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Effect of Higher CO_2 Concentration on Photosynthesis in Codiaeum Variegatum under Different Sky Conditions

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Abstract: The objective of this study was to evaluate the effect of different CO_2concentrations that influences photosynthesis of Codiaeum variegatum under different sky conditions. Accordingly, diurnal changes in photosynthetic responses among plants grown at ambient concentration (AC) and elevated concentration (EC) of CO_2 were studied under contrasting sky conditions. EC stimulated the daily sum of fixed CO_2 and light use efficiency under clear sky. Both these parameters were reduced under cloudy sky compared with AC treatment. Photosynthesis rate was reduced under cloudy sky particularly associated with EC-stimulated, xanthophylls dependent thermal dissipation of absorbed light energy. Anoticeable depression of CO_2 assimilation rate was found in sun-adapted leaves under EC compared with AC conditions in case of clear sky condition, in the afternoon.

Keywords: ***Codiaeum variegatum,*** **photosynthesis, CO_2, ambient concentration (AC), elevated concentration (EC)**

1. Introduction

The mechanism of plant acclimation to a changeable environmental condition is a major scientific problem. Due to anthropogenic activities CO_2 concentration in the atmosphere is steadily increasing, which affects on plant physiology, morphogenesis, and photosynthesis. There is currently no general model to predict plant acclimation to a varied environment, because the response to elevated carbon dioxide concentration is dependent on species, on plant development stage and can be modified by a number of factors, including light, nutrient and water availability [1-3]. Biochemical and molecular responses are not well documented yet due to a lack of understanding about the regulatory mechanisms, metabolic signaling and phytochemical changes in plants under elevated CO_2 conditions [4-5].

Codiaeum variegatum is an ornamental plant used for the interior and garden decoration, belongs to the family Euphorbiaceae, is one of the most popular ornamental plants because of vivid foliage colours and varied leaf shapes. *Codiaeum variegatum* is native to Indonesia, Malaysia, Philippines, India, Thailand and Sri Lanka. It is an evergreen shrub, up to 6 m in height but usually maintained at 60-90 cm and grows well in areas having humid climate. More than 200 varieties of croton exist on the globe, available in different leaf sizes, shapes and colour patterns [6-8]. Young leaves are usually green, bronze, yellow, or red, later changes to gold, cream, white, scarlet, pink, maroon, purple, black or brown. Sometimes totally different forms of leaves and colour variations occur on the same plant.Generally crotons are multiplied vegetatively by means of cuttings and air layering. It has a flexible response to various levels of light intensity. In different light intensity growing conditions, it shows different leaf colours. The shade leaves are more greenish than the sun leaves. The mosaic pattern on the leaves may also be influenced by light intensity. However, this plant can be maintained in a wide range of light conditions [9-13].

In this study we tested the hypothesis that differences in the diurnal patterns of microclimate drivers typical for clear and cloudy sky conditions affect the relative impact of elevated [CO_2] on photosynthesis . The specific objectives of our study were to investigate diurnal changes in CO_2 assimilation rate and the role of photosynthetic pigments in the photo protection of plants during sunny and cloudy days.

2. Materials and methods

Plants and experimental design

This area has a cool (annual mean air temperature 29.7^{0}C) and humid (annual mean relative air humidity 72%) climate with high annual precipitation (the average for 2000-2009 is 1374 mm). Approximately 74% of incident photosynthetic photon flux density (PPFD) is ≤500 µmol (photons) $m^{-2}s^{-1}$due to frequent cloud cover (Fig. 1).

Physiological measurements

Leaf-level physiological measurements were done on three representative trees for each [CO_2] treatment. Each replicate consisted of an independent plant selected randomly within the glass dome among those trees of average height, stem diameter, and leaf chlorophyll content. Two fully developed sun-exposed leaves per tree with south or south-west orientation were evaluated and the average from these two measurements used for statistical analyses. All physiological measurements were done at 1.5-2 h intervals from 03:00 to 7:30 h (after-sunset). The same leaves were measured on both cloudy and sunny days.

Statistical data analysis

Before the analysis of variance (ANOVA), the data was tested for normality of individual parameters using a Kolgomorove Smirnov test and homogeneity of variances was tested using Levene's test. For effects of sky conditions, [CO_2] and time of day, the photosynthetic parameters were analysed using a three-way fixed-effect ANOVA model. For analysis of sky conditions and [CO_2] effects on content of non-structural saccharides and starch in leaves, a two-way fixed-effect ANOVA was used.

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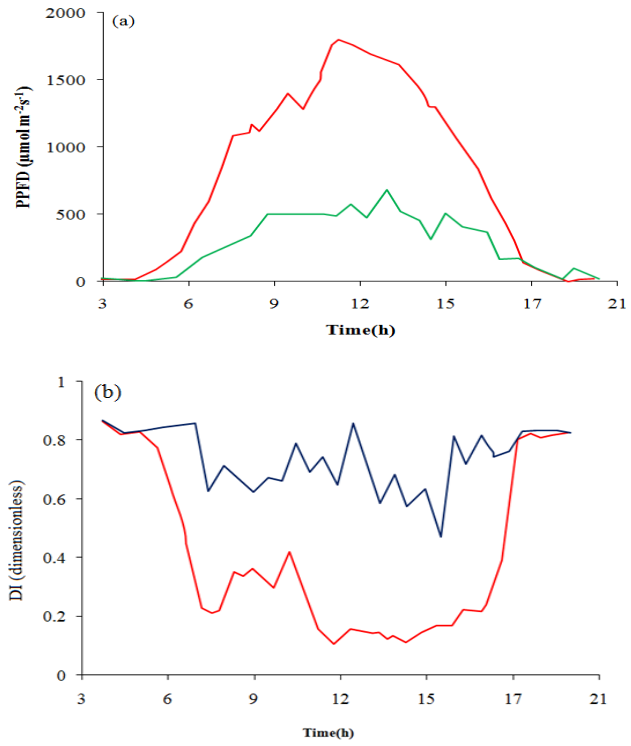
3. Result and Discussion

3.1. Microclimate conditions

The measuring procedure included days that differed primarily in their sky conditions. Although there were transient changes in PPFD (Fig. 1a), DI remained mostly within the ranges of ≤0.4 and ≥0.6 during the sunny and cloudy days, respectively (Fig. 1b). Changes in sky conditions from clear to cloudy tended also to change the other microclimatic parameters. On sunny days, air temperature (Ta; Fig. 1c) and VPD (Fig. 1d) showed typical daily courses, as characterized by their maximum and minimum values, but they remained more or less constant under the cloudy sky. Under the clear sky, daily maxima of Ta and VPD rose to ca 30.5 ^{0}C and 2.7 kPa, respectively, while these were only ca 17.8 ^{o}C and 0.5 kPa under the cloudy sky. The average microclimatic conditions during the preceding two days for each of the two periods had been similar to those occurring during the measuring campaigns (data not shown). No statistically significant ($p > 0.05$) differences in PPFD, Ta or VPD were observed between the domes with AC versus EC.



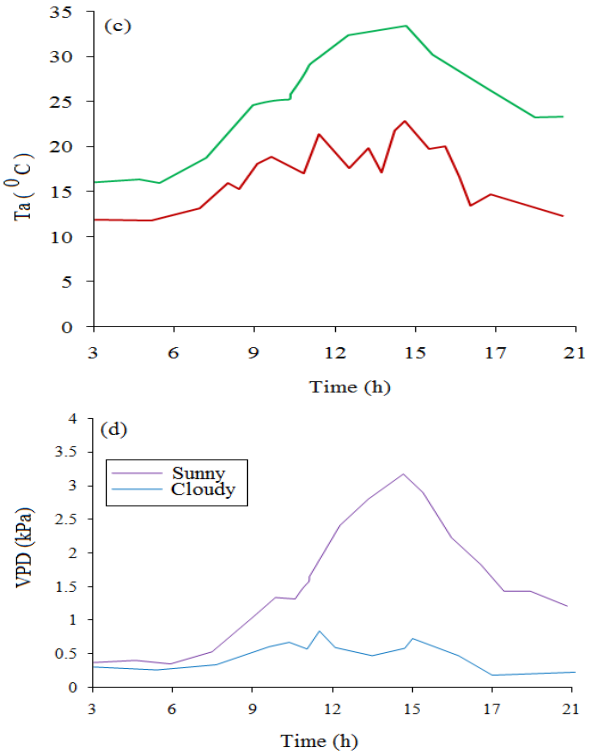


Fig. 1. Diurnal courses of incident photosynthetic photon flux density (PPFD; a), diffuse index (DI; b), air temperature (Ta; c), and vapour pressure deficit (VPD; d) during sunny (open circles) and cloudy (closed circles) days when physiological measurements were carried out at 30 min intervals are presented.

3.2. Dynamics of assimilation activity and stomatal conductance

3.3. Diurnal courses of A and GS during sunny and cloudy days are shown in Fig. 2. Under clear sky conditions, significant stimulation of A by the EC treatment (33-37%) was found only during 10:00-12:00, while there were no differences in A values between treatments during the early morning and late afternoon hours (Fig. 2a), i.e. at PPFD ≤550 mmol (photons)$m^{-2}s^{-1}$. Since the assimilation processes are limited by electron transport rate at low irradiances, identical courses of A under AC and EC had been expected under cloudy skies. However, significant reduction in A by as much as 47% was observed in EC plants as compared to AC plants during the afternoon hours (Fig. 2b). Except during early morning and late afternoon, EC treatment led to decreases in GS under both sky conditions (Fig. 2c,D). Whereas the maximum GS values were ca 35% lower in EC as compared to AC plants under clear sky conditions, under cloudy sky conditions that difference in GS between AC and EC leaves was ca 72%. The stomata of EC plants remained almost closed throughout the cloudy day, although the leaf-to-air vapour deficit (LAVD) ranged between 0.75 and 0.85 kPa irrespective of CO_2 treatment. Intercellular CO_2 was ca 320 and 580 mmol(CO_2) $m^{-2}s^{-1}$, respectively, during afternoon hours (12:00-16:00) of cloudy days in AC and EC conditions.

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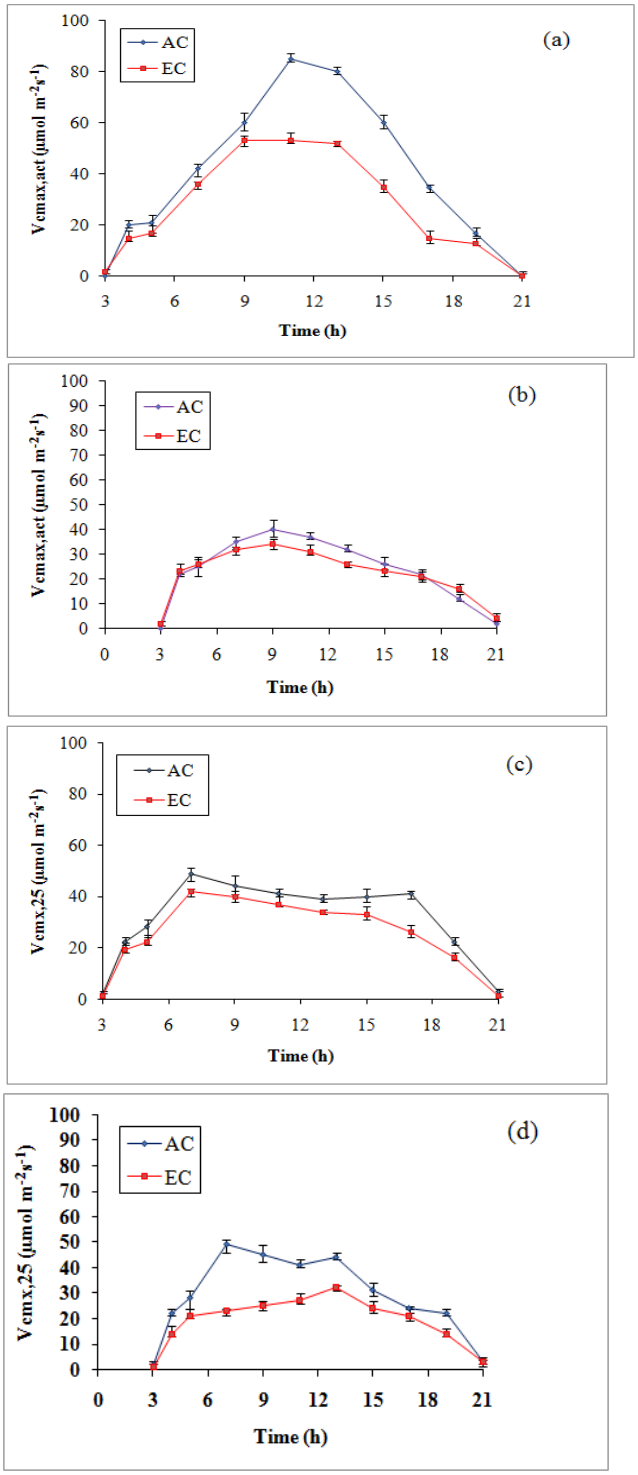

Fig. 2. Diurnal course of CO_2 assimilation rate (A) and stomatal conductance (GS) under the conditions of sunny (a,c) and cloudy days (b,d). The measurements were done on the intact sun-adapted leaves of plants cultivated under ambient (AC; empty circles, dashed line) and elevated (EC; full circles, full line) CO_2 concentrations. The means (points) and standard deviations (error bars) are presented (N = 3).

4. Conclusion

In case of *Codiaeumvariegatum*it was found that elevated level of [CO_2] on photosynthesis and stomatal conductance and subsequently on the light use efficiency and total carbon gainare highly influenced by the condition of the sky i.e. whether the sky is cloudy or sunny. In this study a reduced stimulatory effect of EC on carbon uptake by the leaves was observed when the sky is covered with clouds.

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