Growth and Flowering of *Lantana camara* L. subsp. *camara* as Affected by Triapenthenol and Environmental Factors

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Abstract. The various concentration effects of the growth regulator triapenthenol (0, 43.75, 87.5, 175, and 350 mg/pot) on the growth and flowering of *Lantana camara* L. subsp. *camara* under different shading levels (0%, 28%, and 66%) were studied in 1997 and 1998 in a glasshouse in Attica, Greece. It was found that minimum temperature and photosynthetic photon flux density were the most important factors to plant growth. The growth index (GI) decreased as the regulator concentration increased while the number of flower heads per plant increased up to a maximum at the concentration of 87.5 mg triapenthenol per pot with a decrease afterwards, at all shading levels. The interaction between shading level and triapenthenol concentration significantly affected GI and flowering of lantana plants. The growth index of the control plants increased and the number of flower heads per plant decreased significantly at all concentration levels examined, as shading increased from 0% to 66%. Triapenthenol resulted in darker green foliage and at higher concentrations in some leaf distortion. The most attractive plants were produced with triapenthenol concentration of 87.5 mg/pot at the nonshaded plot; they were small with the greatest number of flowers. Chemical name used: (E)-(RS)-1-cyclohexyl-4,4-dimethyl-2-(1H-1,2,4-triazol-1-yl)-pent-1-en-3-ol (triapenthenol).

Lantana camara L., a vigorous small shrub (Ruter, 1996), has ornamental interest because of its dense attractive foliage and the multi-coloured flowers (Pizzetti and Cocker, 1975). Due to these features, lantana and especially *Lantana camara* L. subsp. *camara* is used widely in several countries as landscape plant. The use of plant growth regulators is required to produce marketable plants.

Triapenthenol, a growth regulator of the triazole class (Graebe, 1987), has been shown to provide height control at *Pelargonium hortorum* 'Yours Truly' (Tayama and Carver, 1990) and *Fuchsia* sp. (Biermann, 1989), compactness of *Exacum affine* cv. Blue Champion (Barrett et al., 1987); and control of the internode length of many ornamental plants (Lürssen and Reiser, 1987). It was also found that, in general, triapenthenol increases flowering (Lürssen, 1988).

The uptake and translocation of growth regulators is known to be influenced by temperature and light intensity (Muzik, 1976). A change in light intensity by the use of shading

materials above plant canopies in combination with triapenthenol was studied in gardenia (*Gardenia jasminoides*) plants by Kamoutsis et al. (1998).

The present work was carried out to evaluate the effects of triapenthenol on the growth and flowering of *Lantana camara* L. subsp. *camara* under various light levels.

Materials and Methods

The investigation took place from June to Nov. 1997 and 1998 in a glasshouse in Attica (lat. 37°48'20"N, long. 23°57'48"E), Greece. The experimental plant material was started from 16 to 18 cm mid-stem cuttings of lantana, each with one leaf pair. Eleven weeks later, rooted cuttings were placed in 1.1-L (14-cm top diameter) plastic pots (one cutting per pot) containing a white peat potting substrate (Klasmann-Deilmann GmbH, Germany). Plants were pruned to a height of 12 cm and transferred to a nonshaded glasshouse. After 4 weeks, the plants received a commercial liquid fertilizer containing trace elements (Compleal Fluid-AgrEvo; Hellas Co., Athens, Greece), with 50 mL solution per pot (1 mL per liter of water, 5N–8P–10K). Ten days later the plants were pinched in the second internode from the tips; the experiments started 12 d later (on 24 and 20 June, for 1997 and 1998 respectively) when the new-developing stems had a length of ≈1 cm. No flower buds were present.

Triapenthenol (Baronet 70% w/w, Bayer, Germany) was applied once as foliar spray solution (0.25 L/plant), to runoff, on plants of lantana at the concentrations of 0, 175, 350, 700, and 1400 mg·L⁻¹ (0, 43.75, 87.5, 175, and 350 mg/pot a.i., respectively). A surfactant [Agral 90, 94.8% (w/w) nonylphenoethoxylate Zeneca, United States] was used at 0.25 mL·L⁻¹.

The experiment was carried out according to the two-factor completely randomized design. The first factor had three shading levels created using shading polyethylene nets; one black thin and one dense woven (models 103 and 201 respectively of Manioudaki Bros S.A. knitting factory Greece) were placed the first at the R₂ and the second at the R₃ shade plot while a nonshaded plot (R₁) was also existed. The second factor had five levels corresponding to the triapenthenol concentrations. There were eight one-plant replicates.

Environmental data including temperature and relative humidity (RH) were monitored by three dataloggers 903 (Wilh. Lambrecht GmbH, Germany) with sensors for these parameters (model 809 L 0-100 of Wilh. Lambrecht GmbH, Germany; accuracy ±0.3 °C at 0 °C and ±2.5% for temperature and RH respectively). Mean daily maximum and minimum temperatures ranged from 27.2 to 33.0 and 17.1 to 18.1 °C, respectively, with their higher values at the nonshaded plot (R₁) and the second experimental period (1998) being warmer than the first (1997). On the contrary, the mean daily RH was lower at 1998 at all plots without differing more than 5.3% among them. Photosynthetic photon flux density (PPF) measurements were taken hourly during daytime, from 0500 to 1600 hr Greenwich meridian time beneath the shading materials, at the top of the plant canopies, using three LI-190 SA quantum sensors (LI-COR, Lincoln, Nebr.; sensitivity of 8 μA per 1000 μmol·m⁻²·s⁻¹) each connected with a LI-1000 datalogger (LI-COR). During the experimental periods, PPF ranged from 390 to 1340 μmol·m⁻²·s⁻¹ for the nonshaded plot, while for the shaded plots R₂ and R₃ it ranged from 280 to 970 and 140 to 470 μmol·m⁻²·s⁻¹, respectively. The higher mean values of PPF were recorded during 1998 and presented greater reduction with the increase of shading than the other environmental parameters.

Biometric measurements were carried out every 5 d until 18 and 23 Nov. 1997 and 1998, respectively, and included plant height (at the level of the tallest shoot from pot rim), maximum plant diameter (width 1), perpendicular width to maximum diameter (width 2) and the number of flower heads per plant (with three at least open florets). Growth index (GI) was calculated as (height + width 1 + width 2)/3 according to Ruter (1996). To study the change of the GI after pinching (as computed by subtracting initial from final GI) and the total number of flower heads per plant, statistical models were used (Dimopoulos, 1997) and also analysis of variance (after the exclusion for each treatment of the two extreme values) with mean separation by Tukey's honestly significant difference (HSD) test. The combined effects of temperature,

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relative humidity and PPF on plant GI change were evaluated by a step-wise multiple regression analysis technique in each treatment. The statistical analysis was conducted separately for each year of the experiments because the measured plant characteristics appeared statistically significant variation among 1997 and 1998, for a number of same treatments, probably due to the different environmental conditions between the 2 years.

Results and Discussion

During the second experimental period the plants presented greater increases to their GI changes and number of flower heads at all plots due to the more advantageous environmental conditions referred to higher values of PPF and temperature.

Significant differences to the changes of the GI and the total number of flower heads per plant among the various triapenthenol concentrations and shading levels were identified (Table 1). Concentration $\times$ shading level interaction was significant for both cases.

Treated plants with triapenthenol had smaller changes of GI (Figs. 1a and 2a) than the nontreated ones; this reduction may be attributed to the lower content of their biologically active gibberellic acids induced by triapenthenol application (Rademacher, 1991) compared to nontreated plants. According to

Lürssen and Reiser (1987) triapenthenol inhibited gibberellin biosynthesis in vitro between ent-kaurene and ent-kaurenoic acid and may be interfered with both gibberellin and sterol metabolism in plants. Higher triapenthenol concentrations produced smaller plants at all shading levels.

However, the number of flower heads increased with increasing concentrations of triapenthenol up to 87.5 mg/pot, followed by a decrease at higher concentrations (Figs. 1b and 2b), indicating that a saturation point existed above which flowering was decreased. The regulator-treated plants produced more flowers than the nontreated ones which comes to conflict for gardenia treated with triapenthenol at 70, 140, and 280 mg·L⁻¹ (Chronopoulou-Sereli et al., 1998).

Increasing shading from 0% (R₁) to 28% (R₂) reaching 66% at R₃ plot caused generally no significant changes of GI for plants treated with the same concentration of the regulator. On the other hand, the GI of the nontreated plants was increased significantly (Tukey's HSD test); this could be attributed to plants effort to avoid low light environments, a known feature of shade intolerant plants (Tang, 1997). An inverse relation between light intensity and plant growth parameters was also reported by Sim et al. (1997) on *Campanula takesimana*, Norcini et al. (1991) on *Photinia fraseri* and Svenson (1993) on *Acalypha hispaniolae* plants.

The number of flower heads was significantly decreased for the plants treated with the same concentration of the regulator while

Table 1. Analysis of variance for effects of shading level and concentration of triapenthenol on the growth index change (GI) and the number of flowerheads/lantana plant for the years 1997 and 1998.

Source	df	GI (cm)		No. of flowerheads	
		1997	1998	1997	1998
----- Mean square -----					
S ²	2	84.75***	123.43***	4941.70***	5066.10***
CT ²	4	1370.27***	1709.84***	4538.56***	4043.46***
S × CT	8	41.87***	63.43***	101.51***	135.46***
Error	75	0.90	0.82	5.34	6.44

²S = Shading level.

²CT = Concentration of triapenthenol.

***Significant at $P = 0.001$.

Fig. 1. Changes of growth index (GI) and number of flowerheads/lantana plant as a function of triapenthenol concentrations (0, 43.75, 87.5, 175, and 350 mg/pot), at the plots R₁, R₂, and R₃. Growth index = (height of tallest shoot + maximum diameter + perpendicular to maximum diameter)/3. Each value is the mean of six replicates. R1obs, R2obs, R3obs, and R1est, R2est, R3est are the measured and estimated GI (a) and flower (b) values, respectively for 1997.

Fig. 2. Changes of growth index (GI) and number of flowerheads/lantana plant as a function of triapenthenol concentrations (0, 43.75, 87.5, 175, and 350 mg/pot), at the plots R₁, R₂, and R₃. Growth index = (height of tallest shoot + maximum diameter + perpendicular to maximum diameter)/3. Each value is the mean of six replicates. R1obs, R2obs, R3obs, and R1est, R2est, R3est are the measured and estimated GI (a) and flower (b) values, respectively for 1998.

for the nontreated ones significant differences were found only between 0% and 66% as well as 28% and 66% shading (Tukey's HSD test). The great reduction of flowering at R₃ plot could be attributed to the strong light exclusion (Muzik, 1976).

The multiple regression analysis showed that minimum temperature and PPF were the most important factors in plant GI change for 1997 and 1998 respectively (data not shown), at all shading levels. Kamoutsis et al. (1998) reported that the maximum temperature was the most important factor in the development of gardenia.

Plants treated with triapenthenol exhibited darker green foliage than the nontreated ones consistent with previous studies (Lürssen and Reiser, 1987). Some leaf distortion was noticed in plants treated with the higher concentrations of the regulator. Kamoutsis et al. (1998) observed wrinkling on the leaves of *Gardenia jasminoides* treated with triapenthenol.

It is also interesting to note, that the more attractive plants were produced with triapenthenol at the concentration of 87.5 mg/pot at the nonshaded plot; they were small with the greatest number of flower heads, over three times the respective number of the nontreated ones at the same plot.

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