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Impact of light intensity on flowering time and plant quality of *Antirrhinum majus* L. cultivar Chimes White

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Abstract: Shades of different light intensities (29%, 43%, 54%, 60% or 68%) along with control (no shade) were studied to observe their effects on the flowering time and plant quality. A hyperbolic relationship was observed between different light intensities under shade, and time to flowering. The total number of flower buds showed a curvilinear relationship with light intensities. Growth parameters related to the plant characteristics such as plant height, leaf area and plant fresh weight were improved under shading treatments at the expense of flowering time and number of flower buds. However, both linear and polynomial models applied assumed that cultivar Chimes White was equally sensitive to light intensity throughout development.

Key words: *Antirrhinum majus* L., Snapdragon, Growth and development, Flowering, Light intensity.
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INTRODUCTION

Many angiosperms flower at about the same time every year. This occurs even though they may have started growing at different times. Their flowering is a response to the changing length of day and night as the season progresses. In the early 20th century, a mutation in tobacco cultivar Maryland Mammoth was discovered that prevented the plant from flowering in the summer as normal tobacco plants do. 'Maryland Mammoth' would not bloom until late December (Garner and Allard, 1920). This reflected the effect of photoperiod on flowering. Afterwards, on the basis of light requirement, plants were categorized as long day, short day and medium length day. Duration of photoperiod (light requirement) is measured by the biological clock (circadian rhythm) within the leaves and in response a stimulus is released towards the apex to induce flowering (Munir, 2003). It had also been emerged that photoperiod significantly influenced photosynthesis, seed germination, breaking of dormancy, and the flowering process particularly (Thomas and Vince-Prue, 1997). However, intensity of daylength varies seasonally and is the total amount of light that received by a plant each day. The daily light intensity in winter is about one tenth that in the summer, particularly in temperate climate. Therefore, growers of high value ornamental plants who fail to invest in supplementary lighting for winter production are likely to be out of business in the said climatic region.

In *Antirrhinum*, the increasing light intensity significantly decreased the flowering time and leaf numbers (Cremer *et al.*, 1998; Flint, 1960; Hedley, 1974). A decrease in light intensity can be naturally caused by clouds or artificially by shading nets. However, shading nets are commonly used in countries like Pakistan and the U.K., during summer months to decrease the temperature inside the glasshouses and to protect the plants from the harsh effects of severe sunshine. Limited attention was paid previously to explore this environmental factor. As described in the general photo-thermal model, the major influencing factors were considered as photoperiod and temperature on flowering time (Hadley *et al.*, 1984; Ellis *et al.*, 1990). The effect of light intensity was successfully incorporated in the same model in *Petunia*, *Viola* and *Antirrhinum* (Adams *et al.*, 1997; 1998; Munir, 2003). The main objective of the present study was to determine the effects of different shade levels on the flowering time and plant quality of an early cultivar of *Antirrhinum*.

MATERIAL AND METHOD

The objective of the experiment was to determine the flowering response of *Antirrhinum majus* L. cultivar Chimes White, to different light intensity. 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 ºC in a growth room with photosynthetic photon flux density of 72 μmol/m^2·s at approximately one meter above tray height from a mixture of white fluorescent and tungsten bulbs (6.3% tungsten by nominal wattage), with 16 h/d photoperiod.

After 70% seed germination, plants were transplanted into 9 cm pots (volume 370 ml) containing a mixture of peat-based compost (SHL) and perlite (3:1 v/v) and transferred to the glasshouse (7.3 m×11.3 m). Six plants were placed on each of the trolleys covered either with 29%, 43%, 54%, 60% or 68% shade. Similar numbers of plants were also kept as control (under no shade; 0%). In the glasshouse, plants received natural daylength under temperature of 19.9 ºC. Ventilation occurred automatically at 3 ºC above set point temperature. The temperatures were recorded using a Campbell CR10 data logger (Campbell Scientific Inc, Logan, UT) with K type thermocouples. The shading percentage of each shading net was measured with a microvolt (mV) quantum sensor light meter. Each reading was converted into μmol/m^2·s and then into a percentage of the non-shaded light intensity. Tube solarimeters were used to measure the average light transmission into the glasshouse and approximately 7.03 MJ/m^2·d light intensity 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 (182×10^{-6} N; 78×10^{-6} P; 150×10^{-6} 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 regression statistical technique of GENSTAT-5, Release 4.1 (Lawes Agricultural Trust, Rothamsted Experimental Station, U.K.).

RESULTS

Directly measured parameters

1. Flowering parameters

The relationship between days to flowering and light intensity was hyperbolic i.e. as the light intensity increased time to flowering decreased ($P<0.05$). Plants without shading took minimum time to flower (95 days) while those receiving minimum of light (68% shade) throughout their development delayed flowering by 38 days. The increase in flowering time was a linear function of the light intensity (Fig.1a). However, the rate of progress to flowering ($1/f$) was the inverse function to light levels i.e. if light intensity decreased, rate of progress to flowering also decreased until 60% of shade; after this, the difference was found to be not significant (Fig.1b). Plants did not produce the number of flowering buds linearly. The model applied was a second degree polynomial showing a significant ($P<0.05$) but curvilinear response of flowering

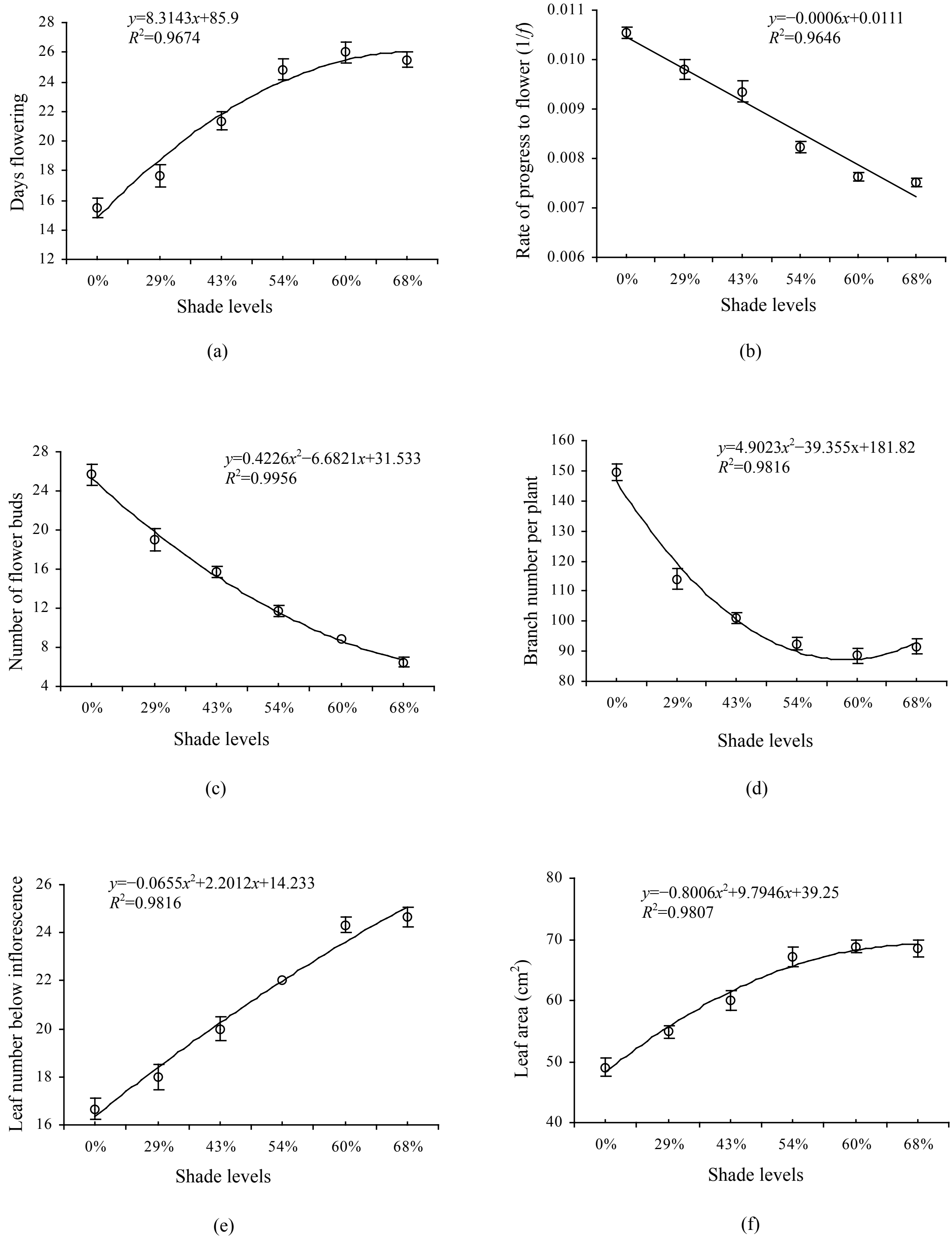

Fig.1 Effect of different light intensities on (a) days to flowering, (b) rate of progress to flowering, (c) No. of flower buds, (d) No. of branches per plant, (e) leaf numbers, and (f) leaf area (cm^2). Vertical bars (where larger than the points on lines) represent the standard error (s.e.) of variability within replicates

buds to light intensity. Number of flowering buds decreased significantly (P<0.05) with increase in light intensity, i.e. 26 to 7 buds were counted at two extreme shade levels (Fig.1c).

2. Plant quality parameters

Plants that received high light intensity were dense and produced maximum branches per plant (150) at control. Branch numbers decreased gradually with decreasing light intensity (P<0.05). At 29% shading, plants produced 114 branches whereas 13 less branches were counted in plants that received 43% shade. However, plants produced maximum number of branches afterward; i.e. from 54% to 68% shade and produced minimum (89−93) number of branches (Fig.1d). Leaf numbers per plant below the inflorescence were also significantly (P<0.05) affected by different shading material (Fig.1e). Control plants produced less numbers of leaves (17) than the shaded plants (18−25).

However, shade treatments did not affect this parameter significantly above 60% shade. Leaf area was minimum (49 cm^2) at higher light intensity treatment (no shade) and gradually increased (P< 0.05) with the decrease in light intensity (Fig.1f). However, the gradient point was 60% shade treatment (69 cm^2) above this level shade did not influence the leaf area. Plant height was significantly (P<0.05) increased as the light intensity decreased (Fig.2a). After 54% shade treatment, plants in 54% −68% shade were approximately 10 cm taller than the control ones. Similar trend was noted in plant fresh weight (Fig.2b) and plant dry weight (Fig.2c) parameters.

Derived parameters

There was no significant effect of shade levels on leaf area ratio (Fig.2d). For example, in most shade treatments including control the leaf area ratio was 25−27 cm^2/g; however, a slight (11%) increase was recorded in 29% shade. Relative growth rate (Fig.2e) and net assimilation rate (Fig.2f) of 'Chimes White' declined significantly (P<0.05) with increase in shade level. For example, relative growth rate and net assimilation rate for the plant under 54% to 68% shade declined by approximately 33% compared to unshaded plants.

DISCUSSION

Higher light transmission shade net (29%) allowed more photosynthesis to take place at a higher rate from the early stage, producing more branches and leaves, allowing the plants to flower earlier. In a *vice versa* effect, low light transmission nets (60% and 68%) delayed flowering time by 30 days. Cremer *et al.* (1998) observed similar results while working with two *Antirrhinum* inbreds. Similarly, shading greatly reduced branching, especially in the high shading densities, possibly because the plants etiolated (Fig.2a) rather than produce more branches under low light. Leaf numbers below the inflorescence were almost the same in control and 29% shade whereas in the rest of the shade treatments they increased significantly. Cremer *et al.*(1998) also reported similar results which showed that as the light intensity increased, the leaf numbers prior to flower anthesis decreased. The possible reason was that under low light intensity, plants were unable to perceive the developmental signal in the leaves that induced competence in flowering. A linear decrease in the number of flowering buds was observed when the light transmission was gradually reduced. Plants produced 63% less flowering buds at low light transmission shade (68%). This indicated that the switch to flowering was maintained at subsequent flower formation under higher light intensity. In gardenia, a 30% decrease in floral number was recorded under 67% shade. However, *Antirrhinum* showed more sensitivity to light levels than gardenia (Kamoutsis *et al.*, 1999). Similarly, in *Leucospernum* (pincushions), 80% shading decreased the number of flower buds considerably (Napier and Jacobs, 1989). The shaded plants (54% to 68%) produced larger leaves and taller stem, in order to capture more light, probably because of a shade-avoidance mechanism (Ballaré, 1999) which resulted in decreasing the flower buds and delaying flowering time. Plant fresh weight and plant dry weight were increased in a similar logical pattern from lower to higher shade levels showing that the plants under low light conditions tended more towards vegetative rather than reproductive growth (Evans, 1972; Fitter and Hay,

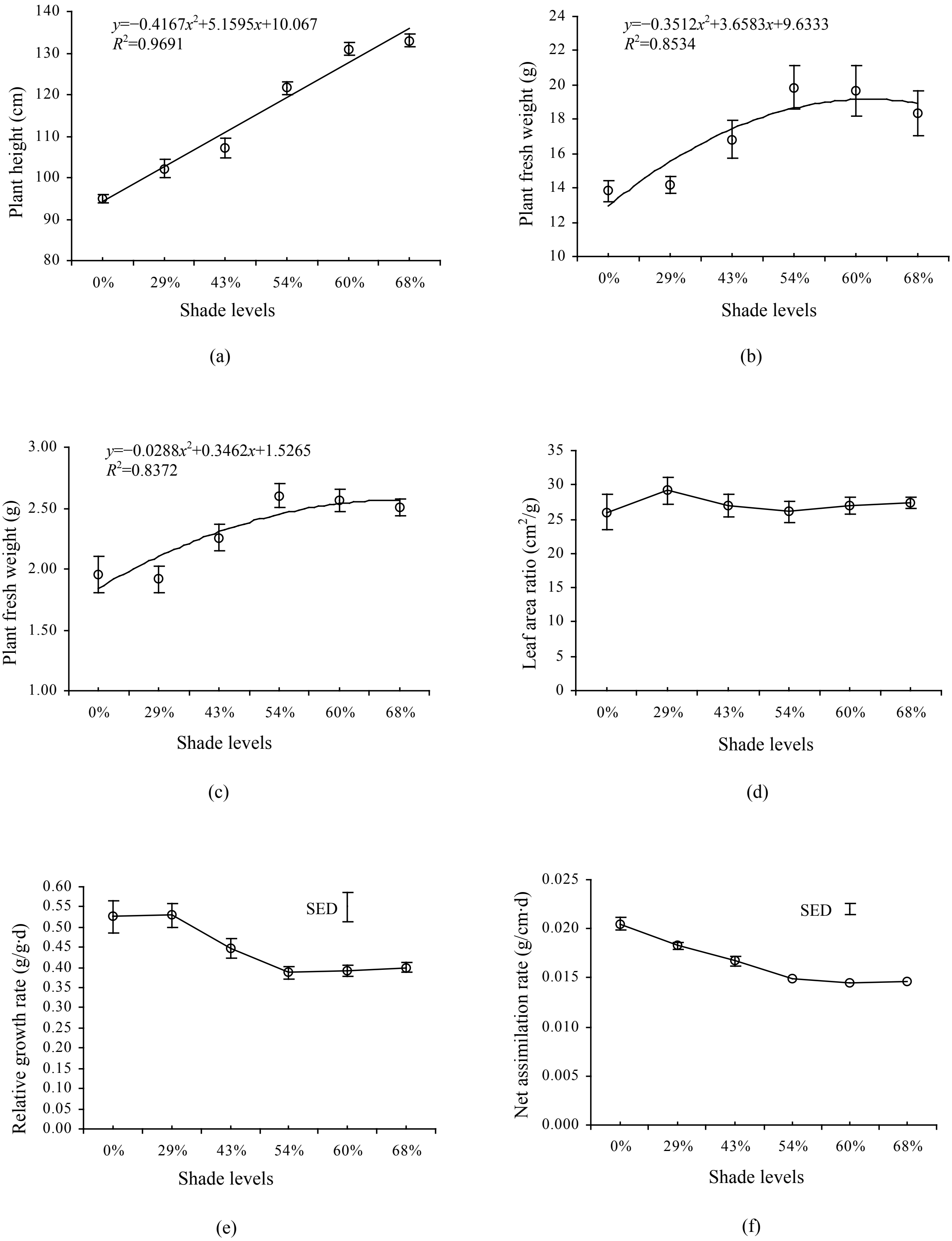

Fig.2 Effect of different light intensities on (a) plant height (cm), (b) plant fresh weight (g), (c) plant dry weight (g), (d) leaf area ratio (cm^2/g), (e) relative growth rate (g/g·d), and (f) net assimilate rate (g/cm·d). Vertical bars (where larger than the points on lines) represent the standard error (s.e.) of variability, whereas the separate ones represent the standard error of difference (SED) within means

1987).

Commercial bedding plant producers are mostly interested in producing the most attractive, quality plants, with the most flowers and in the shortest space of time. The best method, in this case, is obviously to use no shading at all, as the control plants produced the most number of flower buds in 95 days, and the best looking compact plants. In countries like Pakistan where it is required to control temperature or excessive sunlight, it is best to use shading of around 29%, as plants in this treatment flowered earlier than that of other shading levels, produced more number of flower buds, and nice and compact plants suitable for selling as high quality pot-plants. However, if timing of production is critical, in order to produce flowered snapdragons for selling on a particular date or occasion, different shading levels can be used in order to delay flowering accordingly.

References

Adams, S.R., Pearson, S., Hadley, P., 1997. The effects of temperature, photoperiod and light integral on the time to flowering of pansy cv. Universal Violet (*Viola*× *witrockiana* Gams). *Annals of Botany*, **80**:107-112.

Adams, S.R., Hadley, P., Pearson, S., 1998. The effects of temperature, photoperiod, and photosynthetic photon flux on the time to flowering of petunia ‘Express Blush Pink’. *Journal of the American Society for Horticultural Science*, **123**:577-580.

Ballaré, C.L., 1999. Keeping up with the neighbours: phytochrome sensing and other signalling mechanisms. *Trends in Plant Science*, **4**:97-102.

Cremer, F., Havelange, A., Saedler, H., Huijser, P., 1998. Environmental control of flowering time in *Antirrhinum majus*. *Physiologia Plantarum*, **104**:345-350.

Ellis, R.H., Hadley, P., Roberts, E.H., Summerfield, R.J., 1990. Quantitative Relations between Temperature and Crop Development and Growth. *In*: Jackson MT, Ford-Lloyd BV, Parry ML, eds. Climatic Change and Plant Genetic Resources. Belhaven Press, London, p.85-115.

Evans, G.C., 1972. The Quantitative Analysis of Growth. Blackwell, London.

Fitter, A.H., Hay, R.K.M., 1987. Environmental Physiology of Plants. 2nd Edition. Academic Press, London.

Flint, H.L., 1960. Relative effects of light duration and intensity on growth and flowering of winter snapdragon (*Antirrhinum majus* L.). *Proceeding of the American Society for Horticultural Science*, **75**:769-773.

Garner, W.W., Allard, H.A., 1920. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. *Journal of Agricultural Research*, **18**:553-606.

Hadley, P., Roberts, E.H., Summerfield, R.J., Minchin, F.R., 1984. Effects of temperature and photoperiod on flowering in soya bean [*Glycine max* (L) Merrill]−a quantitative model. *Annals of Botany*, **53**:669-681.

Hedley, C.L., 1974. Response to light intensity and daylength of two contrasting flower varieties of *Antirrhinum majus* L. *Journal of Horticultural Science*, **49**:105-112.

Kamoutsis, A.P., Chronopoulou-Sereli, A.G., Paspatis, E.A., 1999. Paclobutrazol affects growth and flower bud production in gardenia under different light regimes. *HortScience*, **34**:674-675.

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.

Napier, D.R., Jacobs, G., 1989. Growth regulators and shading reduce flowering of *Leucospernum* cv. Red sunset. *HortScience*, **24**:966-968.

Thomas, B., Vince-Prue, D., 1997. Photoperiodism in Plants. Academic Press, London.