0.45 mg/pot. Plant height was reduced acceptably without reduction in bract size and without bract distortion by applying paclobutrazol as a drench at 0.24 mg/pot or less in one application.

Combining the results from the two experiments, we conclude that application time is critical to control late stretch without significantly reducing bract area. Plant height and bract area were reduced excessively when paclobutrazol was applied anytime from start of short days to first bract color. Plant height was acceptably reduced without statistically significant reduction in bract area when paclobutrazol was applied at 1 mg·L⁻¹ as a drench 1 or 2 weeks after first bract color. Paclobutrazol had a larger effect when applied as a subapplication. Our study indicated that application concentrations lower than 1 mg·L⁻¹ were inadequate, and concentrations >2 mg·L⁻¹ were unnecessary.

Literature cited

Barrett, J. 1999. Bottoms up with growth regulators. *Greenhouse Product News* 9(9):32-33.

Barrett, J. and C. Wieland. 1997. Improve the quality of your poinsettias. *Greenhouse Product News* 7(8):14-17.

Cox, D. 2000. Late season application of paclobutrazol to control stretch of poinsettia. *S.E. Floricult.* 10(5):18-20.

Faust, J.E. and R. Klein. 1998. The five factors that contribute to late-season stretch in poinsettias and how to apply growth regulators to compensate for them. *Greenhouse Product News* 8(10):19-22.

Faust, J.E., P.C. Korczynski, and R. Klein. 2001. Effects of paclobutrazol drench application date on poinsettia height and flowering. *HortTechnology* 11(4):557-560.

Fisher, P. and R. Heins. 1997. Height control—From pinch to first color. *Greenhouse Growers* 15(10):81-82.

Hammer, P.A. 1996. Poinsettia primer. *GrowerTalks* 59(14):42, 44, 46-50.

Hartley, D.E. 1992. Poinsettias, p. 305-331. In: R. Larson (ed.). *Introduction to floriculture*. 2nd ed. Academic Press, San Diego, Calif.

Moore, S.R. 1996. Late growth regulator tips. *GrowerTalks* 60(7):52.

Effects of Paclobutrazol and Chlormequat on Growth and Flowering of Lavender

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ADDITIONAL INDEX WORDS. growth retardants, greenhouse, pot plants, *Lavandula stoechas*

SUMMARY. Growth retardants allowed production of more uniform, compact, flowering plants for commercial use of lavender (*Lavandula stoechas*). Paclobutrazol at 200, 400 and 600 mg·L⁻¹ (ppm) was sprayed in a single or double application. Chlormequat was applied at 4000, 6000 and 8000 mg·L⁻¹ in single, double or triple spray applications repeated every 13 days. Paclobutrazol reduced lateral shoot elongation and plant height, increased the number of nodes within lateral shoots, but delayed time to anthesis. In contrast, chlormequat reduced plant height with no effect on flowering. Paclobutrazol potentially may be used commercially on lavender at rates of 200 to 400 mg·L⁻¹ in single or double applications. The same result may be achieved with chlormequat by using 4000 to 6000 mg·L⁻¹ in three or more applications.

The demand for wild plant species native to Mediterranean regions is increasing as consumers ask for innovative and

ecologically diverse products. The commercial availability of such species is limited, mainly because the growing techniques for large-scale production are still under development. Lavender is a small perennial shrub that is native to many Mediterranean regions (Herrera, 1991; Kokkalou, 1988; Scroubis, 1985). It has a potential as a flowering pot plant if the uneven vegetative growth and flowering can be controlled.

Chlormequat and paclobutrazol are two commercially available growth regulators known to reduce shoot elongation and plant height and to cause uniform and earlier flowering of ornamental plants (Barett et al., 1994; Carpender and Carlson, 1970; Goulston and Shearing, 1985; Rathore et al., 1981; Sanderson et al., 1988; Tezuka et al., 1989). There have been many studies of their effects on ornamental plant growth and development (Cox and Keever, 1988; Hagiladi and Watad, 1992; Rathore et al., 1981; Tayama and Kuack, 1983; Wilkinson and Richards, 1987, 1988, 1991); however, their application on lavender has not been tested. This study was conducted to investigate the potential of the use of chlormequat and paclobutrazol to control the length and the number of nodes of the shoots and the height and flowering of lavender plants.

Materials and methods

CULTURAL PRACTICES. The experiment was carried out from November to May at Thessaloniki in northern Greece. Rooted apical stem cuttings were transplanted in 5.5-L (1.45-gal) pots containing a 3 gravel : 3 Lithuanian peatmoss : 2 sand mixture. The pots were placed on bottom heated benches in a double-plastic greenhouse at a density of 16 plants/m² of bench area (1.5 plants/ft²). Air temperature in the greenhouse was maintained between 16 and 25 °C (60.8 and 77.0 °F) using heating and fan and pad cooling. After a 10-d acclimation, the plants were pinched to five nodes.

TREATMENTS. The treatments started 3 d after pinching and consisted of one or two paclobutrazol applications at 200, 400 or 600 mg·L⁻¹ and one, two or three chlormequat applications at 4000, 6000 and 8000 mg·L⁻¹. The spraying solution also contained a surfactant [Tween 20 (0.1% v/v); ICI Americas, Wilmington, Del.] and was applied at a rate of 192 mL·m⁻² (0.6 fl oz/ft²). Multiple applications were

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performed at 13-d intervals. Each treatment was applied on 15 randomly selected plants. The treatments were applied during morning hours. Control plants were not sprayed.

MEASUREMENTS. Plants that reached anthesis with at least one well-formed inflorescence with two to five open flowers were recorded daily. The experiment ended 170 d after the first spray application. At this time, the number of nodes and the length of four randomly selected shoots per plant and plant height, defined as the vertical distance from the surface of the substrate to the top edge of the last leaf, were measured.

STATISTICAL ANALYSIS. All statistical analyses in the study were performed with the SPSS for Windows release 9.0.1 software. (SPSS, Chicago) and used the univariate analysis of variance syntax. Multiple mean comparisons were accomplished with the Duncan multiple range test at $P \leq 0.05$.

Results

Chlormequat treatments had no effect on the number of nodes or the days to anthesis (Fig. 1). In contrast, paclobutrazol treatments decreased shoot length, and plant height, but increased the number of nodes of the shoots and the days to anthesis.

CHLORMEQUAT. Chlormequat reduced the length of the shoots when applied twice at 4000 mg·L⁻¹, or three times at 8000 mg·L⁻¹ (Fig. 1A). All chlormequat treatments reduced plant height. The reduction of shoot length was not the result of a reduction of the number of nodes on the shoots, since the treatments did not affect significantly the number of nodes per shoot (Fig. 1C). In contrast, the increased shoot length observed with three applications at 6000 mg·L⁻¹ (Fig. 1A) may be due to the observed increase of the

number of nodes (Fig. 1C). The later may be the result of a chlormequat induced delay of flower induction, as can be deduced from the increased time to anthesis by the plants within this treatment (Fig. 1G).

PACLOBUTRAZOL. The shoots of plants treated with 400 mg·L⁻¹ paclobutrazol were 24.5% (one application) to 63% (two applications) shorter than the shoots of the control plants (Fig. 1B). Paclobutrazol treated plants were from 28.7% to 46.9% shorter than the control plants (Fig. 1F). Spraying plants once at 600 mg·L⁻¹ or twice in any concentration seemed to increase node appearance (Fig. 1D). This effect, combined with the reduction of the mean shoot length, indicated a very significant mean internode length reduction may occur when using paclobutrazol once at 600 mg·L⁻¹ or twice at 200, 400 or 600 mg·L⁻¹. The increased shoot node number resulting from these treatments seemed to be due to a delay of flower induction (Fig. 1H).

Discussion

Paclobutrazol significantly reduced shoot length of lavender as it did on hybrid fuchsia (*Fuchsia ×hybrida* 'Mantilla') (Roberts et al., 1990), princess flower (*Tibouchina urvilleana*) (Roberts and Eaton, 1988), tenweeks stock (*Matthiola incana*) (Ecker et al., 1992), african marigold (*Tagetes erecta*), and french marigold (*T. patula*) (Keever and Cox, 1989). This resulted in shorter plants. Shoot length and height reduction increased with increasing concentration up to 600 mg·L⁻¹ and number of applications up to two.

Chlormequat applied at a rate of 4000 to 8000 mg·L⁻¹ was less effective than paclobutrazol in terms of plant height reduction. Higher chlormequat concentrations are not recommended for lavender because marginal necrosis on the top (edge) of both young and old leaves was observed, especially with the first application of 8000 mg·L⁻¹. This problem did not appear during the fol-

Fig. 1. Length (A and B), number of nodes (C and D) of the shoots, plant height (E and F) and days to anthesis (G and H) of control plants and plants treated once, twice, or three times with three concentrations of chlormequat [4000, 6000, or 8000 mg·L⁻¹ (ppm)] and once or twice with three concentrations of paclobutrazol (200, 400, or 600 mg·L⁻¹) after 170 d of cultivation. Values are means of four shoots of 15 plants per treatment for shoot height and node number and of 15 plants per treatment for plant height and days to anthesis. Columns with the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$; 1 cm = 0.4 inch.

lowing applications but the marginal necrosis remained and was progressively covered by the new vegetation. The same problem was also reported for zonal geranium (*Pelargonium ×hortorum*) and carnation (*Dianthus caryophyllus*) (Foley and Keever, 1991). It should be noted that despite the fact that chlormequat did not reduce plant height as much as the paclobutrazol applications, lavender plants sprayed with chlormequat had a better appearance than the control plants. Lateral shoots in treated plants were more uniformly distributed inside the volume occupied by the plant, which that was not the case for the plants treated with paclobutrazol. Unfortunately, the appropriate data to demonstrate this observation is not available. It might be interesting to investigate the possibility to further reduce plant height with more frequent applications of chlormequat, with an interval less than 13 d.

Data suggests that, in northern Greece, lavender plants transplanted in November and grown in temperatures ranging from 16 to 25 °C, without growth regulators, can reach commercial maturity in 117 d (end of February). At this time the plants may be about 40 cm (15.8 inches) in height. For the condition, "plant height or volume = twice the volume or height of the pot" to be satisfied, the plants should be potted in pots 20 cm (7.9 inches) tall. Compact flowered ornamentals are usually sold in pots 14 cm (5.5 inches) tall, thus an acceptable plant height is about 28 cm (11 inches). Chlormequat treatments from 4000 to 8000 mg·L⁻¹ applied up to three times at 13-d intervals were not adequate to satisfy this requirement. In contrast, one application of paclobutrazol at 200 or 400 mg·L⁻¹ or two applications at 200 mg·L⁻¹ generated plants that were 28.9, 28.2 and 27.0 cm (11.4, 11.1 and 10.6 inches) tall, respectively. However, the application of 400 mg·L⁻¹ once and 200 mg·L⁻¹ twice may also delay flowering by as much as 12 d and 20 d, respectively. The flowering delay occurring with two applications of 200 mg·L⁻¹ might be beneficial, because the shoots will produce two additional nodes when compared to the control, and this will result in a denser plant canopy. The importance of this delay depends on the marketing target set by the grower and on the cost of production, which might be very elevated by the end of February. During this period frosts are very fre-

quent in Mediterranean climates. Additionally the heating cost per plant will be increased by the end of cultivation because of the wider spacing of the plants. Thus one application at 200 mg·L⁻¹ seems optimal for lavender. Financial benefits that might be achieved from the potential quality improvement by doubling the concentration or the number of applications, must recompense for the additional heating, greenhouse space occupation and application costs. Assuming that the mean price of Bonzi [4 g·L⁻¹ (4000 ppm) paclobutrazol (a.i.); Zeneca Corp., Stoney Creek, Ont., Canada] is about \$115/L (\$109/qt) (Bailey and Whipker, 1998), the solution alone is expected to cost an additional \$0.069/plant.

Conclusions

One paclobutrazol spray at 200 mg·L⁻¹ on lavender was found to be very effective in producing flowered pot plant that satisfied the 2 plant : 1 pot height or volume condition, using standard pots 14 cm tall. Applying 400 to 600 mg·L⁻¹ paclobutrazol concentrations once or twice in a 13-d interval, adequately reduced plant height but also significantly delayed flowering.

Up to three applications of chlormequat with concentrations ranging from 4000 to 8000 mg·L⁻¹ were found not sufficient to reduce plant height; however, it was observed that chlormequat treatments produced more uniform plants. This is believed to be due to a better partitioning of growth between competing shoots. Further research should be conducted to test the effect of more than three chlormequat applications with concentrations up to 8000 mg·L⁻¹ on plant height.

Literature cited

- Barrett, J.E., C.A. Bartuska, and T.A. Nell. 1994. Comparison of paclobutrazol drench and spike applications for height control of potted floriculture crops. *HortScience* 29(6):180-182.
- Bailey, D.A. and B.E. Whipker. 1998. Height control of commercial greenhouse flowers. N.C. State Univ. Coop. Ext. Serv., Raleigh, Hort. Info. Lft. 528.
- Carpender, W.J. and W.H. Carlson. 1970. The influence of growth regulators and temperature on flowering of seed propagated geraniums. *HortScience* 5(3):183-184.
- Cox, D.A. and G.J. Keever. 1988. Paclobutrazol inhibits growth of zinnia and geranium. *HortScience* 23(6):1029-1030.
- Ecker, R., A. Barzilay, L. Afgin, and A.A. Watad. 1992. Growth and flowering responses of *Mathiola incana* L.R. BR. to paclobutrazol. *HortScience* 27(12):1330.
- Foley, J.T. and G.J. Keever. 1991. Growth regulators and pruning alter growth and axillary shoot development of *Dianthus*. *J. Environ. Hort.* 9(4):191-195.
- Goulston, G.H. and S.J. Shearing. 1985. Review of the effects of paclobutrazol on ornamental pot plants. *Acta Hort.* 167:339-348.
- Hagiladi, A. and A.A. Watad. 1992. *Gordyline terminalis* plants respond to foliar sprays and medium drenches of paclobutrazol. *HortScience* 27(2):128-130.
- Herrera, J. 1991. Allocation of reproductive resources within and among inflorescences of *Lavandula stoechas* (Lamiaceae). *Amer. J. Bot.* 78(6):789-794.
- Keever, G.J. and D.A. Cox. 1989. Growth inhibition in marigold following drench and foliar-applied paclobutrazol. *HortScience* 24(2):390.
- Kokkalou, E. 1988. The constituents of the essential oil from *Lavandula stoechas* growing wild in Greece. *Planta Medica* 54:58-59.
- Rathore, S.V.S., R. V. Gore, and I.J. Singh. 1981. Effect of maleic hydrazide (MH) and chlormequat (CCC) on the performance of annual chrysanthemum. *J. Agr. Sci. Res.* 21(1):26-29.
- Roberts, C.M. and G.W. Eaton. 1988. Response of *Tibouchina* to chlormequat, paclobutrazol, and fertilizer. *HortScience* 23(6):1082.
- Roberts, C.M., G.W. Eaton, and F.M. Seywerd. 1990. Production of *Fuschia* and *Tibouchina* standards using paclobutrazol or chlormequat. *HortScience* 25(10):1242-1243.
- Sanderson, K.C., W.C. Martin, and J. McGuire. 1988. Comparison of paclobutrazol tablets, drenches, gels, capsules and sprays on chrysanthemum growth. *HortScience* 23(6):1008-1009.
- Skroubis, B.G. 1985. Lavender, section 2, p. 116-123. In: *Aromatic plants and essential oils*. Offset Giahoudi-Giapouli, Ltd, Thessaloniki, Greece.
- Tayama, H.K. and D.L. Kuack, 1983. Foliar spray versus soil-drench applications of chlormequat on poinsettias. *Flor. Rev.* 173(4481):32-33.
- Tezuka, T., C. Takahara, and Y. Yamamoto, 1989. Aspects regarding the action of CCC in hollyhock plants. *J. Exp. Bot.* 40(215):689-692.
- Wilkinson, R.I. and D. Richards. 1987. Influence of paclobutrazol on growth and flowering of *Bouvardia humboldtii*. *HortScience* 22(3):444-445.
- Wilkinson, R.I. and D. Richards. 1988. Influence of paclobutrazol on growth and flowering of *Camellia × Williamsii*. *HortScience* 23(2):359-360.
- Wilkinson, R.I. and D. Richards. 1991. Influence of paclobutrazol on growth and flowering of *Rhododendron* 'Sir Robert peel'. *HortScience* 26(3):282-284.