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Salinity and Heavy Metal Stress

SHORT COMMUNICATION

Mepiquat chloride and shading effects on specific leaf area and K, P, Ca, Fe and Mn content of *Lantana camara* L.

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Abstract

The effects of mepiquat chloride (MC) (0, 500 and 1000 mg l^{-1}) on specific leaf area (SLA) and leaf potassium (K), phosphorus (P), calcium (Ca), iron (Fe) and manganese (Mn) content of *Lantana camara* L. plants were examined under 0% and 66% shading levels. All examined parameters and Fe were affected significantly by MC at 66% and 0% shading, respectively. MC decreased SLA of lantana compared to the control (0 mg l^{-1}) irrespective of shading level with no significant differences in general. Increased SLA values were estimated with increased shading. K was increased significantly after spraying with MC at 1000 mg l^{-1}, to a maximum, at 66% shading, compared to 0 mg l^{-1}. P and Fe contents, in general, augmented as MC concentration increased. Mn remained stable with the increasing MC concentrations at 0% shading. On the other hand, Ca and Mn exhibited a significant peak after spray with MC concentration at 500 mg l^{-1}, followed by a slight reduction, at the highest concentration, at 66% shading. K, P and Fe, in most cases, increased significantly, while Ca and Mn, in general, decreased, as shading increased. Our results could aid towards a fertilization program for lantana plants.

Key words: *Lantana camara*, Mepiquat chloride, Mineral content, Shading, Specific leaf area

Introduction

Mepiquat chloride (MC), a gibberellin biosynthesis blocking onium-type regulator (Rademacher, 1991), has been reported to increase the number of flower heads on *Lantana camara* L. subsp. *camara* (lantana) plants (Matsoukis and Chronopoulou-Sereli, 2003), a desirable characteristic for many landscape uses; for example, the creation of attractive flowering plant fences. Although *Lantana camara* might show great ornamental value, because of its beautiful multicoloured flower heads (Heywood, 1982), with a wide use for landscaping in several countries, literature provides no information, to our knowledge, on important parameters of lantana growth after treatments with MC, such as specific leaf area (SLA) and mineral content. The only available information concerning the aforementioned parameters on lantana has been reported by Matsoukis et al. (2007; 2009) for plants treated with the growth regulators paclobutrazol and triapenthenol.

SLA, the projected leaf area per unit leaf dry matter (DM) (Evans and Poorter, 2001), is an important parameter in many agronomic and ecological processes (Awal et al., 2004), where plant nutrient elements are involved. Their requirements can be evaluated by the well-established method of leaf tissue analysis (Van den Driessche, 1974). The knowledge of these requirements may be used for the establishment of appropriate plant fertilization programs. The purpose of this study is to evaluate the effects of MC on SLA and on the contents of K, P, Ca, Fe and Mn in the leaves of lantana under different photosynthetic flux density (PFD) conditions, since their role is of special importance for commercial growing (Al Juboory et al., 1998).

Materials and Methods

Lantana plants derived from 16 to 18 cm mid-stem cuttings were grown in a glasshouse in Attica, Greece located at 37^{0}48΄20΄΄N, 23^{0}57΄48΄΄E. Details of growth and experimental conditions have been reported in Matsoukis and Chronopoulou-Sereli (2003). MC (Pix 5 A.S. 5% w/v, BASF AG, Germany) was sprayed (24 June) on foliage of lantana

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plants at concentrations of 0 (control), 500 and 1000 mg l^{-1}. At the same time, the plants were placed in two plots, under different levels of PFD, i.e. a plot covered with black, dense woven net (66% shading level), model 201 (Manioudaki Bros S.A. knitting factory, Greece) and a non-shaded plot (0% shading level). The two PFD regimes for 0% and 66% shadings provided average daily light quantities of about 27.8 and 9.4 mol m^{-2} d^{-1}, respectively. Mean daily maximum and minimum temperatures ranged from 27.2°C (66% shading) to 30.4°C (0% shading) and from 17.1°C (66% shading) to 17.5°C (non shaded plot), respectively. The mean daily relative humidity (RH) showed its higher value (70%) at 66% shading without differing more than 5.3% between the shading levels. Plants irrigated as needed, with water containing K^+ at 0.05 meq l^{-1}, Ca^{++} at 2.50 meq l^{-1}, Mg^{++} at 3.0 meq l^{-1}, HCO_3^- at 5.0 meq l^{-1}, Na^+ at 0.50 meq l^{-1} and Cl^- at 0.3 meq l^{-1} with a pH of 6.8 and electrical conductivity of 463 μS cm^{-1}.

At the end of the experimental period (23 November), five months after the onset of the trial, 512 leaves, with no signs of senescence, from each MC treatment (consisted of 8 plant-replicates) were collected from each shading level. The collection was made from the second to ninth node of the four highest shoots of each plant. The leaf area (LA) of each leaf (excluding the petiole) was measured with an area meter (LICOR, USA). Leaves (totally 3072) were then oven-dried in paper bags at 65°C for 60 h till constant dry weight, giving a DM. SLA was calculated by dividing LA by DM.

Sub-samples used for the determination of SLA were also used for the determination of K, P, Ca, Fe and Mn. The dry leaf samples were ground (40 mesh sieve) to a fine powder. For the analysis, 0.5 g of ground dry material was placed in porcelain crucibles and ashed in a muffle furnace at temperature of 550°C for 4 h. The ashes were subjected to wet digestion in concentrated HNO_3. K, Ca, Fe and Mn were analyzed with atomic absorption spectrometry (Jones and Case, 1990) while P was determined colorimetrically (Gasparatos et al., 2011). All analyses were made twice and an average value was calculated for each element and plant-replicate per regulator treatment.

The experiment was carried out according to the two-factor completely randomized design. The first factor consisted of the two examined shading levels and the second factor by the three levels of MC treatment. For the SLA data as well as for the mineral element data, means were calculated for each experimental plant and studied parameter and used for the analysis of variance (ANOVA). The two (out of eight) extreme means of each treatment were excluded from the data before the analysis. Due to the non significant interaction of the examined factors ($P > 0.05$), ANOVA was carried out separately at each studied shading. Where the F-test proved significant ($P \leq 0.05$), means were compared by the Tukey's-HSD test. Additionally, t-tests were used for the comparison of the same MC concentrations for each examined parameter between the shading levels. Statistics was performed using SPSS version 21.0 for Windows and MS Excel 2003. Results were considered to be significant at $P \leq 0.05$.

Results and Discussion

All examined parameters and Fe were affected significantly by MC at 66% and 0% shading levels, respectively (Table 1). SLA after treatments with MC at 500 and 1000 mg l^{-1} was always lower than the respective value of control with significant difference in the case of MC at 1000 mg l^{-1}, at the shaded plot (Table 2). This concentration of MC at 66% shading was the most effective in decreasing SLA, compared to control (maximum decrease by 19.1%). It has been reported that MC at 49 g active ingredient (a.i.) ha^{-1} and mepiquat pentaborate at 115 g a.i. ha^{-1} increased specific leaf weight (SLW), equivalent to SLA decrease, as SLW is the inverse of SLA (Steinbauer, 2001), in *Gossypium hirsutum* L. cvs PM 1218BR, STV 4691B, STV 4892BR and DPL 555BR (Pettigrew and Johnson, 2005).

SLA values of lantana under 66% shading were significantly higher in comparison to the respective values at the non shaded plot, when examining the same concentration of the regulator (Table 2). These SLA increases were ranged from 24.6% (MC at 1000 mg l^{-1}) to almost 44.5% (controls) and they were due to the greater increases of LA than DM. These LA increases may be a part of the lantana strategy to increase its competitive ability under 66% shading. A similar hypothesis was suggested by Devkota and Jha (2010) for *Centella asiatica* (L.) Urb. plants grown at similar shading (70%), as these plants presented significantly higher SLA values compared to plants grown at full light conditions.

In agreement with our aforementioned results, Matsoukis et al. (2004) reported that the leaf area of lantana increased at 34% light transmittance (equivalent to 66% shading) compared to 100% light transmittance (equivalent to 0% shading) for each of the examined concentrations of MC at our study. Gobbi et al. (2011) reported increased values of SLA for *Brachiaria decumbens* Stapf. cv. Basilisk and *Arachis pintoi* Krap. *et* Greg. *nom. nud.* cv. Amarillo as shading increased progressively from 0% to 70%.

Table 1. Probabilities of effects of mepiquat chloride on specific leaf area and leaf nutrient content on a dry matter basis of lantana plant at the examined shading levels.

MC[a]											
SLA[b] ($cm^2 g^{-1}$)		K ($mg g^{-1}$)		P ($\mu g g^{-1}$)		Ca ($mg g^{-1}$)		Fe ($\mu g g^{-1}$)		Mn ($\mu g g^{-1}$)	
S[c]											
0%	66%	0%	66%	0%	66%	0%	66%	0%	66%	0%	66%
0.28[d]	4.48	0.05	4.25	3.49	5.05	0.55	5.57	12.15	4.78	2.02	8.96
ns[e]	<0.05[f]	ns	<0.05	ns	<0.05	ns	<0.05	<0.01	<0.05	ns	<0.01

[a]MC: mepiquat chloride, 0, 500 and 1000 mg l^{-1}. [b]SLA: specific leaf area. [c]S: shading level, 0% and 66%. [d]variance ratio. [e]ns: not significant ($P > 0.05$). [f]probability.

The concentration of K in lantana leaves increased significantly after spray with MC at 1000 mg l^{-1}, relatively to 0 mg l^{-1}, to a maximum, at 66% shading. P and Fe contents, in general, augmented as the regulator concentration increased, irrespective of the examined light environment (Table 2). Mn remained stable (i.e., without significant increase) with the increasing concentrations of MC at 0% shading. On the other hand, Ca and Mn showed a significant peak after 500 mg l^{-1} MC spraying, followed by a slight reduction, at the highest concentration of the regulator, at the low light environment (Table 2). The greater content of certain mineral elements in MC-treated plants, in most cases, may be attributed merely to a greater number of cells per unit LA, as this parameter decreased with MC at 500 and 1000 mg l^{-1}, compared to control at both studied light environments. A similar hypothesis was suggested by Monge et al. (1994) for treated *Prunus persica* (L.) Batsch plants with the plant growth regulator paclobutrazol. Also, Matsoukis et al. (2004) reported decreased LA values on lantanas after spray with MC at 500 and 1000 mg l^{-1}. Increased contents of P and Ca have been reported, with higher and lower concentrations of MC than those of our study, in *Gossypium hirsutum* L. cv. Stoneville 825 (Zhang et al., 1990) and *Arachis hypogaea* L. (Jeyakumar and Thangaraj, 1998) plants.

The contents of K, P and Fe, in most cases, increased significantly with the increasing shading from 0% to 66%. These increases ranged from 22.7%, in the case of K, to almost 100% in the case of Fe, at the control plants. On the contrary, Ca and Mn in the leaves of lantana decreased, as the shading increased, although not significantly in some cases. These patterns were more and less pronounced in the cases of Ca (control) and Mn (MC at 500 mg l^{-1}), respectively (Table 2), and could be partly explained by the antagonistic effects among certain mineral elements, like K and P, which increased at 66% shading, against Mn (Kabata-Pendias and Pendias, 2001). In agreement with our data, increased contents of P and K have been reported for *Brachiaria brizantha* (Hochst ex A. Rich.) Stapf. Cv. Marandu, *Brachiaria decumbens* Stapf. and *Melinis minutiflora* Beauv. plants under 60% shading compared to 0% shading (Castro et al., 2001). Nevertheless, decreased contents of Mn (which is in accordance with our results), K and Fe were reported in the leaves of *Swietenia macrophylla* King at 87% shading (Gonçalves et al., 2005).

Conclusion

MC decreased slightly SLA of lantanas compared to control (0 mg l^{-1}), irrespective of shading level. Increased SLA values were estimated with increased shading. The contents of P and Fe, in general, augmented as MC concentration increased. Mn remained stable with increasing concentrations of MC at 0% shading. On the other hand, Ca and Mn exhibited a significant peak after spraying with MC at the concentration of 500 mg l^{-1}, followed by a slight reduction, at the highest concentration of the regulator, under the low light intensity. K, P and Fe, in most cases, increased significantly, while Ca and Mn, generally, decreased, as shading increased from 0% to 66%. Our findings could contribute to the establishment of a fertilization program for *Lantana camara* which is grown extensively as an outdoor ornamental plant, with many uses in landscaping, in Greece and other Mediterranean countries.

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Table 2. Effect of mepiquat chloride on specific leaf area and leaf nutrient content on a dry matter basis of lantana plants at the examined shading levels.

MC[a] (mg l^{-1})	SLA[b] (cm^2 g^{-1} DM[c])		K (mg g^{-1} DM)	
	0% S[d]	66% S	0% S	66% S
0	161.24±12.43[e] a[f] a[g](-4.81)[h]	232.72±8.17 a[f] b	6.60±0.24[1] a[f] a[g](-2.24)[h]	8.10±0.62 a[f] b
500	150.49±13.78 a a[g](-2.51)[h]	201.72±15.08 ab b	6.50±0.50 a a[g](-2.67)[h]	8.70±0.65 ab b
1000	151.11±6.41 a a[g](-3.80)[h]	188.26±7.38 b b	6.40±0.58 a a[g](-5.48)[h]	10.40±0.44 b b
	P (μg g^{-1} DM)		Ca (mg g^{-1} DM)	
	0% S	66% S	0% S	66% S
0	1035.20±149.15a[f] a[g](-2.98)[h]	1508.17±54.81 a[f] b	27.30±2.10 a[f] a[g](5.22)[h]	15.92±0.58 a[f] b
500	1232.89±83.91 a a[g](-7.87)[h]	2114.29±74.20 b b	26.20±1.78 a a[g](2.11)[h]	22.10±0.78 b a
1000	1529.00±154.10a a[g](-2.14)[h]	2162.48±265.49 b a	24.20±2.44 a a[g](2.06)[h]	17.50±2.15 ab a
	Fe (μg g^{-1} DM)		Mn (μg g^{-1} DM)	
	0% S	66% S	0% S	66% S
0	71.00±5.47 a[f] a[g](-9.44)[h]	141.99±5.16 a[f] b	80.00±6.17 a[f] a[g](4.20)[h]	52.90±1.92 a[f] b
500	114.00±10.44 b a[g](-3.74)[h]	176.97±13.23 b b	83.80±7.68 a a[g](1.00)[h]	74.29±5.55 b a
1000	117.01±4.97 b a[g](-6.9)[h]	176.00±6.90 b b	100.71±9.15a a[g](3.44)[h]	68.10±2.47 b b

[a]MC: mepiquat chloride, 0, 500 and 1000 mg l^{-1}. [b]SLA: specific leaf area. [c]DM: dry matter. [d]S: shading level, 0% and 66%. [e]:Mean of the treatment±standard error of the mean, n=6. [f]: In each column, separately for each examined parameter and S, entries with different letters indicate significant differences as regards to different concentrations of MC at *P* = 0.05 by Tukey's-HSD test. [g]: In each row, separately for each examined parameter, entries with different letters indicate significant differences as regards to different Ss at *P* = 0.05 by t-test. [h]: Number in parenthesis is the t-test value, for each studied parameter, for the comparison of the same MC concentrations between the examined Ss.

Author contributions

A. M. contributed to planning, supervision and evaluation of the results. D. G. was involved in the process of analyses and measurements and contributed to the evaluation of the results. A. C. was involved in the general planning and supervision and in the partial evaluation of the results.

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