Leaf Area Response of *Lantana camara* L. subsp. *camara* to Plant Growth Regulators under Different Photosynthetic Flux Conditions

Aristidis S. Matsoukis,¹ Ioannis Tsiros,² and Athanasios Kamoutsis²

Department of General Sciences, Agricultural University of Athens, 75, Iera Odos Str., Athens 11855, Greece

Additional index words. light intensity, lantana, leaf area, triazoles, onium-type compounds

Abstract. The effect of various plant growth regulators on leaf area development of *Lantana camara* L. subsp. *camara* was investigated under three photosynthetic photon flux (PPF) conditions (100%, 72%, and 34% light transmittance). The triazole compounds paclobutrazol (0, 50, 100, 200, and 500 mg·L⁻¹) and triapenthenol (175, 350, 700, and 1400 mg·L⁻¹), as well as the onium-type compounds mepiquat chloride (125, 250, 500, and 1000 mg·L⁻¹) and chlormequat chloride (750, 1500, 3000, and 6000 mg·L⁻¹), were applied as foliar spray solutions in each PPF level after pinching the plants. Leaf area, in general, decreased logarithmically as the concentrations of paclobutrazol and triapenthenol increased at all PPF levels. On the other hand, PPF reduction was found to increase leaf area of lantana plants treated with all concentrations of each regulator. Leaf area reduction of the paclobutrazol and triapenthenol treated plants at all PPF levels exceeded 60% compared with that of nontreated plants. However, the corresponding reduction was 22%, up to 51% for the plants treated with mepiquat chloride and chlormequat chloride. These results indicate that the triazole compounds have a greater effect on the reduction of lantana leaf area than the onium-type compounds. Chemical names used: (2RS, 3RS)-1-(4-chlorophenyl)-4, 4-dimethyl-2-(1H-1, 2, 4-triazol-1-yl) pentan-3-ol (paclobutrazol); (E)-(RS)-1-cyclohexyl-4,4-dimethyl-2-(1H-1, 2, 4-triazol-1-yl) pent-1-en-1-ol (triapenthenol); 1,1-dimethyl-piperidinium chloride (mepiquat chloride); (2-chloroethyl) trimethylammonium chloride (chlormequat chloride).

Plant growth regulators (PGRs) serve many purposes in commercial plant production (Gianfagna, 1990). For example, they are applied on horticultural crops to reduce shoot growth without lowering flower productivity (Rademacher, 2000). They are also used to reduce leaf area of various ornamental plants as in the case of the triazole paclobutrazol. Yewale et al. (1998) reported that paclobutrazol was very effective at reducing several growth parameters of *Dendranthema* sp., including leaf area and, thereby producing more compact plants. Paclobutrazol was also found to reduce leaf area of *Fuchsia* × *hybr.* 'Balerina' and 'Beacon' (Bazzocchi et al., 2001), *Pelargonium zonale* (Nasr, 1995) and *Ligustrum japonicum* (Ruter and Martin, 1994). Further, leaf area decrease was also reported on *Euphorbia pulcherrima* Willd. 'Gutbier V-10 Amy' (Lee et al., 1998) and *Salvia splendens* plants (Mao et al., 1991) after treatments with chlormequat chloride, an onium-type regulator; the same PGR also reduced bract diameter of *Euphorbia pulcherrima* (Elkiey et al., 1987). However, information on the role of the triazole triapen-

thenol and the onium-type compound mepiquat chloride on the leaf area of ornamental plants is not available.

Lantana is an evergreen tropical shrub with several species being in cultivation as greenhouse ornamentals for their attractive vibrantly colored flowers; one of these, *Lantana camara*, a prickly stem shrub with aromatic leaves (Heywood, 1982), is also used in xeriscape landscaping (Ellefson et al., 1992). Previous studies reported that paclobutrazol, triapenthenol and chlormequat chloride play a positive role on the ornamental potential (small height accompanied with increased flowering) of potted lantana plants (Elkiey et al., 1987; Matsoukis et al., 2001; Matsoukis and Chronopoulou-Sereli, 2000). The purpose of the study is to evaluate the effects of the above PGRs and mepiquat chloride on the leaf area of *Lantana camara* L. subsp. *camara*. In addition, since the role of PPF conditions on the canopy structure is of special importance for commercial growing of ornamental crops (Albright, 1997; Al Juboory et al., 1998; Myster, 1999), different PPF conditions were considered.

Materials and Methods

The research was carried out from June to November 1998 in a greenhouse located in Attica (37°48'N, 23°57'E), Greece. Rooted cuttings of *Lantana camara* L. subsp. *camara* were produced under mist propagation from

16 to 18-cm-long midstem cuttings, each with one leaf pair. The cuttings were treated with a commercial growth regulator (Rooton 0.066%; I.B.A., Sege, Greece) and placed in perlite rooting medium. Temperatures were 15 to 20 °C and 20 °C in the air and the rooting substrate, respectively. Eleven weeks later, rooted cuttings were placed in 1.1-L (14-cm-diameter) plastic pots (one cutting per pot) containing a peat potting substrate (Klasmann-Deilmann; GmbH, Germany), pruned and transferred to the greenhouse. After 4 weeks the plants received a commercial liquid fertilizer containing trace elements (Complezal Fluid-AgrEvo; Hellas Co., Athens, Greece), with 50 mL solution per pot (1 mL·L⁻¹ water, 5N–8P–10K). Ten days later the plants were pinched at the second internode from the tips; the experiments started 12 d later (on 20 June) when the new-developing stems had a length of ≈1 cm. There were no flower buds present.

Foliar spray solutions (0.25 L/plant) of paclobutrazol (Cultar 25% w/v, Zeneca) of concentrations of 0, 50, 100, 200, and 500 mg·L⁻¹, triapenthenol (Baronet 70% w/w, Bayer, Germany) of concentrations of 175, 350, 700 and 1400 mg·L⁻¹, mepiquat chloride (Pix 5 A.S. 5% w/v; BASFAG, Germany) of concentrations of 125, 250, 500 and 1000 mg·L⁻¹ and chlormequat chloride (Affix 60 A.S. 60% w/v; Chemische produkten, Germany) of concentrations of 750, 1500, 3000, and 6000 mg·L⁻¹ were applied 11 d after pinching. All treatment solutions were applied with a surfactant (Agral 90, 94.8% w/w nonylphenoethoxylate Zeneca) at a rate of 0.25 mL·L⁻¹ solution.

Four experiments (one for each growth regulator) were carried by using the two-factor factorial experiment in a completely randomized design. The first factor had three shading levels created by using polyethylene nets. So, there were plots covered with black thin and dense woven nets (models 103 and 201; Manioudaki Bros S.A. knitting factory, Greece), while a nonshaded plot was also included. The second factor had five levels corresponding to the concentrations of each growth regulator (including the 0 mg·L⁻¹ concentration). There were eight one-plant replicates.

Hourly photosynthetic photon flux (PPF) measurements were taken during daytime, from 0500 to 1600 hr Greenwich meridian time under the shading materials and at the top of the plant canopies; three quantum sensors (LI-190 SA; LI-COR, Lincoln, Nebr.) (sensitivity of 8 μA/1000 μmol·m⁻²·s⁻¹), each connected to a datalogger (LI-1000; LI-COR), were used. During the experimental period, PPF ranged from 430 to 1340 μmol·m⁻²·s⁻¹ for the nonshaded plot (R₁), while for the shaded plots (R₂ and R₃) it ranged from 300 to 970 and 170 to 470 μmol·m⁻²·s⁻¹, respectively. The three PPF regimes for R₁, R₂ and R₃ plots (100%, 72%, and 34% light transmittance, respectively) provided average daily light quantities of 30.7 ± 1.3 (mean ± SE), 21.9 ± 0.8 and 10.3 ± 0.4 mol·m⁻²·d⁻¹, respectively. Also, environmental data including temperature and relative humidity were monitored by three dataloggers (model 903; Wilh. Lambrecht, GmbH) and sensors for these parameters (model 809 L 0-100 of

Received for publication 15 July 2002. Accepted for publication 28 Dec. 2003. This work has been partly funded by the State Scholarships Foundation of Greece. The first author thanks Charles Stirton for the identification of the experimental plants.

¹Research agronomist. To whom reprint requests should be addressed; e-mail armatsoukis@aau.gr.

²Lecturer.

Wilh. Lambrecht GmbH, Germany; accuracy $\pm 0.3^\circ\text{C}$ at 0°C and $\pm 2.5\%$ for temperature and relative humidity respectively).

At the end of the experimental period (23 Nov.), 128 leaves from each PGR treatment were collected (in total 2176 leaves for each plot). The collection was made from the second to ninth node of the highest shoot for each plant. The leaf length, width and area were measured with an area meter (maximum length 1 m, width 1 to 127 mm, accuracy $\pm 2\%$ for samples with area $>50\text{ cm}^2$) (LI-3000 A; LI-COR). For the leaf area data, recorded means were calculated for each experimental plant and used, separately for each PGR, for the analysis of variance (ANOVA) according to the previously mentioned experimental design. The two (out of eight) extreme means of each PGR concentration were excluded from the data before the analysis. Where appropriate, treatment means were compared using least significant difference (LSD) test. Also, the leaf area means of each PPF level were regressed against concentrations of each PGR with the use of statistical models (Dimopoulos, 1997). Statistical analysis was performed using Statgraphics plus, version 2.1 for Windows.

Results and Discussion

The shading materials affected both temperature and humidity regimes. More specifically, mean daily maximum and minimum temperatures ranged from 29.3 ± 0.7 (mean $\pm$ SE) to 33.0 ± 0.6 and from 17.7 ± 0.5 to $18.1 \pm 0.4^\circ\text{C}$, respectively with their higher values at the nonshaded plot (R_0). On the contrary, the mean daily relative humidity showed its higher value (62.8%) at the R_3 shaded plot without differing more than 3.5% among the plots.

ANOVA showed that PGR and PPF both had significant effects on leaf area, but there was no interaction between the two factors. Plants treated with any of the growth regulators had significantly less leaf area than nontreated plants independently of PPF level (Fig. 1a and b, Fig. 2a and b). These results are in agreement with previous findings for paclobutrazol (Bazzocchi et al., 2001; Latimer, 1991) and chlormequat chloride (Mao et al., 1991) effects on other ornamental plants. The leaf area showed a significant reduction tendency as the concentrations of paclobutrazol and triapenthenol increased (Fig. 1a and b). On the other hand, the increased concentrations of chlormequat chloride and mepiquat chloride ($>250\text{ mg}\cdot\text{L}^{-1}$)

had no noticeable effect on the leaf area of the lantana plants (Fig. 2a and b). Regression analysis of leaf area on PGR concentrations indicated that logarithmic equations provided the best fit for all PPF levels (Fig. 1a and b, Fig. 2a and b); these results are in contrast with those of LeCain et al. (1986) who found linear response of the *Ficus benjamina* leaf area with increased paclobutrazol concentrations.

Also, PPF reduction, in general, led to a significant increase of the leaf area of experimental lantana plants (Fig. 1a and b, Fig. 2a and b). Published works reported various radiation responses on leaf area of ornamental plants. Yeh and Atherton (1999) did not find any response for *Cineraria* sp. Bange et al. (1997) also found that lower incident radiation had no effect on leaf area of *Helianthus annuus*. Plant leaf areas of *Eucalyptus marginata* (Jarrah) and *Ilex paraguariensis*, however, were found to be less for sunlight-exposed plants than for plants grown under shade (Riveros Rey, 1990; Stoneman and Dell, 1993). A similar inverse relation between light intensity and leaf area was reported for *Phalaenopsis* hybrid (Kim et al., 1999), *Euonymus japonicus* 'Luna' (Hosni and Shehata, 1996), and *Photinia x fraseri* plants (Norcini et al., 1991). Also, Brand (1997) found that the leaf area of several *Kalmia latifolia* cultivars decreased with increasing levels of

shade. Further, no change in the leaves' shape of the experimental plants (data not shown) was observed among the plants treated with the same regulator at all PPF levels.

In our experiments the leaf area reduction of the paclobutrazol and triapenthenol treated plants exceeded 60% at all PPF levels in comparison to nontreated plants; reduction was 22% up to 51% for plants treated with mepiquat chloride and chlormequat chloride. These results indicate that triazole compounds have a greater effect on the reduction of lantana leaf area than the onium-type compounds under the typical greenhouse conditions examined in this study. Therefore, we can conclude that the treated with paclobutrazol and triapenthenol plants appear to have an improved floral display; this may contribute to an enhanced aesthetic quality in commercial production of potted lantanas. Future studies should focus on the effects of other PGRs on leaf growth of other ornamental plants under various micrometeorological conditions.

Literature Cited

Albright, L.D. 1997. Greenhouse thermal environment and light control, p. 33–47. In: E. Goto, K. Kuratam, M. Hayashi, and S. Sase (eds.). Plant production in closed ecosystems. Intl. Symp. Plant Production in Closed Ecosystems,

Fig. 1. Effect of the growth regulators (a) paclobutrazol (0, 50, 100, 200, and $500\text{ mg}\cdot\text{L}^{-1}$) (b) triapenthenol (0, 175, 350, 700, and $1400\text{ mg}\cdot\text{L}^{-1}$) and light transmittance (100%, 72%, and 34% at the plots R_1 , R_2 , and R_3 , respectively) on leaf area of *Lantana camara* L. subsp. *camara*. Each value is the mean of six replications. The vertical bars are LSD values for the main effects ($***P = 0.001$) of plant growth regulator (PGR) and photosynthetic photon flux (PPF). R1Obs, R2Obs, R3Obs, and R1Est, R2Est, R3Est are the measured and estimated leaf area values, respectively. R^2 =coefficient of determination. The slopes of regression lines yR2 and yR3 for paclobutrazol do not differ significantly ($P = 0.05$) and the pooled slope is -2.349 .

Narita, Japan. Kluwer Academic Publ., The Netherlands.

Al-Juboori, K.H., D.J. Williams, R. Skirvin, and D.G. Bullock 1998. Influence of photoperiod, photosynthetic photon flux, and temperature on growth of canary island ivy. *HortScience* 33(2):237–239.

Bange, M.P., G.L. Hammer, and K.G. Rickett 1997. Effect of radiation environment on radiation use efficiency and growth of sunflower. *Crop Sci.* 37(4):1208–1214.

Bazzocchi, R., M.E. Giorgioni, and B. Bedonni 2001. Modificazioni morfologiche indotte da paclobutrazolo ed uniconazolo in *Fuchsia x hybr.* (I deg contributo). *Italus Hortus* 8(1):26–33.

Brand, M.H. 1997. Shade influences plant growth, leaf color, and chlorophyll content of *Kalmia latifolia* L. cultivars. *HortScience* 32(2):206–208.

Dimopoulos, I. 1997. La mise en œuvre des modèles statistiques linéaires et non linéaires en sciences de l'environnement, p. 350. Doctorat, Thèse de l'Université Paul Sabatier-Toulouse III, France.

Elkiey, T., M. Haikel, and A. Nooh 1987. Application of growth regulators for the adaptation of some perennial plants to container production. *Gartenbauwissenschaft* 52(5):210–213.

Ellefson, C., T. Stephens, and D. Welsh 1992. Xeriscape gardening. Water conservation for the American landscape. Macmillan Publ. Co., Boston.

Gianfagna, T.J. 1990. Natural and synthetic growth

regulators and their use in horticultural and agronomic crops, p. 614–635. In: P.G. Davies (ed.). Plant hormones and their role in plant growth and development. Kluwer Academic Publ., Dordrecht, The Netherlands.

Heywood, V.H. 1982. Popular encyclopedia of plants, p. 191. Cambridge Univ. Press, Cambridge, U.K.

Hosni, A.M. and S.A.M. Shehata 1996. Influence of shading on specific leaf weight, leaf thickness and internal structure of leaves in *Euonymus japonicus* cv. "Luna". *Ann. Agr. Sci.* 41(1):397–411.

Kim T., J. Kim, J. Lee, C. Lee, H. Lee, K. Choi, and K. Paek 1999. Effect of photosynthetic photon flux on growth and flowering in highland culture of *Phalaenopsis* hybrid. *J. Kor. Soc. Hort. Sci.* 40(5):611–614.

Latimer, J.G. 1991. Growth retardants affect landscape performance of *Zinnia*, *Impatiens* and marigold. *HortScience* 26(5):557–560.

Lee, E., S. Chung, S. Lee, and K. Choi 1998. Effects of plant growth retardants on the growth and flowering in poinsettia (*Euphorbia pulcherrima* Willd.). *RDA J. Hort. Sci.* 40(1):102–106.

LeCain, D.R., K.A. Schekel, and R.L. Wample 1986. Growth-retarding effects of paclobutrazol on weeping fig. *HortScience* 21(5):1150–1152.

Mao, L.S., Y. Gao, Y.Y. Yao, Y. Qian, and Y.L. Tang 1991. Dwarfing effects of paclobutrazol, daminonide and chlormequat on potted scarlet sage. *Acta Hort. Sinica* 18(2):177–179.

Matsoukis, A. and A. Chronopoulou-Sereli 2000. The creation of compact plants of *Lantana camara* L. subsp. *camara* with the aid of plant growth regulators. *Acta Hort.* 541:311–316.

Matsoukis, A.S., A. Chronopoulou-Sereli, I.D. Dimopoulos, and A. Kamoutsis 2001. Response of *Lantana camara* L. subsp. *camara* to paclobutrazol and shading. *Can. J. Plant Sci.* 81(4):761–764.

Myster, J. 1999. The effects of temperature alterations, irradiance level, photoperiod, and day extension light quality on morphogenesis, growth and flowering of *Begonia xhiemalis* Fotsch. *Gartenbauwissenschaft* 64(5):206–213.

Nasr, M.N. 1995. Effect of methods of application and concentration of paclobutrazol on *Pelargonium zonale* (L.) L'Her. ex Ait. as a pot plant. *Alexandria J. Agr. Res.* 40(3):261–279.

Norcini, J.G., P.C. Andersen, and G.W. Knox 1991. Light intensity influences leaf physiology and plant growth characteristics of *Photinia xfraseri*. *J. Amer. Soc. Hort. Sci.* 116:1046–1051.

Rademacher, W. 2000. Growth retardants: Effects on gibberellin biosynthesis and other metabolic pathways. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 51:501–531.

Riveros Rey, F.E. 1990. Relación entre materia seca y diámetro de las ramas en plantas de yerba mate. *Revista Forestal-Universidad Nacional de Asunción, Carera de Ingeniería Forestal* 6(1):26–31.

Ruter, J.M. and C.A. Martin 1994. Effects of contrasting climate and paclobutrazol on the growth and water use of two container-grown landscape plants. *J. Environ. Hort.* 12(1):27–32.

Stoneman, G.L. and B. Dell 1993. Growth of *Eucalyptus marginata* (Jarrah) seedlings in a greenhouse in response to shade and soil temperature. *Tree Physiol.* 13(3):239–252.

Yeh, D.M. and J.G. Atherton 1999. Effects of irradiance on growth and flowering in the shade plant, cineraria. *Ann. Appl. Biol.* 134(3):329–334.

Yewale, A.K., P.V. Belorkar, M.A. Chanekar, J. Bhattacharya, and B.S. Chimukar 1998. Effect of growth-retardant paclobutrazol on growth parameters of chrysanthemum. *J. Soils Crops* 8(1):82–84.

Fig. 2. Effect of the growth regulators (a) mepiquat chloride (0, 125, 250, 500, and 1000 mg·L⁻¹), (b) chlormequat chloride (0, 750, 1500, 3000, and 6000 mg·L⁻¹) and light transmittance (100%, 72%, and 34% at the plots R₁, R₂, and R₃, respectively) on leaf area of *Lantana camara* L. subsp. *camara*. Each value is the mean of six replications. The vertical bars are LSD values for the main effects (***, P=0.001) of plant growth regulator (PGR) and photosynthetic photon flux (PPF). R1Obs, R2Obs, R3Obs, and R1Est, R2Est, and R3Est are the measured and estimated leaf area values, respectively. R²=coefficient of determination. The slopes of regression lines yR1, yR2, and yR3 do not differ significantly (P=0.05) and the pooled slopes for mepiquat chloride and chlormequat chloride are -0.976 and -0.693, respectively.