

THE EFFECT OF DIFFERENT LIGHT CONDITIONS ON THE GROWTH AND DEVELOPMENT OF *CHLOROPHYTUM AMANIENSE* ENGL. 'FIRE FLASH'

Manuela MANDA¹, Carmen NICU¹, Diana ZAMFIR-VÂȘCĂ²

¹University of Craiova, Faculty of Horticulture, 13 Al.I. Cuza Street, Craiova, Dolj, Romania

²University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Mărăști Blvd, District 1, Bucharest, Romania

Corresponding author email: manda_manu@yahoo.com

Abstract

Chlorophytum amaniense Engl. is a foliage plant, member of the family Liliaceae, originates from the rainforests of East Africa. 'Fire Flash', the only cultivar of this species, known by several common names including Fire Glory, Mandarin Plant and Tangerine, present unique decorative characteristics. *C. amaniense*, 'Fire Flash' do not support the direct action of the sun's rays and the placement in bright exposures. Given the claims of *C. amaniense* versus light and insufficient information in the literature, the objective of this research was to study the reaction of 'Fire Flash' under different lighting conditions. Plants attained the greatest leaf size and petioles when 'Fire flash' were grown in low and medium light intensity while plants exposed to high light showed lowest values of growth parameters. In addition, high light intensity produced chlorosis and leaf burn and plants have become unmarketable after a 3 months period. The best size and quality of 'Fire Flash' plants, occurred when plants were grown at a medium light levels of $80 \mu\text{mol m}^{-2} \text{s}^{-1}$.

Key words: *Chlorophytum amaniense*, growth, light, photosynthetic parameters.

INTRODUCTION

The genus *Chlorophytum* belongs to Liliaceae and encompasses about 200 species chiefly native to tropical Africa, Australia and Asia (Anton, 2009). Most species are evergreen perennials with rhizomatous roots either short and fibrous or thick and translucent.

Chlorophytum amaniense Engl., member of the family Liliaceae, is a foliage plant originates from the rainforests of East Africa. 'Fire Flash', the only cultivar of this species, known by several common names including Fire Glory, Mandarin Plant and Tangerine, present unique decorative characteristics (Anton Doina et al., 2006).

Bright coral petioles and midveins contrast with deep green, ovate-lanceolate leaves making an exotic appearing and exciting plant. The flowers are white in a dense cylindrical panicle partially hidden by the foliage.

The inflorescence does not add any value to the aesthetic appearance. In fact, it is detrimental. Removal of the inflorescence at an early stage of flowering improves plant growth (Chen et al., 2002).

Unlike *C. comosum* (Thunb.) Jacques (spider plant), *C. amaniense* 'Fire Flash' does not produce stolons, and propagation could be realized through seed, division and *in vitro* regeneration (Cui et al., 2011).

In addition to ornamental value, the rhizomes of 'Fire Flash' form nearly oval tubers, which may contain antitumor steroidal saponins as do other species of *Chlorophytum* Ker. Gawl (Kaushik, 2005; Cui et al., 2011). Of the twelve species analyzed, *C. amaniense* Engl., showed highest phenol, flavonoid, saponin contents and *in vitro* antioxidant activity (Shinde et al., 2016; Patil, 2016).

'Fire Flash' is grown in shady greenhouses at temperatures between 18-32°C (optimum temperature between 24-29°C) and relative humidity between 50% and 100%. Water used for 'Fire Flash' production should be free of fluoride since it may cause leaf necrosis. Light intensity is extremely important for quality of 'Fire flash' plant production (Chen et al., 2002). *C. amaniense* 'Fire Flash' do not support the direct action of the sun's rays and the placement in bright exposures. Depending on the intensity of light, the leaves may have

different shades from intense green to light green. It also influences the color and length of petioles, these being the main decorative element. Higher light levels will cause leaf chlorosis and, eventually, scorching and necrotic lesions that can cause unsalable plants. Based on the evaluation study, Chen et al. (2005 a) recommended that 'Fire Flash' can be propagated through seed, division, or tissue culture and produced as a potted foliage plant under light levels from 114 to 228 $\mu\text{mol m}^{-2} \text{s}^{-1}$ and temperatures from 18 to 32°C. After being placed in building interiors, plants should be located in interior light levels between 50 to 200 foot candles (10-40 $\mu\text{mol m}^{-2} \text{s}^{-1}$) (Chen et al., 2005 b). 'Fire Flash' plants are able to maintain their aesthetic appearances under a low light level of 8 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for 8 months or longer (Chen et al., 2005 a).

Given the claims of *C. amaniense* 'Fire Flash' versus light and insufficient information in the literature, the objective of this research was to investigate the response of *C. amaniense* plants under different light intensities. For this aim a pot experiment was conducted to analyze growth parameters and some photosynthetic parameters.

MATERIALS AND METHODS

The experiment was established at the Floriculture Research Area, Faculty of Horticulture from Craiova (Romania), during February to August, 2016. The biological material consists of plants of *Chlorophytum amaniense* Engl. 'Fire Flash' from the didactic greenhouse of the Floriculture discipline.

Ambient temperatures ranged from 20°C-22°C and relative humidity from 60%-80%.

We studied the effect of different lighting intensity of the 'Fire Flash' plants to assess the effect on morphological, ornamental and some photosynthetic characteristics.

Young plants of *C. Amaniense* 'Fire Flash' (obtained from seeds), with 4-5 leaves, were selected and transplanted in the first week of February 2016 into black, 2.8 liter pots (17 cm diameter) filled with a substrate consisting of a 40:30:30 mix of peat, coconut fibre, and perlite. Controlled-release fertilizers (Osmocote 18-6-12) was added to the substrate. Plants were placed in a greenhouse with natural light for 8-

10 hours per day and were maintained in moderate shade during the first month and then transferred to the different light treatments (in the first week of March 2016), by placing the plants in three areas of the greenhouse with different light level: low light intensity (LL): 7.98-9.12 $\mu\text{mol}\cdot\text{m}^{-2} \text{s}^{-1}$; medium light intensity (ML): 77.9-82.46 $\mu\text{mol}\cdot\text{m}^{-2} \text{s}^{-1}$; high light intensity (HL): 220.4-233.7 $\mu\text{mol}\cdot\text{m}^{-2} \text{s}^{-1}$.

The light intensity inside the greenhouse was measured with a Lux meter at 10.30 am, 2.00 pm and 4.00 pm, in three zone of greenhouse with different light levels. These evaluations were performed on five different days in an interval of five months corresponding to the experimental time. The luminous flux per unit area was converted into photon flux density (PFD) using a conversion factor of 0.0185 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ per lux valid for sunlight (Hershey D.R., 1991; Pedersen et al., 2016).

The experiment was conducted in a completely randomized design, using a monofactorial arrangement with three treatments represented by three levels of light availability (T1-LL; T2-ML; T3-HL), with three replicates, and five plant per experimental unit.

The observations on average height of the plants, number of leaves per plant, leaves size, length of petiole, width of petiole were recorded 90 days after the experiment was established. We also measured some photosynthetic parameters: the incident radiation in the leaf (Qleaf) expressed in $\mu\text{mol photons m}^{-2} \text{s}^{-1}$; stomatal conductance (gs), $\text{mol H}_2\text{O m}^{-2} \text{s}^{-1}$, transpiration (E), $\text{mmol H}_2\text{O m}^{-2} \text{s}^{-1}$, net photosynthesis (A), $\mu\text{mol CO}_2 \text{m}^{-2} \text{s}^{-1}$, on the third or fourth leaf counting from the apex to the base, by using Lcpro+® Portable Photosynthesis System. Water Use Efficiency (WUE; $\mu\text{mol CO}_2 \text{mmol}^{-1} \text{H}_2\text{O}$) was calculated as A to E ratio (Ribeiro et al., 2009). The data were submitted to variance analysis and the averages compared by Tukey test at 5% error probability ($p < 0.05$) in MINITAB 16 software.

RESULTS AND DISCUSSIONS

Effects of Light Intensity on Plant Growth

In ornamental horticulture, the leaf forms and color, sizes, and shapes of pot plants is essential components of their visual quality that determines the commercial value of the

products (Boumaza et al., 2010). Light intensity influence plant characteristics and quality attributes (Runkle, 2013). Knowledge of the morphological and physiological characteristics of *C. amaniense* in response to various light conditions is still sparse. Clear external differences were observed among plants grown under five months under different light intensities.

Regarding the average height of the plants, the highest values were recorded in an exhibition characterized by low light intensity (LL-13,7 cm). Moreover, the plants grown in a high intensity area of light recorded the lowest average height (HL-9.7 cm). Similarly, shade induced more growth in height in *Passiflora edulis* f. *flavicarpa* plants (Valladares et al., 2000; Zanella et al., 2006). Apical dominance tends to increase when plants are submitted to high shade levels, due to a decrease in the production of photoassimilates and the highest level of auxin at the stem apex bud (Vanneste and Friml, 2009; Woodward and Bartel, 2005). The average leaf number on the plant was maximum under medium illumination (ML - 9.7), and in variants grown under low or high light conditions, the values of this parameter were significantly reduced (LL - 8.3 leaves, respectively HL-7.3 leaves) (Table 1).

Placement of plants in areas with different luminous intensities caused significant differences in the average leaf length. Compared to plants grown in intense light, where the average value of this parameter was minimal (HL-21.5 cm), the plants placed in a low light intensity recorded the highest value (LL-32.5 cm), followed at a significant difference by the variant in which the plants received a medium light intensity (ML - 27.2 cm). In contrast, the increase of the leaf width was proportional to the decrease in the shade, with the highest average values occurring under high light intensity (HL-5 cm) (table 1). The lowest value corresponds to the plants grown in an area with a minimum intensity of light (LL - 4.5 cm).

Low light intensity may lead to increase in leaf number and leaf size and these changes may maximize the capture of available light to meet the demand for leaf photosynthesis (Steinger et al., 2003).

Regarding the average dimensions of the petioles, the main decorative element of this

species, there were also significant differences according to the intensity of the light. The average length of petioles recorded the lowest value at HL (3 cm), and the highest value was recorded at LL (6.8 cm). Instead, average petiole widths were between 1.2 cm in low light intensity (LL) plants and 1.7 cm in intensive light (HL) plants.

In addition to the measurable parameters, the study of *C. amaniense* 'Fire Flash' plants under different illumination conditions had the following results: low intensity ($7.98-9.12 \mu\text{mol m}^{-2}\text{s}^{-1}$) caused a more intense color of the leaves and the petiole, the elongation and thinning of the main decorative element, the petiole; high intensity ($220.4-233.7 \mu\text{mol m}^{-2}\text{s}^{-1}$) produced chlorosis and leaf burn and plants have become unmarketable after a 3 months period. Visual observations indicated that *C. amaniense* produced commercially acceptable plants at $7.98-9.12 \mu\text{mol m}^{-2}\text{s}^{-1}$, however the optimal growth and development occurred from $77.9-82.46 \mu\text{mol m}^{-2}\text{s}^{-1}$. Although Chen et al. (2005 a), recommends as optimal light interval $10-40 \mu\text{mol m}^{-2}\text{s}^{-1}$ for 'Fire Flash' production, our results suggest that a light level of about $80 \mu\text{mol m}^{-2}\text{s}^{-1}$ appeared to be optimal.

Effects of light intensity on plant photosynthetic parameters

Physiologically, light has both direct and indirect effects. It affects on metabolism directly through photosynthesis, whilst indirectly through growth and development (Zhang et al., 2011). Table 2 presents the effects of different light intensities on leaf photosynthetic parameters.

Net CO₂ assimilation (A) was highest in HL ($7.73 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) followed by ML ($6.81 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) treatment and, finally, LL treatment ($5.44 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$). Similar results were obtained on *Dieffenbachia longispatha* and *Camellia x williamsii* (Skillman et al., 2005; Fini et al, 2010). The authors have shown that that A was higher in full sun and mild shade plants if compared to heavy shaded plants.

The greatest leaf stomatal conductance (gs) was observed under medium light intensity (ML- $0.12 \text{ mol H}_2\text{O m}^{-2} \text{ s}^{-1}$), and the lowest under low light intensity (LL- $0.03 \text{ mol H}_2\text{O m}^{-2} \text{ s}^{-1}$).

Stomatal conductance (gs) was significantly higher in ML than that of all other treatments. As also reported in other works, plants grown at high light are characterized by greater stomatal conductances than plants grown at low light (Baroli et al., 2008; Niinemets et al., 2006). Previous studies also showed that changes in photosynthesis and transpiration were correlated with stomatal conductance (Greer, 2012; Miyashita et al., 2012).

Transpiration (E) was affected by different shading treatments and followed a similar pattern to A. Significant differences were observed between the HL irradiance treatment and all other treatments. There were significant differences on leaf transpiration rate (E) between the HL treatment ($1.75 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$) and all other treatments ($0.71\text{-}1.68 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$).

Water use efficiency (WUE) varied significantly with light intensity in *C. amaniense* plants. Significant differences were observed between plants submitted to high shade levels

(LL- $7.61 \mu\text{mol CO}_2 \text{ mmol}^{-1} \text{ H}_2\text{O}$) compared to plants placed under medium and high intensity (ML- $4.05 \mu\text{mol CO}_2 \text{ mmol}^{-1} \text{ H}_2\text{O}$, HL- $4.46 \mu\text{mol CO}_2 \text{ mmol}^{-1} \text{ H}_2\text{O}$). No significant differences were observed between the ML and HL treatments (Table 2).

Intercellular CO_2 concentration (Ci) showed same evolution as WUE. Light reduction resulted in significantly higher values of Ci (LL-439.33 ppm) (Table 2). Previous studies showed that, in some species, the intercellular CO_2 concentration (Ci) declined with increases with the increase of light intensity (e.g. Hanba et al., 2002; Oguchi et al., 2005).

Our findings show the higher light levels have provoked severe leaf damage, characterized by leaf chlorosis or scorching. Huang et al., 2015 show that under high light condition, excess absorbed light energy can induce photoinhibition explaining why shade-established species cannot survive under high light.

Table 1. Effect of different light conditions on mean vegetative growth parameters at the end of experiment

Treatments	Height of plants (cm)	Number of leaf (cm)	Length of leaf (cm)	Leaf area (cm^2)	Length of petiole (cm)	Width of petiole (cm)
LL	13.7a	8.3ab	32,5a	109,53a	6.8a	1,2b
ML	11.2b	9.7a	27,2b	95,1ab	4,5b	1,5ab
HL	9.7b	7.8b	21,5c	80,65b	3c	1,7a

Means comparison were done using Tukey's test ($p < 0.05$). For each variable lowercase letters indicate comparison among treatments and uppercase ones comparison among species.

Table 2. Net photosynthetic rate (PN), stomatal conductance to water vapour (gs), leaf transpiration rate (E), intercellular CO_2 concentration (Ci) and water use efficiency (WUE) of *C. amaniense* leaves were subjected to different levels of irradiance

Treatments	A ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)	E ($\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$)	Gs ($\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$)	Ci (ppm)	WUE ($\mu\text{mol CO}_2 \text{ mmol}^{-1} \text{ H}_2\text{O}$)
LL	5.44 b	0.71 c	0.03 c	439.33a	7.61a
ML	6.81 ab	1.68 b	0.12 a	354.33ab	4.05b
HL	7.73 a	1.75 a	0.08 b	320.33b	4.46b

Means comparison were done using Tukey's test ($p < 0.05$). For each variable lowercase letters indicate comparison among treatments and uppercase ones comparison among species.

CONCLUSIONS

The cultivation of *C. amaniense* 'Fire Flash' in Romania is almost nonexistent, though is a exciting ornamental foliage plant as a result of its unique coral-colored midribs and petioles and tolerance to interior low light levels.

Light intensity had different effects on *C. amaniense* growth. The results showed that *C. amaniense* attained greatest height of plant, number of leaf and leaf size when cultivated under low light intensity. Under high light intensity values of plants grown were the smallest. With the reduction in light intensity,

petioles have elongated by over 50% but their diameter has decreased significantly. Visual observations indicated that *C. amaniense* produced commercially acceptable plants at 7.98-9.12 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, however the optimal growth and development occurred from 77.9-82.46 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Plants exposed to full light conditions (220.4-233.7 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) become unmarketable within a 3 months period. Our findings suggests that the net photosynthesis (A) was higher in high (HL) and medium light (ML) and low light intensity (LL) can decrease photosynthesis. The results from this study show that a light level of about 80 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ appeared to be optimal for *C. amaniense* when both morphological and physiological performance were considered.

REFERENCES

- Anton D., Nicu C., Mandă M., 2006. Floricultură specială - vol. II, Editura Universitaria, Craiova.
- Boumazza R., Huché-Théliér L., Demotes-Mainard S., Le Coz E., Leduc N., Pelleschi-Travier S., Qannari E.M., Sakr S., Santagostini P., Symoneau R., Guérin V., 2010. Sensory profiles and preference analysis in ornamental horticulture: the case of the rosebush. *Food Quality and Preference*, 21: 987-997.
- Chen J., Henny R.J., McConnell D.B., 2002. Development of new foliage plant cultivars. In Janick, J., and Whipkey, A. (eds). *Trends in New Crops and New Uses*. ASHS Press, Alexandria, 466-472.
- Chen J., McConnell D.B., Henny R.J., Everitt K., Caldwell R.D., 2005 a. 'Fire Flash': An Exotic Ornamental Foliage plant. *Hort Technology* July-September, 15 (3): 686-689.
- Chen J., McConnell D.B., Henny R.J., 2005 b. Cultural Guidelines for Commercial Production of Intiorscape 'Fire Flash' (*C. amaniense*). Environmental Horticulture Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. <https://edis.ifas.ufl.edu/pdf/files/EP/EP25300.pdf>.
- Cui Jin, Juanxu Liu, Jianjun Chen, Richard J. Henny, 2011. Regeneration of *Chlorophytum amaniense* 'Fire Flash' Through Indirect Shoot Organogenesis. *Hort Science*, 46 (3): 466-469.
- Baroli I., Price, G.D., Badger M.R., von Caemmerer S., 2008. The contribution of photosynthesis to the red light response of stomatal conductance. *Plant Physiology*, 146 (2): 737-747.
- Fini A., Ferrini F., Frangi P., Amoroso G., Giordano C., 2010. Growth, leaf gas exchange and leaf anatomy of three ornamental shrubs grown under different light intensities. *European Journal of Horticultural Science*, 75 (3): 111-117.
- Greer D.H., 2012. Modelling leaf photosynthetic and transpiration temperature-dependent responses in *Vitis vinifera* cv. Semillon grapevines growing in hot, irrigated vineyard conditions. *AoB Plants*, 1: 1-13. <https://doi.org/10.1093/aobpla/pls009>.
- Hershey D.R., 1991. Plant Light Measurement and Calculations. *The American Biology Teacher*, 53 (6): 351-353.
- Huang W., Zhang S.B., Zhang J.L., Hu H., 2015. Photo-inhibition of photosystem I under high light in the shade-established tropical tree species *Psychotriarubra*. *Frontiers in plant science*, 6: 801.
- Kaushik N., 2005. Saponins of *Chlorophytum* Species. *Phytochem Reviews*, 4(2): 191-196.
- Miyashita K., Tanakamaru S., Maitani T., Kimura K., 2005. Recovery responses of photosynthesis, transpiration, and stomatal conductance in kidney bean following drought stress. *Environmental and experimental botany*, 53 (2): 205-214.
- Niinemets Ü., Cescatti A., Rodeghiero M., Tosens T., 2006. Complex adjustments of photosynthetic potentials and internal diffusion conductance to current and previous light availabilities and leaf age in Mediterranean evergreen species *Quercus ilex*. *Plant, Cell & Environment*, 29: 1159-1178.
- Oguchi R., Hikosaka K., Hirose T., 2005. Leaf anatomy as a constraint for photosynthetic acclimation: differential responses in leaf anatomy to increasing growth irradiance among three deciduous trees. *Plant, Cell & Environment*, 28: 916-927.
- Patil S.M., Rane N.R., Adsul A.A., Gholave A.R., Yadav S.R., Jadhav J.P., Govindwar S.P., 2016. Study of molecular genetic diversity and evolutionary history of medicinally important endangered genus *Chlorophytum* using DNA barcodes. *Biochemical Systematics and Ecology*, 65: 245-252.
- Pedersen O., Colmer T.D., Borum J., Zavala Perez A., Kendrick G.A., 2016. Heat stress of two tropical seagrass species during low tides-impact on underwater net photosynthesis, dark respiration and diel in situ internal aeration. *New Phytologist*, 210 (4): 1207-1218.
- Ribeiro R.V., Machado E.C., Santos M.G., Oliveira R., 2009. Photosynthesis and water relations of well-watered orange plants as affected by winter and summer conditions. *Photosynthetica*, 47 (2): 215-222.
- Runkle E.S., 2013. Manipulating Light Quality to Elicit Desirable Plant Growth and Flowering Responses. *IFAC Proceedings Volumes*, 46 (4): 196-200.
- Shinde S.S., Patil S.M., Rane N.R., Adsul A.A., Gholve A.R., Pawar P.K., Govindwar S.P., 2016. Comprehensive investigation of free radical quenching potential, total phenol, flavonoid and saponin content, and chemical profiles of twelve *Chlorophytum* Ker Gawl. species. *Indian Journal of Natural Products and Resources (IJNPR)* [Formerly *Natural Product Radiance (NPR)*], 7 (2): 125-134.
- Skillman J.B., Garcia M., Virgo A., Winter K., 2005. Growth irradiance effects on photosynthesis and growth in two co-occurring shade-tolerant neotropical perennials of contrasting photosynthetic pathways. *American Journal of Botany*, 92 (11): 1811-1819.
- Steinger T., Roy B.A., Stanton M.L., 2003. Evolution in stressful environments II: adaptive value and costs of plasticity in response to low light in *Sinapis arvensis*. *Journal of Evolutionary Biology*, 16: 313-323.

- Valladares F., Martinez-Ferri E., Balaguer L., Perez-Corona E., Manrique E., 2000. Low leaf-level response to light and nutrients in Mediterranean evergreen oaks: a conservative resource-use strategy? *The New Phytologist*, 148 (1): 79-91.
- Vanneste S., Friml J., 2009. Auxin: a trigger for change in plant development. *Cell*, 136 (6): 1005-1016.
- Woodward A.W., Bartel B., 2005. Auxin: regulation, action, and interaction. *Annals of Botany*, 95 (5): 707-735.
- Zanella F., Soncela R., Lima A.L., 2006. Formação de mudas de maracujazeiro 'amarelo' sob níveis de sombreamento em Ji-Paraná/RO. *Ciência e Agrotecnologia*, 30 (5): 880-884.
- Zhang Y.J., Xie Z.K., Wang Y.J., Xi Su P., An L.P., Gao H., 2011. Light intensity affects dry matter, photosynthesis and chlorophyll fluorescence of oriental lily. *The Philippine Agricultural Scientist*, 94 (3): 232-238.