INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
08–324/CAJ/2009/11–2–138–144
http://www.fspublishers.org

Full Length Article

Effects of Different Shade Levels (Light Integrals) on Time to Flowering of Important Ornamental Annuals

JALAL-UD-DIN BALOCH[1], M. QASIM KHAN, M. ZUBAIR† AND M. MUNIR‡
Faculty of Agriculture, Gomal University, D.I. Khan, Pakistan
†University College of Agriculture, Bahauddin Zakariya University, Multan, Pakistan
‡School of Plant Sciences, The University of Reading, Reading, U.K
[1]Corresponding author's email: jalaluddinbaloch@live.com

ABSTRACT

Present study was carried out to evaluate the effects of different shade levels on flowering time on ten long day plants (LDP, sown on 1st March 2006) and six short days plants (SDP, sown on 1st September 2006). Days taken to flowering were increased significantly ($P<0.05$) when LDPs were grown under low light integrals (40%, 30% & 20% shade). However, SDPs grown under low light integrals took minimum time to flower. The benefits of using different shade levels (low light integrals) can be achieved to prolong flowering time in LDPs as they will continue their juvenile growth therein. However, SDPs can be grown under shades if an early flowering is required. A steady supply of these flowering annuals can be maintained in the market by grown them under different shades.

Key Words: Ornamental annuals; Shade; Light integrals; Flowering time

INTRODUCTION

Flowering plants grown in ambient environment, bloom at about the same time every year. Their flowering is a response to the changing length of day and night (photoperiod or day length) as the season progresses. Afterwards, on the basis of light requirement, plants were categorized as long day, short day and day-neutral (Thomas & Vince-Prue, 1997). Duration of photoperiod (light requirement) is measured by the biological clock (circadian rhythm) within the leaves (O'Neil, 1992) and in response a stimulus is released towards apex to induce flowering (McDaniel, 1996; Corbesier & Coupland, 2005).

Light is a critical resource for plants and competition for light under shade affects their growth and development (Imaizumi & Kay, 2006). Daily light integral varies seasonally and is the total amount of light that received by a plant each day. 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. A decrease in light intensity can be naturally caused by clouds or artificially by shading nets. However, shading nets are commonly used in most countries such as USA, UK, Canada and Pakistan during summer months to protect plants from the harsh effects of severe sunshine (Munir *et al.,* 2004).

Morphological and physiological responses of plants to high and low irradiance have been extensively investigated, constituting one of the classic examples of plasticity (Ballaré & Scopel, 1997; Callahan & Pigliucci, 2002; Schmitt *et al.,* 2003; Larner *et al.,* 2005). In most of these studies, irradiance has been reduced with neutral shade, contrasting plants from open habitats with those from forest shadows. Under natural conditions, however, plants under leaf canopy experience not only reduction in irradiance but also alter spectral light quality due to the selective filtering of blue and red wavelengths by chlorophyll (Schmitt & Wulff, 1993). In particular, the red to far-red ratio (R:FR) of incident light may be dramatically reduced under the shade as compared with full sunshine and may also vary widely under different shade levels. Thus R:FR is an important signal by which plants may detect micro-environmental variation in shade, both from over the foliage and from neighbours. Similarly, plants grow in dense stands in non-shaded location use R:FR signal to compete with the neighbours for light (Vandenbussche *et al.,* 2005).

Plant perception of R:FR is mediated by phytochrome, family of photoreceptors that convert reversibly between two forms when exposed to red or far-red light (Smith, 2000). It has been reported that the primary function of phytochrome is to act as a sensitive sensor of shade (Schmitt *et al.,* 1995). Phytochrome-mediated morphogenesis in light grown plants is a function of the photoequilibrium between the two forms, resulting in a sensitive, graded morphological response to light quality over the range of

To cite this paper: Baloch, J.U.D., M.Q. Khan, M. Zubair and M. Munir, 2009. Effects of different shade levels (light integrals) on time to flowering of important ornamental annuals. *Int. J. Agric. Biol*., 11: 138–144

R:FR values typical of vegetation shade (Schmitt & Wulff, 1993).

When plants are shaded, two types of reactions can occur. Shade-acclimation responses maximize light harvesting in shade conditions through increases in specific leaf area and reduced chlorophyll a:b ratio (Evans & Poorter, 2001), whereas shade-avoidance responses maximize light capture by positioning the leaves out of the shade (Ballaré, 1999). Shade-avoiding plants have machinery that reacts quickly to changes in R:FR ratio that are sensed by the phytochrome (Franklin & Whitelam, 2005). Many plant species typically respond to reduction in the R:FR of incident light with increased apical dominance, reduced branching, the upward orientation of leaves (hyponasty), stem extension and internode elongation. Plants grown under low light etiolate and subsequently accelerate flowering time (Cerdá & Chory, 2003; Pierik *et al.,* 2004).

These studies indicated that manipulating light integrals control plant growth and development. Hence, an assumption appeared that flowering process is slow down if long day plants (LDPs) are grown under low light integrals and *vice versa*. However, an opposite assumption can be made for short day plants (SDPs) i.e., flowering process is accelerated if SDPs are grown under low light integrals and *vice versa*. To test these assumptions an experiment was design to grow various LDPs and SDPs under different light levels (shades) to observe their flowering response under the ecological conditions of D.I. Khan, Pakistan.

MATERIALS AND METHODS

Present experiment was conducted at Agricultural Research Institute, D.I. Khan, Pakistan, during the year 2006. Seeds of LDPs such as Moss Rose (*Portulaca grandiflora* L.) cv. Sundance, Pansy (*Viola tricolour hortensis* L.) cv. Baby Bingo, Snapdragon (*Antirhinum majus* L.) cv. Coronette, Petunia (*Petunia* × *hybrida* Juss.) cv. Dreams, Annual Verbena (*Verbena* × *hybrida* L.) cv. Obsession, Pot Marigold (*Calendula officinalis* L.) cv. Resina, Annual Phlox (*Phlox drummondii* L.) cv. Astoria Magenta, Cornflower (*Centaurea cyanus* L.) cv. Florence Blue, Oriental Poppy (*Papaver orientale* L.) cv. Burning Heart, Flax (*Linum usitatissimum* L.) cv. Scarlet Flax were sown on 1st of March 2006 into module trays containing locally prepared leaf mould compost. Similarly, seeds of SDPs such as Zinnia (*Zinnia elegans* L.) cv. Lilliput, Sunflower (*Helianthus annuus* L.) cv. Elf, French Marigold (*Tagetes patula* L.) cv. Orange Gate, African Marigold (*Tagetes erecta* L.) cv. Crush, Cockscomb (*Celosia cristata* L.) cv. Bombay, Cosmos (*Cosmos bipinnatus* Cav.) cv. Sonata Pink were sown on 1st of September 2006. Seed trays were kept at room temperature at night and they were moved out during the day (08:00–16:00 h) under partially shaded area. The reason of planting LDPs in March (long day length) and SDPs in September (short day length) was to estimate flowering character under their respective responsive environment.

After 70% seed germination, six replicates of each cultivar were shifted to the trolleys of respective shade levels i.e., 0% (control), 20%, 30% and 40%. LDPs grown under 0, 20, 30 and 40% shades received 9.34, 7.47, 6.54 and 5.60 MJ m^{-2} d^{-1} light integrals respectively until flowering. Similarly, SDPs grown under same shade levels received 7.53, 6.02, 5.27 and 4.52 MJ m^{-2} d^{-1} light integrals respectively until flowering. Temperature and solar radiation were measured in the weather station situated one kilometer away from the research venue (Table I). Temperature was recorded with the help of Hygrothermograph (NovaLynx Corporation, USA), while solar radiation was estimated using solarimeters (Casella Measurement, UK). Shade percentage inside the covered trolleys was measured using the light meter quantum sensor (LI-189, LI-COR® Biosciences, USA). Plants were potted into 9 cm pots containing leaf mould compost and river sand (3:1 v/v) after 6 leaves emerged. Plants were irrigated by hand and a nutrient solution [(Premium Liquid Plant Food & Fertilizer (NPK: 8-8-8); Nelson Products Inc. USA)] was applied twice a week. Plants in each treatment were observed daily until flower opening (corolla fully opened). Numbers of days to flowering from emergence were recorded at harvest and the data were analysed using GenStat-8 (Lawes Agricultural Trust, Rothamsted Experimental Station, U.K & VSN International Ltd. U.K).

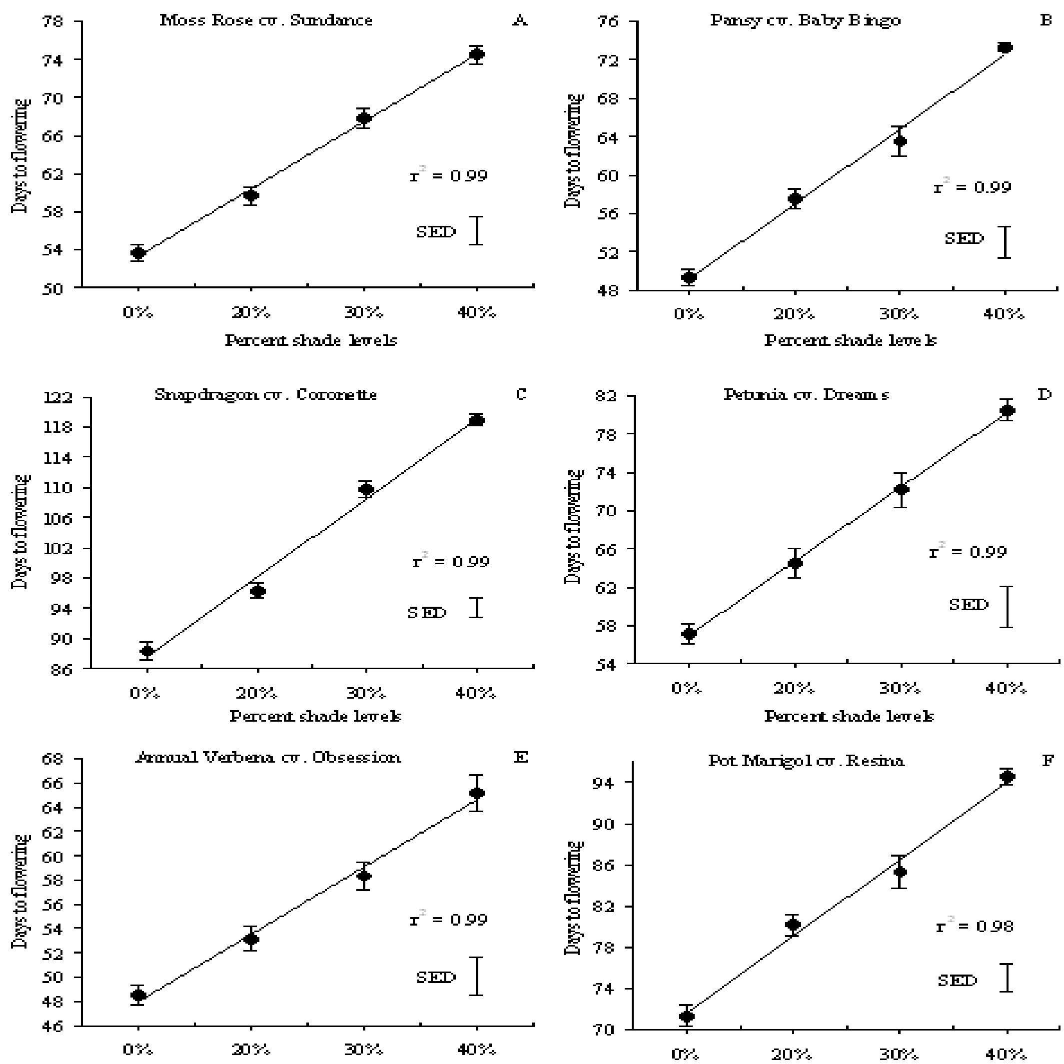
RESULTS

The results of present piece of work revealed a statistically significant ($P<0.05$) difference between shade levels regarding flowering time in LDPs. Plants under low irradiance (high shade level) took more time to flower, whereas it flower time decreased significantly under lower shade levels and control. Moss Rose cv. Sundance (Fig. 1A) flowered 21 days later under 40% shade (75 days) followed by 14 days under 30% shade (68 days) and 6 days under 20% shade (60 days) as compared to control (54 days). Similarly, Pansy cv. Baby Bingo (Fig. 1B) took 24 more days to flower under 40% shade (73 days) followed by 14 days under 30% shade (64 days) and 8 days under 20% shade (58 days) when compared with control plants (49 days). Thirty-one days difference between low irradiance (40% shade, 119 days) and control (88 days) was recorded in Snapdragon cv. Coronette (Fig. 1C) followed by 22 days difference under 30% (110 days) and 8 days under 20% shade (96 days). A 23 days late flowering was observed in Petunia cv. Dreams (Fig. 1D) when they were grown under 40% shade (81 days) as compared to control (57 days). However, this difference was decreased up to 15 days under 30% shade (72 days) followed by 7 days under 20% shade (65 days) when compared with control. Annual Verbena cv. Obsession (Fig. 1E) flowered 17 days late under 40% shade (65 days) followed by 10 days under 30% (58 days) and 5

Table I. Environmental detail of experiment conducted in 2006

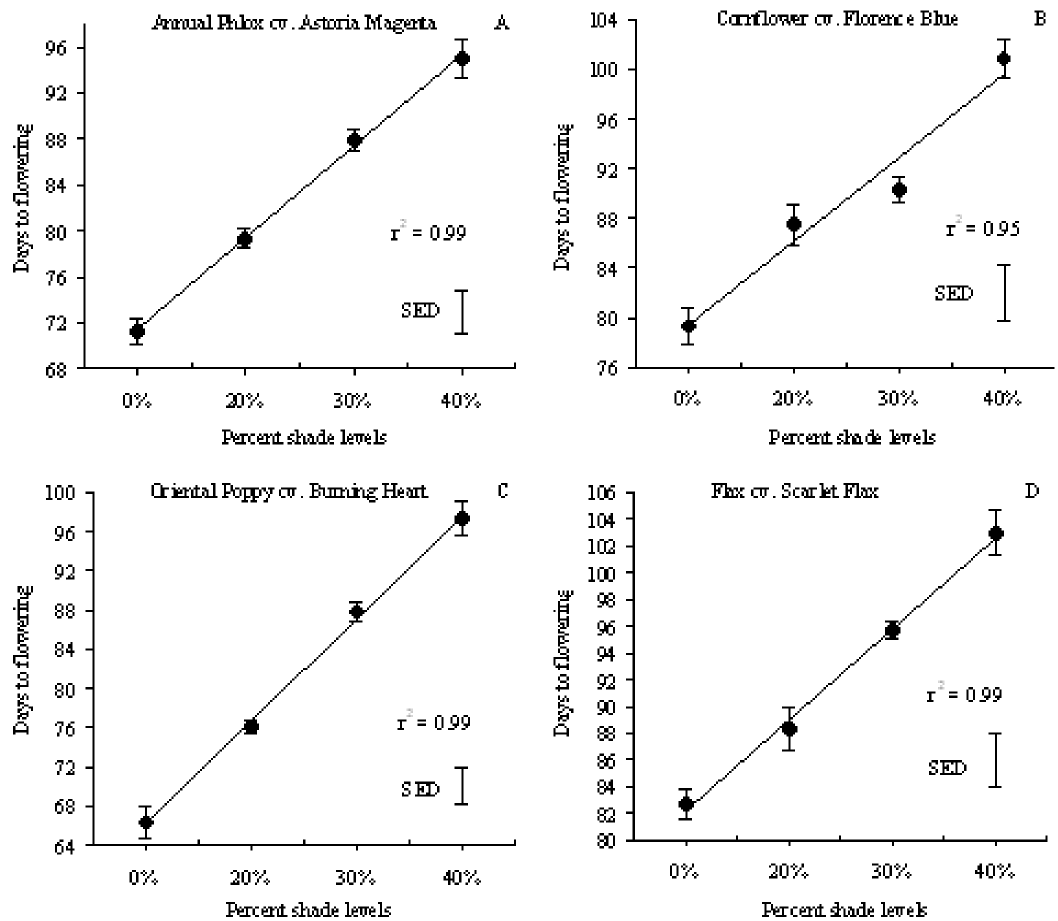
Growing Season		Diurnal temperature (°C)			Light integral MJ m^{-2} d^{-1}	Day Length (h d^{-1})
		Maximum	Minimum	Average		
LDPs	March 2006	26.94	12.71	19.82	8.20	13.30
	April 2006	36.23	18.47	27.35	9.67	14.21
	May 2006	41.87	25.45	33.66	9.64	15.40
	June 2006	41.33	25.37	33.35	9.86	16.16
SDPs	September 2006	37.53	23.97	30.75	6.69	14.25
	October 2006	33.61	20.58	27.10	8.53	13.12
	November 2006	26.50	12.77	19.63	7.48	12.39
	December 2006	23.26	6.03	14.65	7.42	12.15

Fig. 1. Effect of different shade levels (light integrals) on the flowering time of (A) Moss Rose cv. Sundance, (B) Pansy cv. Baby Bingo, (C) Snapdragon cv. Coronette, (D) Petunia cv. Dreams, (E) Annual Verbena cv. Obsession and (F) Pot Marigold cv. Resina. Each point represents the mean of 6 replicates. Vertical bars on data points (where larger than the points) represent the standard error within replicates whereas SED vertical bar showing standard error of difference among means



days under 20% (53 days) shade as compared to control (49 days). Similarly, 23 days late flowering was observed when Pot Marigold cv. Resina (Fig. 1F) was grown under 40% shade (95 days) as compared to control (71 days). Plants under 30% (85 days) and 20% (80 days) shades flowered 14 and 9 days later as compared to control. Low irradiance i.e., 40% shade accelerate flowering time by 24 days (95 days to flower) in Annual Phlox cv. Astoria Magenta (Fig. 2A) as

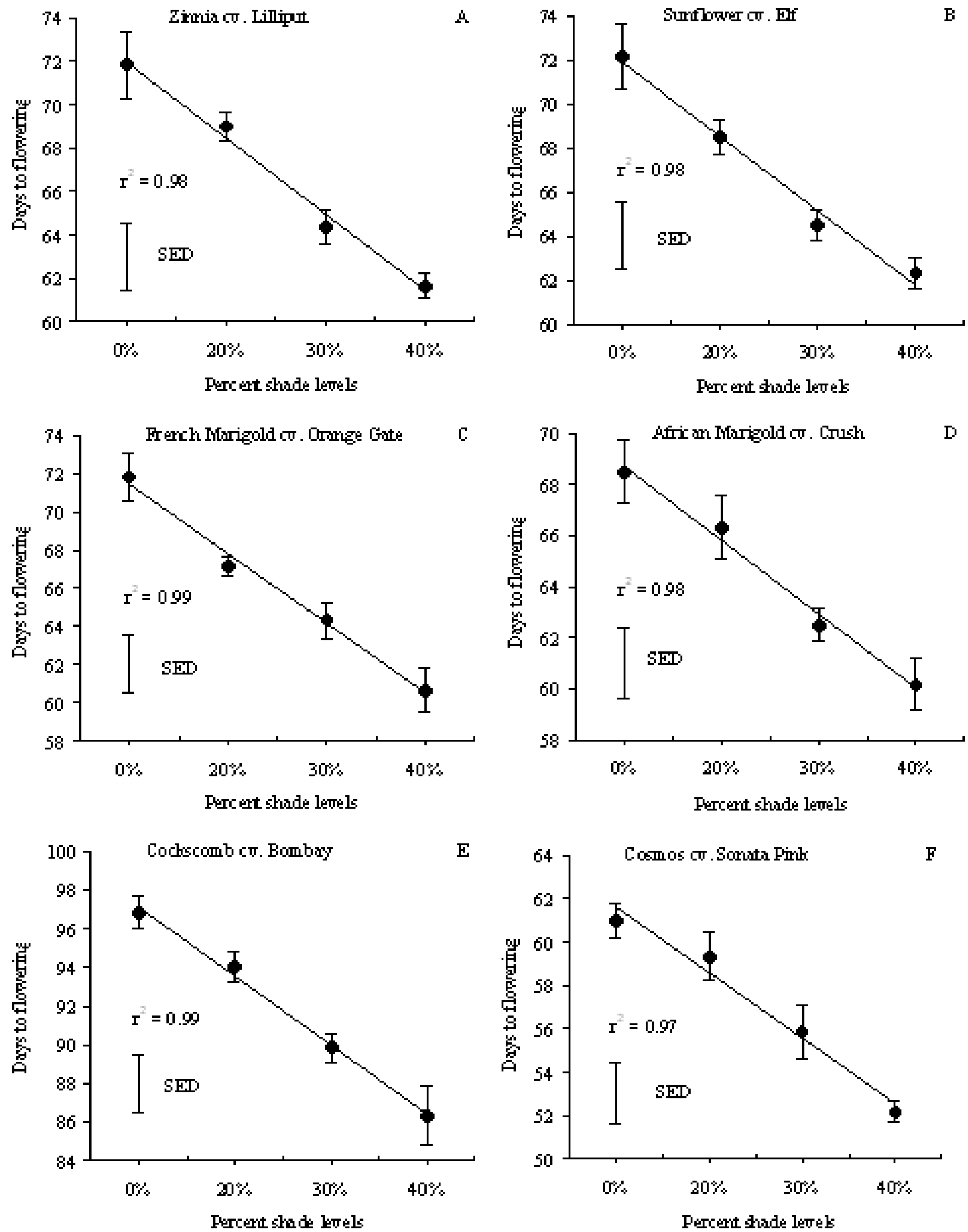
Fig. 2. Effect of different shade levels (light integrals) on the flowering time of (A) Annual Phlox cv. Astoria Magenta, (B) Cornflower cv. Florence Blue, (C) Oriental Poppy cv. Burning Heart and (D) Flax cv. Scarlet Flax. Each point represents the mean of 6 replicates. Vertical bars on data points (where larger than the points) represent the standard error within replicates whereas SED vertical bar showing standard error of difference among means



compared to control (71 day) followed by 17 days under 30% (88 days) 8 days under 20% (79 days) shade. Similarly, time to flowering was increased up to 22 days when cornflower cv. Florence Blue (Fig. 2B) was grown under 40% shade (101 days) as compared to control (79 days) followed by 11 days under 30% (90 days) and 8 days under 20% (88 days) shade treatments. Oriental Poppy cv. Burning Heart (Fig. 2C) flowered 31 days later under 40% shade (97 days) as compared to control (66 days) followed by 22 days under 30% (88 days) and 10 days under 20% (76 days) shade. Similarly, 40% shade (103 days) delayed flowering time up to 20 days in Flax cv. Scarlet Flax (Fig. 2D) as compared to control (83 days), whereas 13 days difference was observed in 30% shade (96 days) followed by 6 days in 20% shade (88 days).

Time to flowering in SDPs such as Zinnia cv. Lilliput, Sunflower cv. Elf, French Marigold cv. Orange Gate, African Marigold cv. Crush, Cockscomb cv. Bombay and Cosmos cv. Sonata Pink was decreased significantly ($P<0.05$) with increase in shade levels i.e., 0-40% shade. Plants under low irradiance (high shade level) took less time to flower whereas it increased significantly under lower shade levels and control. It was observed that Zinnia cv. Lilliput (Fig. 3A) flowered 10 days earlier under low irradiance i.e., 40% shade (62 days) as compared to control (72 days) followed by 8 and 3 days earlier flowering under 30% (64 days) and 20% shade (69 days), respectively. Similarly, Fig. 3B showed 10 days flowering time difference between 40% shade (62 days) and control (72 days), while 8 and 4 days early flowering was noted in plants grown under 30% (65 days) and 20% shade (69 days), respectively in Sunflower cv. Elf. French Marigold cv. Orange Gate (Fig. 3C) flowered 11 days early under 40% low light integrals i.e., 40% shade (61 days) as compared to control (72 days) followed by 8 and 5 days earlier flowering under 30% (64 days) and 20% (67 days) shade levels. Similarly, in African Marigold cv. Crush (Fig. 3D) 8, 6 and 2 days earlier flowering was recorded in plants

Fig. 3. Effect of different shade levels (light integrals) on the flowering time of (A) Zinnia cv. Lilliput, (B) Sunflower cv. Elf, (C) French Marigold cv. Orange Gate, (D) African Marigold cv. Crush, (E) Cockscomb cv. Bombay and (F) Cosmos cv. Sonata Pink. Each point represents the mean of 6 replicates. Vertical bars on data points (where larger than the points) represent the standard error within replicates whereas SED vertical bar showing standard error of difference among means



grown under 40% (60 days), 30% (63 days) and 20% (66 days) shade levels as compared to control treatment (69 days). Cockscomb cv. Bombay (Fig. 3E) flowered 11 days earlier grown under low light integrals i.e., 40% shade (86 days) as compared to control plants (97 days) followed by 7 and 3 days early flowering under 30% (90 days) and 20% (94 days) shade levels. Similarly, Fig. 3F indicated that Cosmos cv. Sonata Pink when grown under low irradiance flowered 9 days earlier (40% shade took 52 day to flower) as compared to control plants (61 days) under high irradiance. Plants grown under 30% (56 days) and 20% (59 days) shade levels flowered 5 and 2 days earlier respectively than control.

DISCUSSION

Previous studies indicated that there is 10-15 days difference in time to flowering when ornamental annuals (LDPs & SDPs) were grown in ambient day length and in controlled photoperiods (data not shown). The results of these studies established an assumption that the difference in flowering time is due to the difference in light integrals. As the light integrals were higher in ambient day length experiment therefore ornamental annuals bloomed 10-15 days earlier (LDPs) or late (SDPs) than the controlled photoperiod experiment (low light integrals). Two experiments were designed to solve this assumption. First experiment was conducted under artificial source of light integrals (light intensities using the SON-E Eliptical sodium lamp), whereas another experiment was conducted under natural light integrals (shade experiment). Results obtained from first experiment showed a difference between different light intensities (data not shown). The results of second experiment (present study) also showed a significant difference among days to flowering in LDPs and SDPs.

Findings of present research showed that LDPs grown under low light integrals (5.60, 6.54 & 7.47 MJ m^{-2} d^{-1} i.e., 40, 30 & 20% shade, respectively) were etiolated because R:FR ratio of incident light reduced under the shade (Schmitt *et al.,* 2003), which subsequently delayed flowering time (Cerdá & Chory, 2003) up to 31 days (Snapdragon & Oriental Poppy), 24 days (Pansy & Annual Phlox), 23 days (Petunia & Pot Marigold), 22 days (Cornflower), 21 days (Moss Rose), 20 days (Flax) and 17 days (Annual Verbena). This indicated that LDPs struggled to capture sufficient sunlight (enriched in far red light) for their growth and development. In present study all LDPs received around 16 h d^{-1} ambient day length therefore it was only shade that interrupted light integrals and extended flowering time (Callahan & Pigliucci, 2002). Consequently, LDPs could not capture enough light to perceive signal from leaf (O'Neil, 1992) to the apex (McDaniel, 1996) therefore flower induction process significantly delayed under low light integrals. Typically, such a response results in an increase in apical dominance and an increase in stem growth (data not shown) as a result of internode elongation (Davies *et al.,* 2002). It has been observed in the present experiment that low light integrals (40% shade or 5.60 MJ m^{-2} d^{-1}) reduced the ability of stem to stand erect without staking.

Shikanori and Hiroshi (2000) reported that low irradiance delayed flowering, reduced flowering rate and increase the leaves size in amaryllis. Similar results were obtained in all LDPs in which rate to progress to flowering *(1/f)* was significantly reduced under high shade level (40% shade). Findings of present research also revealed that LDPs such as Snapdragon, Petunia, Cornflower, Oriental Poppy and Flax, which are normally produced terminal flower, induced lateral floral buds when grown under low light integrals (40% shade or 5.60 MJ m^{-2} d^{-1}). This indicated that these plants should not be kept long under intense shade after juvenile phase otherwise the quality of these plants would be affected (Dana *et al.,* 1980).

A quite opposite response was observed in SDPs as flowering time was reduced significantly when light integrals were reduced (4.52, 5.27 & 6.02 MJ m^{-2} d^{-1} i.e., 40, 30 & 20% shade, respectively). Plants grown under low light integrals (40% shade) flowered 11 days (French Marigold & Cockscomb), 10 days (Zinnia & Sunflower), 9 days (Cosmos) and 8 days (African Marigold) earlier flowering than control plants. The reason is that long nights accelerate flowering process in SPDs as phytochrome reversion appears to be coupled into a time-measuring reaction of some kind, when this is completed hormone synthesis begins in the leaves and continues throughout the remainder of the night which sends a signal to apex to induce flowering (Thomas & Vince-Prue, 1997; Cerdá & Chory, 2003; Corbesier & Coupland, 2005). In present study when SDPs attained an appropriate apex size then under low light integrals they were competent to perceive the stimulus and induced flowering earlier than the other shade treatments.

CONCLUSION

It can be concluded from the present research findings that time of flowering in LDPs can be prolonged under different shade levels in order to continuous supply of these plants in the market and to stretch their flower display period. However, it is not advisable to grow them continuously under 40% shade, which encourage unwanted vegetative growth. On the other hand, SDPs can be grown in low light integrals (high shades) to accelerate flowering process. However, a blend of low and high light integrals could affect significantly on quality of flowering crop such as if LDPs grow under low light levels during their juvenile phase and after attaining a good quality vegetative growth they should expose to high light integrals to induce flowering for marketing. Similarly, SDPs can be grown under high light integrals (without shade or 20% shade) to have a marketable vegetative growth then they can be transferred to high shade levels to induce flowering. It is however assumed that the findings of this piece of work will increase the outcome of ornamental growers.

REFERENCES

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

Ballaré, C.L. and A.L. Scopel, 1997. Phytochrome signalling in plant canopies: Testing its population-level implications with photoreceptor mutants of *Arabidopsis*. *Funct. Ecol.,* 11: 441–450

Callahan, H.S. and M. Pigliucci, 2002. Shade-induced plasticity and its ecological significance in wild populations of *Arabidopsis thaliana*. *Ecol.,* 83: 1965–1980

Cerdá, P.D. and J. Chory, 2003. Regulation of flowering time by light quality. *Nature,* 423: 881–885

Corbesier, L. and G. Coupland, 2005. Photoperiodic flowering of *Arabidopsis*: integrating genetic and physiological approaches to characterization of the floral stimulus. *Plant Cell Environ.,* 28: 54–66

Dana, L.D., W.H. Ronald and H. James, 1980. Methods for selecting flower quality based on consumer evaluation. *Euphytica,* 29: 641–651

Davies, L.J., I.R. Brooking, J.L. Catley and E.A. Halligan, 2002. Effects of constant temperature and irradiance on the flower stem quality of *Sandersonia aurantiaca*. *Sci. Hort.,* 93: 321–332

Evans, J.R. and H. Poorter, 2001. Photosynthetic acclimation of plants to growth irradiance: the relative importance of specific leaf area and nitrogen partitioning in maximizing carbon gain. *Plant Cell Environ.,* 24: 755–767

Franklin, K.A. and G.C. Whitelam, 2005. Phytochromes and shade avoidance responses in plants. *Ann. Bot.,* 96: 169–175

Imaizumi, T. and S.A. Kay, 2006. Photoperiodic control of flowering: not only by coincidence. *Trends Plant Sci.,* 11: 550–558

Larner, V.S., K.A. Franklin and G.C. Whitelam, 2005. Photoreceptors and light signalling pathways in plants. *In*: Hall, A.J.W. and H.G. McWatters (eds.), *Endogenous Plant Rhythms*, Vol. 21, pp: 107–125

McDaniel, C.N., 1996. Developmental physiology of floral initiation in *Nicotiana tabacum* L. *J. Exp. Bot.,* 47: 465–475

Munir, M., M. Jamil, J. Baloch and K.R. Khattak, 2004. Impact of light intensity on flowering time and plant quality of *Antirrhinum majus* L. cultivar Chimes White. *J. Zhejiang University Sci.,* 5: 400–405

O'Neil, 1992. The photoperiodic control of flowering: Progress toward the understanding of the mechanism of induction. *Photochem. Photobiol.,* 56: 789–801

Pierik, R., G.C. Whitelam, L.A.C.J. Voesenek, H. De Kroon and E.J.W. Visser, 2004. Canopy studies on ethylene-insensitive tobacco identify ethylene as a novel element in blue light and plant-plant signalling. *Plant J.,* 38: 310–319

Schmitt, J. and R.D. Wulff, 1993. Light spectral quality, phytochrome and plant competition. *Trends Ecol. Evol.,* 8: 47–51

Schmitt, J., A.C. McCormac and H. Smith, 1995. A test of the adaptive plasticity hypothesis using transgenic and mutant plants disabled in phytochrome-mediated elongation responses to neighbors. *American Nat.,* 146: 937–953

Schmitt, J., J.R. Stinchcombe, M.S. Heschel and H. Huber, 2003. The adaptive evolution of plasticity: Phytochrome-mediated shade avoidance responses. *Integr. Comp. Biol.,* 43: 459–469

Shikanori, M. and O. Hiroshi, 2000. Effects of reduced irradiance on growth and flowering of Amaryllis (*Hippeastrum* × *hybridum*). *Sci. Bull. Fac. Agric. Kyushu Univ.,* 55: 1–4

Smith, H., 2000. Phytochromes and light signal perception by plants-an emerging synthesis. *Nature,* 407: 585–591

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

Vandenbussche, F., R. Pierik, F.F. Millenaar, L.A.C.J. Voesenek and D.V.D. Straeten, 2005. Reaching out of the shade. *Curr. Opin. Plant Biol.,* 8: 462–468

(Received 22 November 2008; Accepted 02 January 2009)