

Growth and flowering response of snapdragons after release from apical dominance

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Abstract

Plants of an early flowering *Antirrhinum* cultivar 'Chimes White' were pinched at 4, 5, 6, and 7 leaf-pair stage to observe the effects on flowering time and plant quality. Though control plants flowered earlier (81 days) than the pinched ones, they produced less number of flower buds. Flower time and rate of progress to flowering in pinched plants increased linearly and significantly. The quality of pinched plants regarding branch numbers, leaf area, plant height, plant fresh weight *etc.* was significantly improved in all treatments. Many plant growth parameters were successfully fitted by the second degree polynomial model whereas linear model indicated a good fit in reproductive development.

Key words: *Antirrhinum majus*, snapdragon, apical dominance, growth, flowering.

Introduction

Snapdragons, apart from been grown as bedding plants and as a cut flower crop, can also be grown as pot plants, as they have a high flower bud to vegetative growth ratio, mature quickly and a range of brightly coloured cultivars are available. Disadvantages when grown as pot plants are that they may grow too tall and so are not self-supporting and a large central flowering inflorescence initially dominates the plant (Wainwright and Irwin, 1987). One possible method of overcoming these problems and producing a well-proportioned flowering pot plant could be to practice pinching technique.

Pinching is the removal of the apical bud to release the lower axillary buds from apical dominance in order to increase branching and stimulate axillary bud development. Apical dominance has been linked to auxins produced in the apical bud, which may indirectly inhibit lateral bud growth. Gocal *et al.* (1991) measured the concentration of IAA in axillary buds after pinching and found that IAA concentrations, firstly, increased and then remained constant. This was accompanied by an increase in the fresh weight of the buds. However, auxins are not the only hormones that control axillary bud growth. Cytokinin content has also been shown to increase after pinching (Mader *et al.*, 2003; Bangreth, 1994; Turnbull *et al.*, 1997). Exogenously applied cytokinin was found to have the same effect as pinching (Bangreth, 1994; Chen *et al.*, 1997). Therefore, there may be an antagonistic relationship between auxin and cytokinin in the control of apical dominance.

Release of apical dominance by pinching has been shown to have significant effects on yield in many crops. In rooted cuttings of chrysanthemum, pinching is used to produce a marketable spray shape. The 'time pinch' must be carried out at a particular time in order to allow a flower bud to initiate in the centre of the spray. This will develop into an arrangement of inflorescences on peduncles of a desired length (Kofranek, 1981). Post (1949) suggested that axillary meristems of chrysanthemum can show a

period of insensitivity to photoperiod when released from apical dominance, but a contradictory result was reported by Adams *et al.* (1998), who found that chrysanthemum plants were capable of responding to short days immediately following pinching. This method of removing apical dominance is also found to delay flowering but did not affect plant height or plant width (Starman and Faust, 1999).

In winter cultivars of *Antirrhinum* (Coronette Yellow and Coronette Scarlet), pinching produces plants with significantly reduced plant height, shorter but increased number of flower spikes and lengthened flowering time. The pinching stage does not seem to influence plant height, but pinching carried out at later stage of plant development reduced the spike length and prolonged flowering time. Pinching at the third pair of leaves from the base of plant produced maximum flower spikes in the shortest time. These effects of pinching are a result of a more even distribution of assimilates between several growing points rather than just one. The delay in flowering is a result pushing the plant back to the juvenile phase. In this way, pinching appears to maintain the juvenile phase for longer and the precise cause of the flowering delay, which may be attributed to the axillary shoots being in a less advanced physiological phase than apical shoot (Wainwright and Irwin, 1987). The stage at which the plants are pinched, though, was found to have significant effects on the time of flowering and the length of spike, the following experiment was however undertaken to evaluate the effect of pinching at different stages of plant development (4, 5 and 6 leaf-pair stage) on the flowering and plant growth of *Antirrhinum*.

Materials and methods

Seeds of *Antirrhinum majus* L. cultivar Chimes White were obtained from Colegrave Seeds Ltd., Banbury, U.K., and were sown on 2nd February 2000 into module trays (P135, volume of each cell, 20ml; 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 $20 \pm 1^\circ\text{C}$ in a growth room providing a photosynthetic photon flux density of $72 \mu\text{mol m}^{-2} \text{s}^{-1}$ 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 d^{-1} photoperiod.

After 70% seed germination, plants were transplanted into 9 cm pots (volume 370ml) containing a mixture of peat-based compost (SHL) and perlite (3:1 v/v) and kept in a glasshouse (7.3m x 11.3m). Ten plants in each treatment were pinched when they produced 4, 5, 6, and 7 pair of leaves. Same number of plants were left without pinched as control. In the glasshouse, all plants were equally spaced to avoid the light competition among them and were subjected to 20°C constant temperature (19.8°C actual temperature) until flowering. The set point temperature was maintained with ventilation and a water pipe heating system above 3°C . Temperature was recorded inside the glasshouse compartments using a sensor situated in an aspirated

screen attached to a data-logger. In the temperature-controlled compartment, PT100 4 wire platinum resistance sensor was connected to a data-logger (Datataker 500, Data Electronics, Letchworth Garden City, U.K.) recording temperature at every 15s. Tube solarimeters were used to measure the average light transmission into the glasshouse and approximately $6.88 \text{ MJ. m}^{-2} \text{.d}^{-1}$ 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 $1500 \mu\text{S cm}^{-2}$ (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 regression and analysis of variance technique of GENSTAT-5, Release 4.1 (Lawes Agricultural Trust, Rothamsted Experimental Station, U.K.).

Results

Directly Measured Parameters

Flowering parameters: Fig. 1A show that time to flowering increased linearly when pinched leaf-pair numbers were increased ($P < 0.05$). An early flower anthesis (81 days) was recorded in control plants followed by 91 days in 4 leaf-pair. However, plants pinched at 7 leaf-pair stage took maximum time to flower (126 days). Similarly, the rate of progress to flowering ($1/f$) was the inverse function to the pinching treatments *i.e.* when plants were pinched late, rate of progress to flowering decreased (Fig. 1B). Similar to time of flowering, a linear relationship between pinching treatments and number of flower buds was observed ($P < 0.05$). Fig. 1C revealed that minimum flower buds (26) were produced by the control plants. Among pinching treatments, 33 flower buds were noted in 4 leaf-pair treatment whilst 58 flower buds were produced in 7 leaf-pair pinching treatment.

Plant quality parameters: A linear increase in number of branches was observed between control and 7 leaf-pair pinching treatments. Minimum branches per plant (77) were produced by control plants followed by 84 in 4 leaf-pair treatment. Branch numbers increased significantly ($P < 0.05$) in all subsequent treatments and up to 119 branches were produced in 7 leaf-pair treatment (Fig. 1D). Leaf numbers below inflorescence did not change following pinching after pinching the plants maintained the same leaf number present at the time of pinching. However, maximum leaf number (20) was produced in control (Fig. 1E). Control plants and those pinched at 4 leaf-pair stage produced minimum leaf area (79 cm^2), which was significantly ($P < 0.05$) different than the other treatments (Fig. 1F). However, it was observed maximum in plants

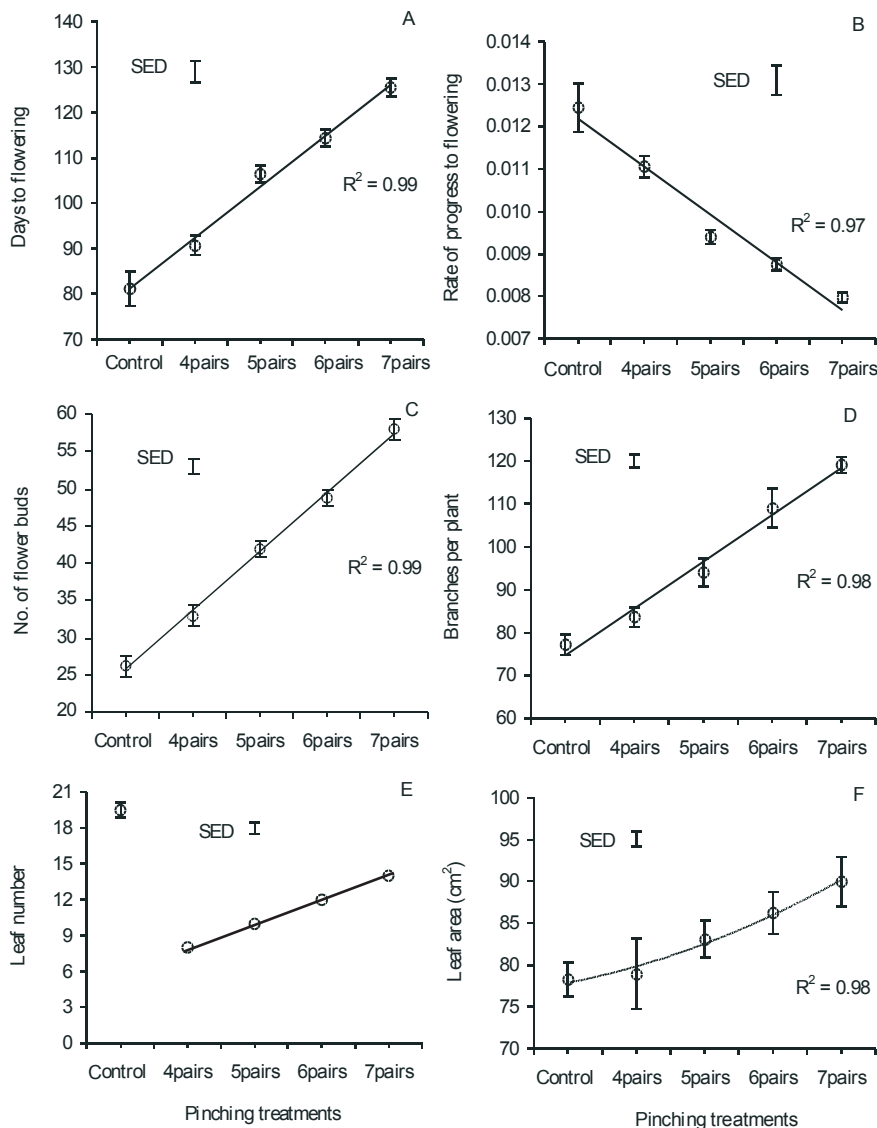


Fig. 1. Effect of different pinching treatments on (A) days to flowering, (B) rate of progress to flowering ($1/f$), (C) Number of flower buds, (D) No. of branches per plant, (E) leaf numbers, and (F) leaf area (cm^2). Vertical bars (where larger than the points on lines) represent the standard error (SE) of variability within replicates, whereas the separate ones represent the standard error of difference (SED) between means.

pinched at 7 leaf-pair stage (90 cm²). As control plants were not pinched therefore they continued their apical growth and attained maximum height (21 cm) as compared to the pinched plants (12–17 cm), which were forced to have a limited size (Fig. 2A). A curvilinear response was observed in plant fresh (Fig. 2B) and dry weight (Fig. 2C). Plants pinched at 7 leaf-pair stage produced maximum plant fresh (34.12 g) and dry (5.25 g) weights. This trend significantly ($P < 0.05$) declined in all preceding treatments including control plants, which produced minimum fresh and dry weights (15.12 and 3.37 g, respectively).

Derived Parameters

A gradual but significant ($P < 0.05$) increase in leaf area ratio (LAR) was seen between control and 7 leaf-pair pinched plants (Fig. 2D). Un-pinched plants (control) have minimum LAR (1184.01 cm² g⁻¹), which gradually increased in all subsequent treatments. However, maximum LAR (3076.76 cm² g⁻¹) was estimated in plant pinched at 7 leaf-pair stage. A fairly similar trend (Fig. 2E) was observed in relative growth rate (RGR) where minimum RGR was observed in control plants (15.12 d⁻¹) whereas it was maximum (34.12 d⁻¹) in plants received 7 leaf-pair pinching treatment. Net assimilation rate (NAR) showed an opposite curvilinear response to those in LAR and RGR parameters (Fig. 2F). As plants in control treatment took minimum time to flower, they had a maximum NAR (0.07 g cm⁻¹ d⁻¹) whereas it was estimated minimum (0.03 g cm⁻¹ d⁻¹) in plants pinched at 7 leaf-pair stage and they took more time to flower.

Discussion

Flowering was generally delayed by pinching, as all of the pinched treatments produced their first flower later than the control plants (Fig. 1A). This delay in flowering seems to be a result of pushing the plants back to the juvenile phase after pinching. The later the pinching occurred, the later the plants flowered. The precise cause of flowering delay may be attributed to the axillary shoots being in a less advanced physiological phase than the apical shoot, as they begin to develop only after pinching. Present results of summer cultivar Chimes White are coincided with winter cvs. Coronette Yellow and Coronette Scarlet (Wainwright and Irwin, 1987). Another possible cause could be the interception of developmental signals from leaves to the apical meristem, which normally carries genes to change growing meristem from vegetative to reproductive phase. If plants are pinched before the perception of development signal in the leaves, induction will never occur and plants never become competent to release the stimulus towards apex (Munir, 2003; McDaniel, 1996). Similarly, in roses, pinching of the apical meristem enhanced the suitability of axillary meristem to determine florally after obtaining a specific nodes/leaf number (Cockshull and

Horridge, 1977). The difference in flowering time can be directly linked to the branch numbers, leaf area, plant fresh and dry weights. It can be assumed from the present study that when plants produced more branches, larger leaf area, maximum fresh and dry weights, they took more time to flower. This indicates that after pinching, plants remained juvenile for longer time than the un-pinched ones and as a consequence the release of developmental stimulus was delayed.

The co-ordination of promotive root-sourced cytokinin (CK) and inhibitory shoot apex-sourced auxin (IAA) is central to all current models on lateral bud dormancy release. For example, in chickpea it has been observed that three potential lateral bud growth inhibitors, IAA, ABA, and *cis*-zeatin 9-riboside (ZR), declined sharply in the released buds and xylem following pinching. This is in contrast to potential dormancy breaking CKs like *trans*-ZR and *trans*-zeatin 9-riboside 5' phosphate (ZRMP), which represented strongest correlative changes by increasing 3.5 fold in xylem sap and 22-fold in buds. However, polyamines had

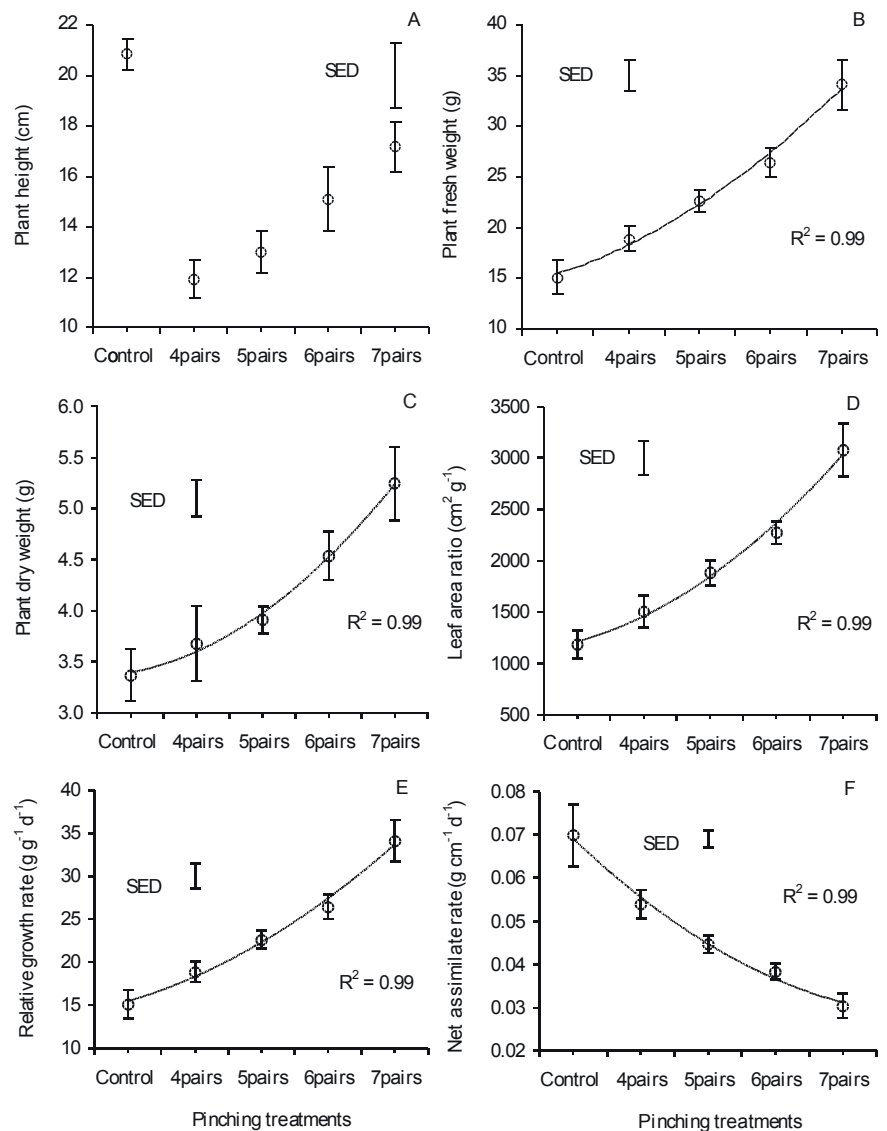


Fig. 2. Effect of different pinching treatments on (A) plant height (cm), (B) plant fresh weight (g), (C) plant dry weight (g), (D) leaf area ratio cm² g⁻¹, (E) relative growth rate (d⁻¹), and (F) net assimilate rate (g cm⁻¹ d⁻¹). Vertical bars (where larger than the points on lines) represent the standard error (SE) of variability within replicates, whereas the separate ones represent the standard error of difference (SED) between means.

not changed significantly in buds or other tissues, so they were not directly involved in the breaking of bud dormancy (Mader *et al.*, 2003). This evidence could be related to the present study on *Antirrhinum* that what would happen at the apex and in the xylem when a plant is released from apical dominance.

The major advantage of pinching is that the pinched plants produced maximum flower buds at harvest (Fig. 1C). This could be a result of more even distribution of assimilates between several growing points (in axillary branches) rather than just the apical one (as in control plants). The later the pinching the greater was the number of flower buds, although they took longer to flower. Similar findings were obtained in *Antirrhinum*, chrysanthemum and cowpea (Wainwright and Irwin, 1987; Starman and Faust, 1999; Argall and Stewart, 1984).

Pinching is a method that can be used to produce well-proportioned plants, suitable for selling as high quality pot-plants and also as a method of controlling the time of flowering, when plants are required for selling them flowered at a certain time and occasion. Similarly, plant quality was much improved in plants pinched at 5-7 leaf-pair stage at the expense of flowering time. Therefore, proper manipulation of the above-mentioned protocol can be used commercially to get maximum outcome.

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