Pak. J. Bot., 45(5): 1589-1595, 2013.

MANIPULATION OF PLANT GROWTH REGULATORS AND NON-INDUCTIVE PLANT ENVIRONMENT TO CONTROL PLANT HEIGHT OF FACULTATIVE SHORT DAY ORNAMENTAL ANNUALS

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Abstract

Seeds of Facultative SDPs (Zinnia cv. Lilliput, Sunflower cv. Elf, French Marigold cv. Orange Gate, African Marigold cv. Crush, Cockscomb cv. Bombay and Cosmos cv. Sonata Pink) were sown into module trays containing leaf mould compost. After 70% emergence of each cultivar, two experiments were conducted to control plant height. In first experiment, plants of each cultivar were treated with standard dose of widely applied PGRs (30ppm of A-Rest, 30ppm of Bonzi, 1000ppm of Cycocel) along with a control treatment. In second experiment, plants of same cultivars were kept under long day (LD) non-inductive environment for 2, 4, 6 and 8 weeks. After each time scale these plants were transferred to their SD inductive environment chamber until flowering. Findings of this study revealed that all three PGRs significantly ($P<0.05$) reduced plant height of Facultative SDPs as compared to control. Similarly, plants placed for a short duration (2 weeks) under LD non-inductive environment produced more or less similar results as PGRs one. However, if taller plants are preferred then this duration can be extended up to 8 weeks. The advantage of preferring non-inductive environment technique over PGRs one is that it is non-hazardous, environment friendly and less expensive.

Introduction

Many floricultural crops tend to grow taller than desired and require height control measures. The floriculture market requires plant heights range from 2.7 to 3.5 times the pot diameter for example, 16 to 21 inches for a 6-inch pot (Schnelle *et al.,* 1992). Some improved cultivars of short day plants (SDPs) do not need additional height management if they are grown under non-inductive environment (maximum light duration), spaced properly and forced at normal temperatures. However, in some cases additional management procedures are necessary to meet the market requirement. Several categories of plant height control methods are available to growers. However, when deciding the best method, the growers should consider the cost (including equipment, labor and other expenses such as fuel), the effect on crop scheduling and plant quality and consumer's preference (Townsley-Brascamp & Marr, 1995; Kelley *et al.,* 2001). Plant height control through biological means is theoretically the ultimate method. Through plant breeding and selection, a plant cultivar can be developed that grows to the perfect height according to the market demands. Unfortunately, optimum-height-cultivars do not exist for all ornamental plants, so growers must rely on other control mechanisms. They need to carefully investigate what cultivars are available which may grow to the desired height, thus eliminating the need to intervene with artificial height controls (Schnelle *et al.,* 1992).

Control of plant height through physical methods is based on knowing how the growing environment and cultural practices affect plant growth habits such as using plant growth regulators (PGRs), light intensity, pot depth, water and nutrient stress, temperature and appropriate plant scheduling (Schnelle *et al.,* 1992; Brigard *et al.,* 2006). PGRs such as A-Rest, B-Nine, Bonzi, Cycocel, Sumagic, Ethephon & Dikegulac sodium are commonly used to control plant height on commercial scale in floriculture industry. However, besides reducing height, PGRs can make plants more compact, darken leaf color and extend the life of certain species (Holt & Jennings, 1999). Most of the available PGRs are anti-gibberellins, which inhibit gibberellin synthesis within the plant which is responsible for cellular elongation, so without it, cells elongate less, and plants do not grow as tall as it should be. However, ethephon and dikegulac sodium are not anti-gibberellins. Ethephon releases ethylene, which reduces elongation and dikegulac sodium slows the growth of terminal buds by removing apical dominance. The triazoles are also used to control plant height and are chemically related to Bonzi for example, Paclobutrazol & Uniconazole (Magnitskiy *et al.,* 2006; Lund *et al.,* 2007; Lykas *et al.,* 2008). Among non-chemical plant height control methods, one of the easiest ways to reduce height and the need for PGR treatment is to manipulate light environment (Keever & Kessler, 2005; Lykas *et al.,* 2008). Higher light intensity tends to retard plant elongation in most LDPs, resulting in shorter plants at maturity.

It is envisioned that the height of floricultural plants can be controlled by a number of non-chemical methods as the hazard and costs of RGRs is increased. Interest in non-chemical techniques is also increasing because of the tighter controls placed by the government on the use of agricultural chemicals and the public's negative perception of chemicals in general. Consumer's interest is also varies from plant to plant such as dwarf sized poinsettia is highly preferred (Heins & Fisher, 1992; Whipker & Hammer, 1994; Clifford *et al.,* 2004) whereas plant height of three times pot diameter of bedding and cut flower plants are ideal for garden or indoor beautification (Schnelle *et al.,* 1992; Incrocci *et al.,* 1994). To cater effectively the preference of consumers, those involved in the production, development or marketing of ornamentals need to be aware of the relative importance of their choice for specific plant height. Keeping in view this objective, present study was designed to compare chemical (PGRs) and non-chemical methods (duration under non-inductive light environment) and their effect on plant height of Facultative SDPs.

Materials and Methods

This study was carried out in Agricultural Research Institute, Dera Ismail Khan, Pakistan, during the year 2007-2008. Seeds of Facultative 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 and Cosmos (*Cosmos bipinnatus* Cav.) cv. Sonata Pink were sown on 15th of September 2007 into module trays containing locally prepared homogeneous leaf mould compost. Seed trays were kept at room temperature at night and were moved out during the day (08:00-16:00 h) under partially shaded area.

Effects of plant growth regulators on plant height: After 70% seed germination, six replicates of each cultivar were treated with PGRs such as 30ppm of A-Rest (Ancymidol), 30ppm of Bonzi (Paclobutrazol) and 1000ppm of Cycocel (Chlormequat) whereas ten plants were kept as control. A 30mg a.i. of A-Rest and Bonzi powder was dissolved in a 10ml volume of ethanol and then diluted it with 990ml double distilled water (one-liter volume) to prepare a solution of 30ppm (Lopes & Stack, 2003). Similarly, the spray solution of Cycocel was prepared by diluting 8.4ml a.i. of Cycocel into one-liter of double distilled water (1000ppm) as described by the Tol-Bert (1960) and Anonymous (2007). First spray of each PGRs was carried out after three weeks of germination (at the emergence of 2-true leaves) whereas a second spray of same concentration was applied after six weeks of germination.

Effects of LD non-inductive environment on plant height: After 70% seed germination, six replicates of each cultivar of Facultative SDPs were transferred into LD non-inductive environment for a duration of 2, 4, 6 and 8 weeks. After completion of each time scale under LD non-inductive environment plants were shifted to SD inductive environment chambers. Plants remained for 8h (from 08:00 to 16:00h) in the field (outside the non-inductive photoperiod chambers) where they were exposed to natural daylight and temperature (Table 1). At 16:00h each day, all plants were moved into their respective non-inductive photoperiod chambers where they remained until 08:00h the following morning. Photoperiod within LD non-inductive chambers was extended by two 60Watt tungsten light bulbs and one 18Watt warm white florescent long-life bulb (Philips, Holland) fixed above 1m high from the trolleys providing a light intensity (PPFD) of 7μmol m^{-2} s^{-1}. In LD non-inductive photoperiod chambers, the lamps were switched on automatically at 16:00h for a 16h duration. These chambers were continuously ventilated with the help of micro exhaust fan (Fan-0051, SUPERMICRO® USA) with an average air speed of 0.2m.s^{-1} over the plants when inside the chambers, to minimize any temperature increase due to heat from the lamps. Temperature and solar radiation were measured in the weather station situated one kilometer away from the research venue. Temperature was recorded with the help of Hygrothermograph (NovaLynx Corporation, USA) while solar radiation was estimated using solarimeters (Casella Measurement, UK). Plants were potted into 9cm 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 and 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, UK & VSN International Ltd. UK).

Results

Effects of plant growth regulators on plant height: Plant height in Facultative SDPs was decreased significantly ($p<0.05$) when PGRs (30ppm of A-Rest, 30ppm of Bonzi and 1000ppm of Cycocel) were used. Plants treated with PRGs produced stunted stem as compared to control ones however there was a non-significant difference among three PGRs studied. Control plants of Zinnia cv. Lilliput (Fig. 1A) were taller (33.17cm) than the sprayed ones, which reduced plant height up to 36 (Bonzi, 21.33cm), 33 (A-Rest, 22.33cm) and 30% (Cycocel, 23.33cm). It was also observed that Sunflower cv. Elf (Fig. 1B) reduced plant height up to 37, 34 and 30% when treated with A-Rest (22.33cm), Bonzi (21.33cm) and Cycocel (23.33cm), respectively. However, maximum plants height (28.83cm) was recorded in those plants which were raised as control. Similarly, French Marigold cv. Orange Gate (Fig. 1C) produced maximum plant height (27.50cm) in untreated control plants however it was decreased significantly (42, 34 and 31%) when they were treated with Cycocel (15.83cm), Bonzi (18.17cm) and A-Rest (19cm). In African Marigold cv. Crush (Fig. 1D) plant height was reduced up to 43 (Cycocel, 18cm), 41 (Bonzi, 18.50cm) and 36% (A-Rest, 20.17cm) as compared to control (31.50cm). Similarly, Fig. 1E showed that PGRs spray reduced plant height of Cockscomb cv. Bombay up to 41 (Cycocel, 47.50cm), 39 (Bonzi, 49.17cm) and 31% (A-Rest, 55.33cm) as compared to control plants (80.17cm). Plant height was reduced significantly (41, 39 and 37%) when Cosmos cv. Sonata Pink (Fig. 1F) was sprayed with Cycocel (38.67cm), Bonzi (39.33cm) and A-Rest (40.83cm). However, control plants were taller (64.83cm) than the treated ones.

Table 1. Environmental detail of experiment.

Growing Season	Diurnal temperature (°C)			Daily light integral 08:00-16:00	Day length (hours)
	Max.	Min.	Avg.		
September	36.53	24.00	30.27	9.69 MJ.m^{-2}.d^{-1}	14.25
October	34.16	15.42	24.79	8.64 MJ.m^{-2}.d^{-1}	13.12
November	27.27	11.03	19.15	7.74 MJ.m^{-2}.d^{-1}	12.39
December	22.32	4.52	13.42	7.58 MJ.m^{-2}.d^{-1}	12.15
January	22.35	3.94	13.15	7.39 MJ.m^{-2}.d^{-1}	12.12

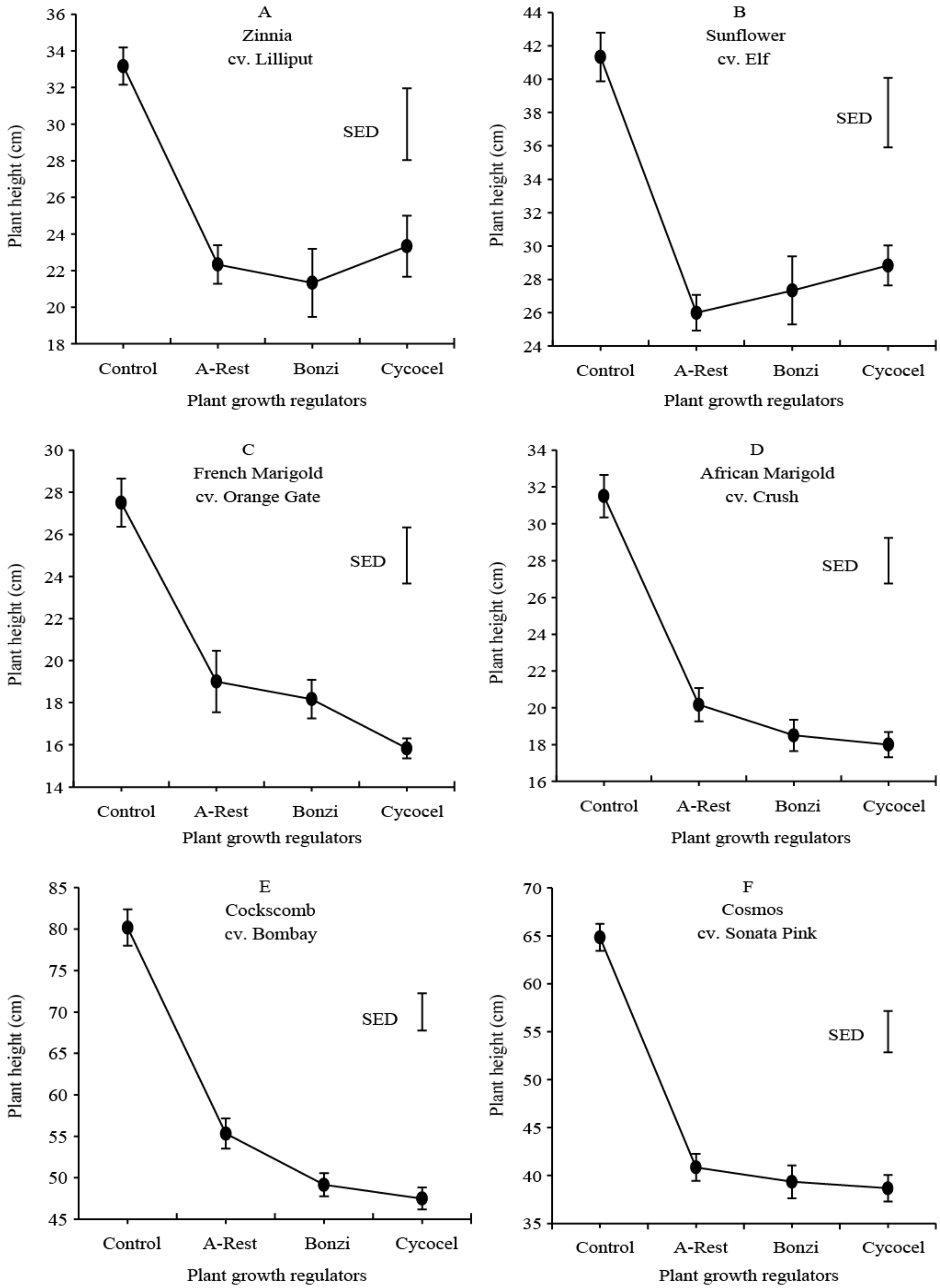

Fig. 1. Effects of PGRs on plant height of (A) Zinnia cv. Lilliput, (B) Sunflower cv. Elf, (C) French Marigold cv. Orange Gate, (D) African Marigold cv. Crush, (E) Cockscomb cv. Bombay and (F) Cosmos cv. Sonata Pink. Vertical bars on data points (where larger than the points) represent the standard error within replicates whereas SED is the standard error of difference within means.

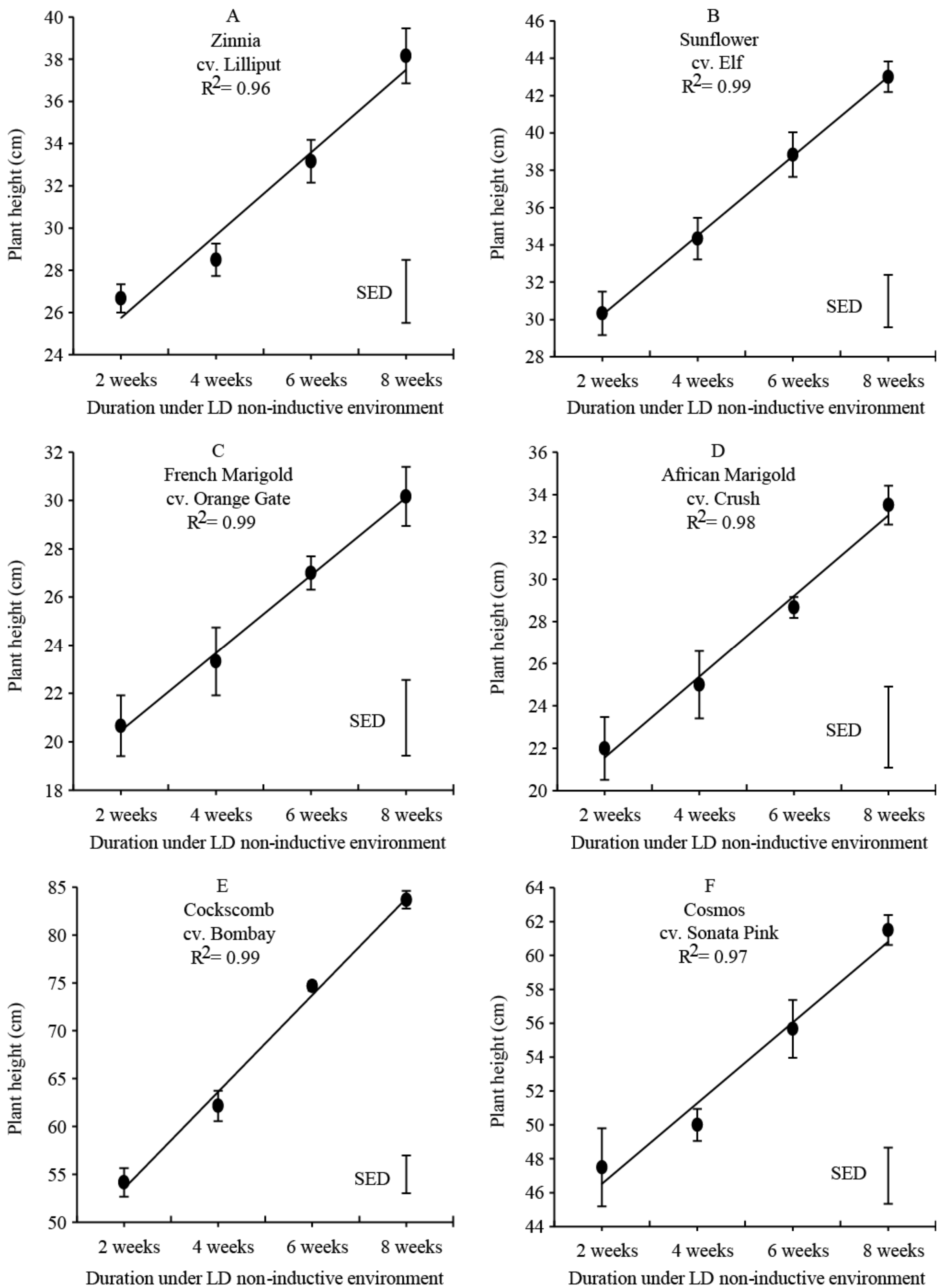

Fig. 2. Effects of LD non-inductive environment on plant height of (A) Zinnia cv. Lilliput, (B) Sunflower cv. Elf, (C) French Marigold cv. Orange Gate, (D) African Marigold cv. Crush, (E) Cockscomb cv. Bombay and (F) Cosmos cv. Sonata Pink. Vertical bars on data points (where larger than the points) represent the standard error within replicates whereas SED is the standard error of difference within means.

Effects of LD non-inductive environment on plant height: The duration of LD non-inductive environment (2, 4, 6 and 8 weeks in LD) significantly ($P<0.05$) controlled plant height in Facultative SDPs. Plants grown for a minimum duration (2 weeks) in LD environment were shorter than those grown for a maximum duration (8 weeks) in the same LD non-inductive environment. In general, a linear trend was observed between short and long durations i.e. plant height was increased linearly with the increase in duration of LD non-inductive environment.

Plants of Zinnia cv. Lilliput (Fig. 2A) grown for 8 weeks in LD environment were taller (38.17cm) than those which were kept for 2 weeks (26.67cm), 4 weeks (28.50cm) and 6 weeks (33.17cm) in the same environment. It was reduced up to 30, 25 and 13% in 2, 4 and 6 weeks LD duration, respectively. It was also observed that Sunflower cv. Elf (Fig. 2B) reduced plant height up to 30, 20 and 10% when grown in LD for 2 (30.33cm), 4 (34.33cm) and 6 weeks (38.83cm), respectively. However, maximum plants height (43cm) was recorded in those plants which were kept for 8 weeks in the same environment. Similarly, French Marigold cv. Orange Gate (Fig. 2C) attained maximum plant height (30.17cm) in 8 weeks LD duration, however, it was decreased significantly (32, 23 and 11%) when grown in 2 (20.67cm), 4 (23.33cm) and 6 weeks (27cm) LD environment, respectively. In African Marigold cv. Crush (Fig. 2D), plant height was reduced up to 34 (2 weeks, 22cm), 25 (4 weeks, 25cm) and 14% (6 weeks, 28.67cm) as compared to 8 weeks duration plants (33.50cm). Similarly, Fig. 2E showed that different duration of LD non-inductive environment reduced plant height of Cockscomb cv. Bombay up to 35 (2 weeks, 54.17cm), 26 (4 weeks, 62.17cm) and 11% (6 weeks, 74.67cm) as compared to plants in LD for 8 weeks (83.67cm). Plant height was reduced significantly (23, 19 and 10%) when Cosmos cv. Sonata Pink (Fig. 2F) was grown in LD environment for 2 (47.50cm), 4 (50cm) and 6 weeks (55.67cm). However, plants in the same environment for 8 weeks attained 61.50cm height.

Discussion

In our previous studies, we focused on flowering time of Facultative SDPs under different light environments (Baloch *et al.,* 2009a, b; Baloch *et al.,* 2010; Baloch *et al.,* 2013a, b). However, consumer's preference regarding plant height characteristic is also coupled with the bedding or cut flower annuals, therefore, present experiment was designed to compare chemical and non-chemical methods which affect plant height parameter. Findings of present research indicated that PGRs such as A-Rest, Bonzi & Cycocel significantly reduced plant height in Zinnia (30-36%), Sunflower (30-37%), French Marigold (31-42%), African Marigold (36-43%), Cockscomb (31-41%) and Cosmos (37-40%). These PGRs are successfully used to control plant height in Zinnia (Latimer, 1991; Pinto *et al.,* 2005), Sunflowers (Whipker & Dasoju, 1997; Dasoju & Whipker, 1997), *Tagetes patula* (Pasian & Bennett, 2001), *Tagetes erects* (Latimer, 1991; Runkle *et al.,* 2006), *Celosia* (Shaw *et al.,* 1999; Magnitskiy *et al.,* 2006; Runkle *et al.,* 2006) and many other herbaceous annuals.

Present results revealed that Bonzi reduced 36% plant height of Zinnia followed by A-Rest (33%) and Cycocel (30%), which are in line with Latimer (1991) where Bonzi (40ppm) significantly reduced plant height of Zinnia and Pinto *et al.,* (2005) where Bonzi (0.5, 0.75 and 1.0mg a. i. per pot) and Cycocel at 1.0g L^{-1} both reduced plant height. Similarly, spray of A-Rest (30ppm) reduced plant height of Sunflower up to 37% followed by Bonzi (34%) and Cycocel (30%). Dasoju & Whipker (1997) observed more than 27% reduction in plant height of Sunflower cv. Pacino when Bonzi is used as drench application (32mg a.i. per pot). Similarly, plants height of French Marigold was reduced up to 40% when Cycocel (1000ppm) is applied followed by Bonzi (34%) and A-Rest (31%). Pasian & Bennett (2001) recorded 30%, 38% and 41% reduction in plant height of *Tagetes patula* when seeds were soaked in 500mg L^{-1} Bonzi for 6, 16 and 24 hour, respectively. Present research also indicated that plant height of African Marigold was significantly retarded when Cycocel (43%), Bonzi (41%) and A-Rest (36%) were applied. Latimer (1991) reported similar results in *Tagetes erects* when Bonzi and A-Rest were used. However, 0.30mg uniconazole drench application inhibited shoot length in *Tagetes* by 13% (Runkle *et al.,* 2006). In Cockscomb, 41% plant height was reduced by Cycocel application (1000ppm) followed by Bonzi (39%) and A-Rest (31%). Runkle *et al.,* (2006) obtained 36% reduction in plant height of *Celosia* by the drench application of 0.30mg uniconazole. However, Magnitskiy *et al.,* (2006) reported that the elongation of *Celosia* seedlings was reduced by soaking seeds in 10, 50, 200 or 500mg L^{-1} Bonzi solutions for 5, 180, or 360 minutes.

Generally, the dwarfing of ornamental plants is done by chemical control method or the use of plant growth control substances, such as phytohormones. With the demand for environmental preservation growing, other controlling methods should be adopted such as modifying the light environment (light duration, light intensity and light quality). Present research findings also suggested that plant height was significantly affected by manipulating the duration of non-inductive environment. Previously, some research work has been done to control plant height using light duration (Carvalho & Heuvelink, 2003; Karlsson & Werner, 2005), light intensity (Fukuda *et al.,* 2002; Carvalho & Heuvelink, 2003) and light quality (Rajapakse *et al.,* 2001; Runkle & Heins, 2002; Clifford *et al.,* 2004; Ilias & Rajapakse, 2005; Lund *et al.,* 2007; Lykas *et al.,* 2008). These studies were mainly focused on light intensity and quality to retard plant height such as Blom *et al.,* (1995) observed a linear increase in plant height of *Lilium longiflorum* (SDP) from high to low light intensity. Research work has also been done on light quality when photo-selective plastic filters that reduce the transmission of far-red light (700-800nm) to potentially reduce plant height in SDP Chrysanthemum (Lund *et al.,* 2007). Present research work not only provide an opportunity to reduce plant height by growing SDPs under inductive or LD non-inductive environment for 2 weeks but if the consumers choice is other way round and taller bedding or cut flower plants are desirable then these SDPs can be kept for 4 to 8 weeks under the same non-inductive environment. Karlsson & Werner (2005) reported that Sunflower plant height was doubled when they were kept for 1-4 weeks under non-inductive environment. Similar results were obtained in present study when plant height of Zinnia, Sunflower, French and African Marigold, Cockscomb and Cosmos was increased up to 30-35% under 8 weeks in LD non-inductive environment. Though there are some reports on use of Biochemicals to promote plant growth in Pakistan (Yoon-Ha Kim *et al*., 2012; Kang *et al*., 2012), but this report will improve such understanding.

Conclusion

Results of present investigation revealed that PGRs (30ppm A-Rest, 30ppm Bonzi and 1000ppm Cycocel) significantly reduced plant height of Facultative SDPs as compared to control. Plants placed for a short duration (2 weeks) under LD non-inductive environment produced more or less similar results as the PGRs ones. However, if taller plants are required then this duration can also be extended up to 8 weeks. The advantage of non-inductive environment technique over PGRs one is that it is non-hazardous, environment friendly and less expensive. Therefore, this technique is not only an alternative method for growers but it can be incorporated with an appropriate photoperiod to obtain early, mid and late flowering along with an apt plant height in accordance with the consumers' choice.

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(Received for publication 2 February 2012)