) and perlite (3:1 v/v) and kept in a glasshouse at 20±1°C temperature until 6-leaf pair stage. Six plants were transferred to three different glasshouse compartments (7.3m x 11.3m) where they were subjected to 0, 10 and 20°C constant temperature until flowering. These set point temperatures were maintained with ventilation and a water pipe heating system above 3°C. Temperatures were recorded inside the glasshouse compartments using a sensor situated in an aspirated screen attached to a data-logger. In these temperature-controlled compartments, PT100 4 wire platinum resistance sensors were connected to a data-logger (Datataker 500, Data Electronics, Letchworth Garden City, U.K.). The data-logger recorded the temperature every 15s and stored the hourly averages. Tube solarimeters were used to measure the average light transmission into the glasshouse and approximately 7.19 MJ $m^{-2}d^{-1}$ light integral from emergence to flowering were received by the plants during this experiment.

Plants were irrigated by hand to avoid *Pythium* attack and nutrient solution (Sangral 111, William Sinclair Horticulture Ltd, Lincoln, U.K.) was applied twice a week with the irrigation at conductivity of 1500 µS $cm^2$ (182 ppm N; 78 ppm P; 150 ppm K), and 5.8 pH. Plants in each treatment were daily observed until first flower opening (corolla fully opened). Flowering and vegetative parameters were recorded at harvest. Data were analysed by using the analysis of variance technique of GENSTAT-5, Release 4.1 (Lawes Agricultural Trust, Rothamsted Experimental Station, U.K.).

## RESULTS

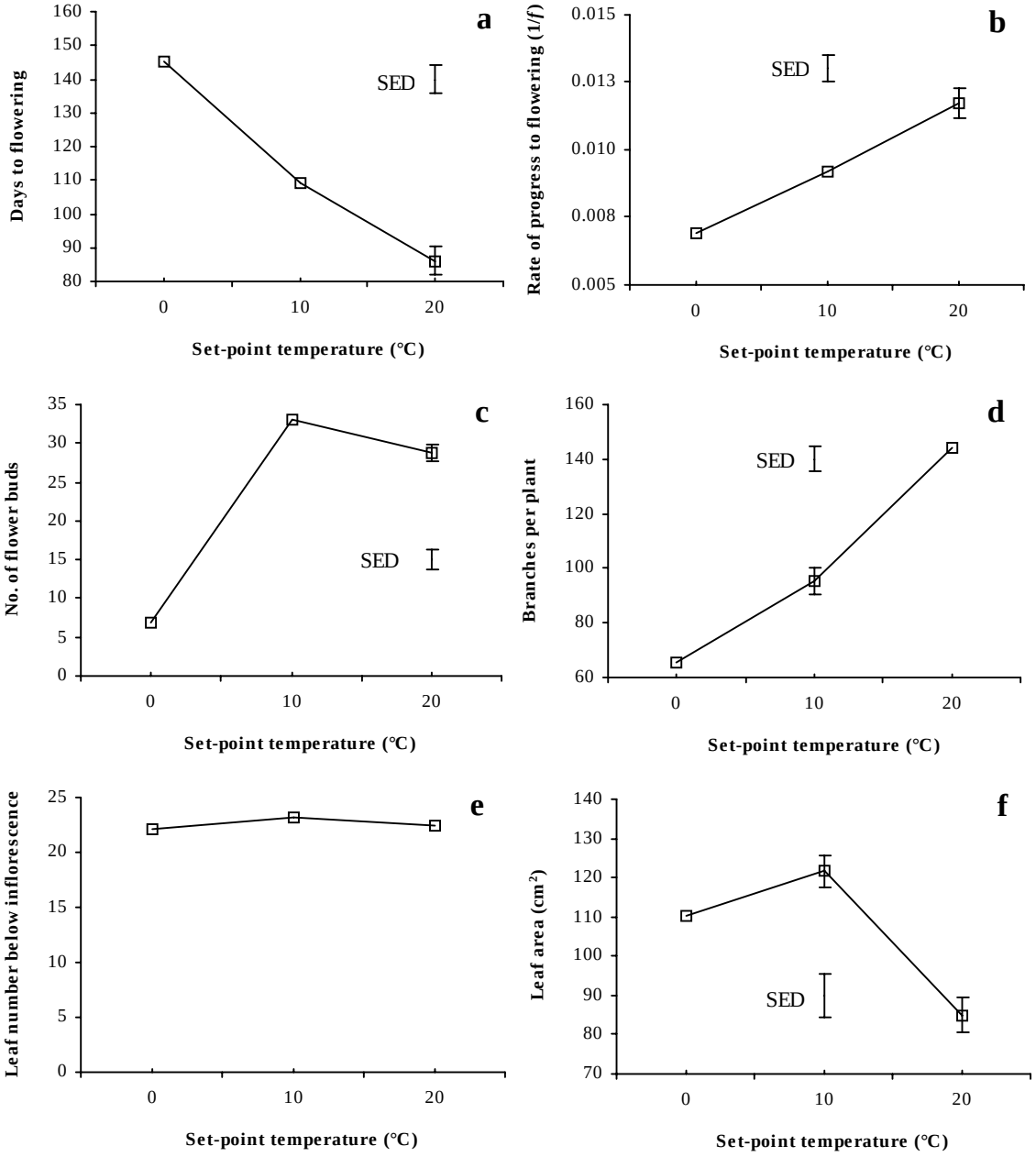
### Directly Measured Parameters

**Flowering parameters.** A statistically significant difference ($P<0.05$) was observed in flowering time among three extreme temperature regimes. Fig. 1a showed that time to flowering decreased linearly when temperature increased. Earlier flower anthesis (86 days) was recorded in plants at 20°C followed by 109 days at 10°C temperature. Plants at lowest temperature (0°C) took maximum time to flower (145 days). Similarly, the rate of progress to flowering was the inverse function to temperature i.e. when temperature increased rate of progress to flowering also increased (Fig. 1b). However, a curvilinear response was noted in number of flower buds parameter along with a significant difference within the treatments ($P<0.05$). Fig. 1c revealed that minimum flower buds (7) were produced by the plants subjected to a lowest temperature (0°C), while maximum flower buds (33) were counted at 10°C temperature. However, the number of flower buds was declined (29) at subsequent treatment (20°C).

**Plant quality parameters.** Plants received highest temperature (20°C) produced maximum branches (144) per plant. Branch numbers decreased significantly ($P<0.05$) by decreasing the temperature i.e. 96 and 65 at 10 and 0°C temperatures respectively (Fig. 1d). However, temperature did not significantly affect leaf number per plant below the inflorescence (Fig. 1e). Approximately 22-23 leaves were counted in each treatment. Plants at higher temperature produced minimum leaf area (84.91 $cm^2$) which was significantly ($P<0.05$) different than those at 10 and 0°C (121.55 and 110.30 $cm^2$). Both lowest temperatures were statistically at par (Fig. 1f). Plant height was significantly ($P<0.05$) increased as the temperature increased (Fig. 2a), however it was non-significant between 10 (21 cm) and 20°C (22 cm). Plants were stunted at 0°C temperature (12 cm). A curvilinear response was observed in plant fresh weight (Fig. 2b) and plant dry weight (Fig. 2c) parameters. Plants at 0°C produced minimum fresh and dry weights whereas at 10°C both parameters were recorded at highest. However, plant fresh and dry weights were declined at 20°C but still significantly ($P<0.05$) higher that 0°C.

**Derived parameters.** A significant difference ($P<0.05$) in leaf area ratio was seen in plants at 10°C temperature. However, this difference was non-significant between 0 and 20°C temperatures (Fig. 2d). Plants at 10°C have maximum leaf area ratio whilst plants at either 0 or 20°C have minimum leaf area ratio. Similarly, relative growth rate (Fig. 2e) was also maximum in plants at 10°C whereas at 0°C the same derived parameter was minimum. Relative growth rate was slightly decreased at highest temperature (20°C) as compared to 10°C but significantly ($P<0.05$) higher than lowest temperature. Net assimilation rate (Fig.

**Fig. 1. Effect of different temperatures on (a) days to flowering, (b) rate of progress to flowering, (c) No. of flower buds, (d) No. of branches per plant, (e) leaf numbers, and (f) leaf area ($cm^2$). Vertical bars (where larger than the points at lines) represent the standard error (s.e.) of variability, whereas the separate ones represent the standard error of difference (SED) in means**

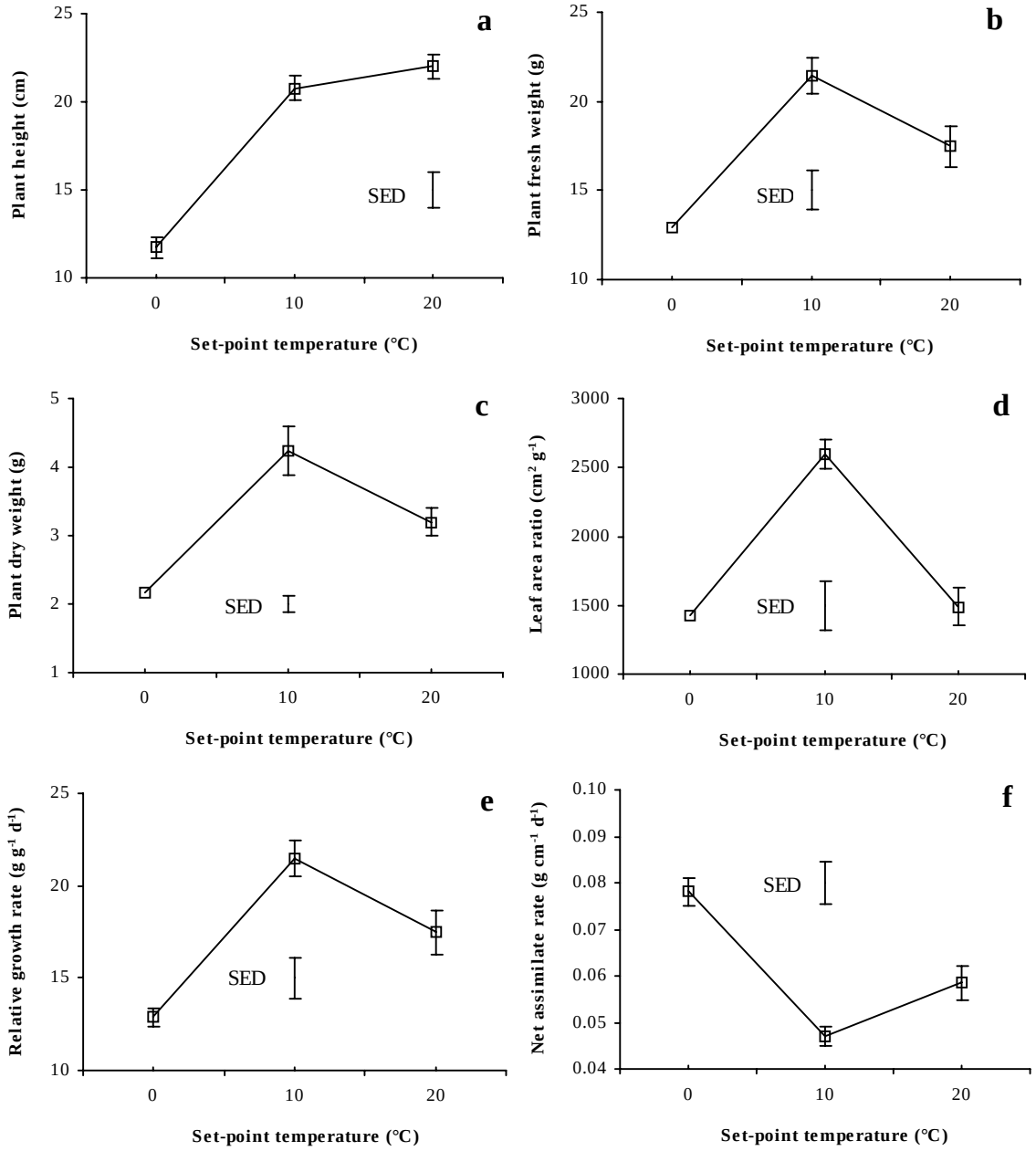



2f) was derived as significantly ($P<0.05$) highest at lowest temperature (0°C) whereas it was minimum at 10°C. A statistically non-significant difference was estimated between 10 and 20°C temperature.

## DISCUSSION

Plants under lowest temperature (0°C) produced minimum number of branches, leaf area, and total leaf

**Fig. 2. Effect of different temperatures on (a) plant height (cm), (b) plant fresh weight (g), (c) plant dry weight (g), (d) leaf area ratio ($cm^2\ g^{-1}$), (e) relative growth rate ($g\ g^{-1}\ d^{-1}$), and (f) net assimilate rate ($g\ cm^{-1}\ d^{-1}$). Vertical bars (where larger than the points at lines) represent the standard error (s.e.) of variability, whereas the separate ones represent the standard error of difference (SED) in means**




number (including main leaf number) as compared to those at 10°C, which severely affected the photosynthesis and respiration processes. In consequence, plants took longer time to complete both vegetative and reproductive phases. As reported earlier, lowering the temperature from 25°C to 5°C increased the number of days to flowering in *Antirrhinum* (Maginnes & Langhans, 1961; Miller, 1962; Sanderson & Link, 1966; Edwards & Goldenberg, 1976). Results of present studies coincide with the past findings. Plants at 10°C temperature took 23 more days to flower than the control plants at 20°C temperature. However, plants at 0°C did not flower during further nine weeks after the flowering in control compartment (20°C) and prolonged 59 days to flower. The reason for taking more time to flower at

lowest temperature is probably the plant stage at which they were subjected to lower temperature (at late stage of development i.e. 6-leaf pairs). Langhans and Maginnes (1962) already reported that the time at which a particular temperature is applied to snapdragons is critical for their flower development. Another possible reason of delay in flowering time could be because at flower development stage the floral organs are incapable to produce carbohydrates (sucrose) due to lack of chlorophyll and therefore cannot carry out photosynthesis for their need. For this reason, flowers are dependent upon other parts, especially leaves, for their carbohydrate supply. It is well known that temperature played an important role during translocation of food (Thomas & Vince-Prue, 1997). Therefore, when plants were transferred to 0°C compartment at late stage of development, the translocation of carbohydrates was checked, which ultimately affected time to flowering.

The interaction of phytochrome and temperature is also reported to prolong flowering time in *Arabidopsis* (Halliday *et al.*, 2003). The *phy*B mutant displayed a constitutive elongated petiole and early flowering phenotype when grown under a constant temperature at 22°C. However, quite remarkably the early flowering phenotype of *Phy*B was completely abolished when plants were grown at the slightly lower temperature at 16°C. Similar results were also noted in wild-type (WT) plants. However, a 6°C difference in temperature had a huge impact on *Phy*B mutant which produced 16 more leaves than WT. In the present studies, though temperature did not affect main leaf number but it significantly prolonged time to flowering at lower temperature. A delay in perception and activation of phytochrome at lower temperature could be another possibility of extending the flowering process in early flowering cultivar 'Chimes White'.

The branch number at 10 and 20°C were increased 32 and 55%, respectively as compared to 0°C temperature. However, temperature did not significantly affect the main leaf number below inflorescence per plant. A similar effect of temperature (data not shown) has also been observed in another study in which only day length significantly affected the leaf number (Munir, 2003). Temperature has a profound effect on rate of leaf appearance as it increased when temperature increased (Adams *et al.*, 1997) making leaves more efficient to manufacture photosynthate and to develop the stimulus. This could be a possible reason why juvenile phase is too short at higher temperature. Though almost same leaf numbers were counted at lower temperatures but due to slow rate of leaf appearance, plants were remained juvenile for long time.

Plants at 10°C produced 12% more flower buds than at control (20°C). However, a huge difference in flower buds (82%) was observed at 0°C which is probably a result of arrest of flower bud initiation and plant development. These results are in agreement with the results obtained by Langhans and Maginnes (1962). The fact that the 10°C plants took more than three weeks longer than the control (20°C) to flower, explains why the leaf area is greater in those plants than the control. Whilst plants at 0°C produced slightly more leaf area than the control but lesser than 10°C which shows that 0°C treatment did not allow growth and photosynthesis but at a very low rate. However, minimum leaf area in control plants indicated that after producing a desirable leaf number and leaf area, plants perceived the inductive signal in leaves and became competent to release the stimulus and when the stimulus reached at the apex it was properly recognized because plants were determined after acquiring a reasonable apex size (Hackett, 1980; Hackett & Srinivasani, 1983).

Plant fresh and dry weights were maximum at 10°C followed by control plants (20°C), whereas these were minimum at 0°C. Maginnes and Langhans (1961) reported similar results in 'Jackpot'. This indicated that the lowest temperature did not allow respiration to take place at high rate in order to use the food supply. A maximum net assimilation rate at lowest temperature showed that 0°C temperature severely suppressed the respiration process which is essential for the breakdown of assimilates produced. Similarly, plants either at 20 or 10°C were taller than the plants at 0°C. However, Maginnes and Langhans (1961) obtained larger plants of 'Jackpot' at 10°C than that of 21°C. The difference could be due to the use of different cultivars, different locations, and subjecting temperature at different plant stages. In another study, Langhans and Maginnes (1962) reported that after acquiring a desirable height, plant could enter into the reproductive phase in a short time. This could be an indication why plants took less time to flower at higher temperature regime.

Above results indicated that temperature around 0°C is extremely harmful and expensive to snapdragons, although it is considered to be a 'cool season crop'. The 10°C treatment produced plants with larger leaves, greater fresh and dry weights, and more flower buds than any other treatment, suggesting that this treatment produced the best quality plants. However, plants at 20°C flowered much earlier than other treatments. It depicted that growth of *Antirrhinum* should take place at temperatures between 10 and 20°C, depending on the requirements and needs of individual growers. For early flowering, temperature around 20°C is more suitable otherwise for better quality 10°C seems much appropriate. However, growers can further manipulate temperature between 10 and 20°C according to the age and size of plants, in order to control the flowering time, and to prepare them for sale at desired time.

## REFERENCES

Adams, S.R., S. Pearson and P. Hadley, 1997. The effects of temperature, photoperiod and light integral on the time to flowering of pansy cv. Universal Violet (*Viola* × *wittrockiana* Gams). *Ann. Bot.*, 80: 107–12

Edwards, K.J.R. and J.B. Goldenberg, 1976. A temperature effect on the expression of genotypic differences in flowering induction in *Antirrhinum majus*. *Ann. Bot.*, 40: 1277–83

Hackett, W.P., 1980. Control of phase change in woody plants. *In*: *Control of Shoot Growth in Trees*, I.U.F.R.O., Fredericton, New Brunswick, USA.

Hackett, W.P. and C. Srinivasani, 1985. *Hedera helix* and *Hedera canariensis*. *In:* Halevy, A. (ed.), *CRC Handbook of Flowering*. CRC-Press Inc. Boca Raton, Florida.

Halliday, K.J., M.G. Salter, E. Thingnaes and G.C. Whitelam, 2003. Phytochrome control of flowering is temperature sensitive and correlates with expression of the floral integrator *FT*. *The Pl. J.*, 33: 875–85

Langhans, R.W. and E.A. Maginnes, 1962. Temperature and light. *In:* Langhans, R.W. (ed.). *Snapdragons; A Manual of the Culture, Insects and Diseases and Economics of Snapdragons.* pp: 47–54. New York State Flower Growers Association, Ithaca, New York

Maginnes, E.A. and R.W. Langhans, 1961. The effect of photoperiod and temperature on initiation and flowering of snapdragon (*Antirrhinum majus*-variety Jackpot). *In: Proc. of the American Soci. for Hort. Sci.*, 77: 600–7

Miller, R.O., 1962. Variations in optimum temperatures of snapdragons depending on plant size. *In: Proc. of the American Soci. for Hort. Sci.*, 81: 535–43

Munir, M., 2003. A study on the effects of environmental factors affecting the phases of flower development in *Antirrhinum majus* L. *Ph.D. Thesis.* Department of Horticulture and Landscape, School of Plant Sciences, The University of Reading, U.K.

Park, L.H., N. Oliviera and S. Pearson, 1998. Temperature affects growth and flowering of the Ballon flower [*Platycodon grandiflorus* (Jacq.) A.DC. cv. Astra Blue]. *HortSci.*, 33: 233–36

Pearson, S., P. Hadley and A.E. Wheldon, 1993. A reanalysis of the effects of temperature and irradiance on time to flowering in Chrysanthemum (*Dendranthema grandiflora*). *J. Hort. Sci.*, 68: 89–97

Sanderson, K.C. and C.B. Link, 1967. The influence of temperature and photoperiod on the growth and quality of a winter and summer cultivar of snapdragon, *Antirrhinum majus* L. *In: Proc. of the American Soci. for Hort. Sci.*, 91: 598–611

Thomas, B. and D. Vince-Prue, 1997. *Photoperiodism in plants.* London. Academic Press.

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