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Seasonal changes of photosynthetic physiology in *Jatropha curcas* L. from autumn to winter

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ABSTRACT

Jatropha curcas L. seedling were pot-planted and grown under natural conditions. Our study was to monitor changes in the composition of the photosynthetic apparatus which accompany these functional changes, and to determine their adaptability to the climatic conditions. Seasonal changes in chlorophyll fluorescence, gas exchanges, rapid light responses curves in chlorophyll fluorescence, pigment concentration and antioxidase in *J. curcas* were examined from autumn to cold winter climate. The results revealed that there were significantly decreased in total parameters except Intercellular CO_2 concentration through fall and winter. But *J. curcas* remained able to have photosynthesis before the leaves fallen. During December, net photosynthetic rate (Pn) and maximum quantum efficiency of PSII (Fv/Fm) were significantly down-regulated. It is conclusion that the high degree of photoinhibition observed in *J. curcas* L. leaves probably represents a dynamic regulatory process protecting the photosynthetic apparatus from severe damage by excess light and low temperature.

KEYWORDS

Jatropha curcas; Photosynthesis; Seasonal changes.

INTRODUCTION

During their development plants are subjected to various environmental stresses, drought, salinity, and low or high temperatures determine the geographical distribution and growth of plants to a great extent. Low temperature is one of the most important abiotic factors limiting the geographical locations suitable for crop growth and periodically accounts for significant losses in plant production. Furthermore, chilling sensitive plants are those that suffer a dramatic and often slowly reversible damage at low temperatures[1-3].

Jatropha curcas L. (physic nut or purging nut) is a multipurpose shrub or small tree belonging to the family of Euphorbiaceae with many attributes and multiple uses, which produces seeds rich in oil easily convertible into biodiesel meeting international standards. It is known that plant growth, development and productivity are closely related to photosynthesis. Under natural conditions, photosynthesis is regulated biochemically to maintain a balance between the rates of its component processes and concentrations of metabolites in response to environment changes[4,5]. The overriding objectives of this study was to investigate the photosynthetic performance and photoinhibitory responses of the tropical plants of *Jatropha curcas* following the natural distribution to autumn and winter in suboptimal regions, mianyang city, sichuan province, P. R. China. Parameters followed, such as quenching of chlorophyll fluorescence, net photosynthetic rate, stomatal conductance, intercellular CO_2 concentration, transpiration rate as well as assays of pigment content and antioxidant enzymatic activities.

MATERIALS AND METHODS

Plant material and experimental site

Sixty *J. curcas* seedlings (2-years old and height about 30 cm) from Xichang region, Sichuan Province, China, were transplanted in 15-L pots at Mianyang, Sichuan Province, China at the beginning of April. The pots were filled with the same weight homogenized garden soil. And the seedlings were grown under field natural condition and uniform watering and fertilization managements. Mianyang (104°41.514′ E, 31°32.630′ N, and altitude 545.0 m) is characterized by a subtropical humid climate with an annual temperature ranging from 14.7 to 17.3°C, a relative of humity 70 – 80 %, and the extreme of lowest and highest temperature are -4.5 and 39.4°C, respectively, an average annual rainfall of 826-1,417 mm, the average temperatures in the coldest of January and the hottest of July are 3.9-6.2°C and 24.2-27.2°C, respectively.

Gas exchange and chlorophyll fluorescence measurements

From 15 September to 20 December, gas exchange and chlorophyll fluorescence measurements were made on a sunny and windless day in each month and for four same plants at every time. Gas exchange parameters were performed with LI-6400 (LI-COR, Lincoln, NE) at 1400 mmol m^{-2} s^{-1} PPFD (i.e., photosynthetic photon flux density) at the leaf surface using the 6400-02 LED light source (LI-COR, Lincoln, NE). Measurements were taken on the mature, healthy, fully expanded, third or fourth leaf from the top of the plant, and made in one day from 9:00 to 11:00.

The data including Fo, Fm,Fv/Fm, ΦPSII, ETR and NPQ were measured by PAM-2100 chlorophyll fluorometer (Walz, Effeltrich, Germany). The fluorometer was connected to a notebook computer with data a cquisition software by RS232 data wire (DA-2100, Walz)..

Assay of pigments content

Leaf tissues were homogenized in chilled N, N-dimethylformamide (DMF) using a mortar and pestle in dark at 4 °C, and the homogenates were centrifuged at 8,800 × g for 10 minutes. The data including chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*) and total carotenoids (Car), were calculated.

Extraction and assay of antioxidant enzymes

Extracts for the determination of antioxidant enzymes activity were prepared according to[6]. Superoxide dismutase (SOD) and Peroxidase (POD) were measured.

Statistical analysis

Data were presented as mean ± standard errors. Differences among months were analyzed with one way ANOVA, and means were compared by the least significant difference (LSD) test. Means were considered to be different when $P < 0.05$. Statistical analysis was done with SPSS 16.0 for Windows statistical software package.

RESULT AND DISSCUSS

Results

Seasonal changes in leaf temperature and air temperature

From September to December, the temperature was decreased with the winter coming. However, in November, the temperature was lowest due to the cold air from northern China, the temperature was ranging from 3～7℃. The temperature rose when entering December ranging from 8～12℃. TABLE 1 shows that leaf temperature was decreased rapidly from September to December.

TABLE 1 : Average air and leaf temperature during Sep. to Dec.

Date	13 Sep.	16 Oct.	14 Nov.	15 Dec.
Average leaf temperature (℃)	21	19	12	11
Average air temperature (℃)	24	18	3	8
RH (%)	66	53	5	3

Seasonal changes in gas exchange parameters

As for the gas exchanges, there were significant differences during the growth season from September to December (Figure 1). Net photosynthesis rate (Pn), stomal conductance (gs) and transpiration rate (Tr) show almost the same trends from September to later December in response to the decrease in air, and soil temperature. Thus Pn for October leaves was 1.26-fold, 9.80-fold and 75.63-fold higher than the September, November and December samples, respectively. During the same time course, the gs and Tr increased significantly to reach a maximum in October of growing (0.223±0.011mol.m^{-2}.s^{-1}, 2.768±0.086mmol.m^{-2}.s^{-1}). A significant decrease was observed after October of growing, and then the value maintain the steady state from November to December. Intercellular CO_2 concentration (Ci), however, was the opposite trend from November and increased to December (326.01±5.63umol.mol^{-1}) rapidly with gradual increase of the light intensity.

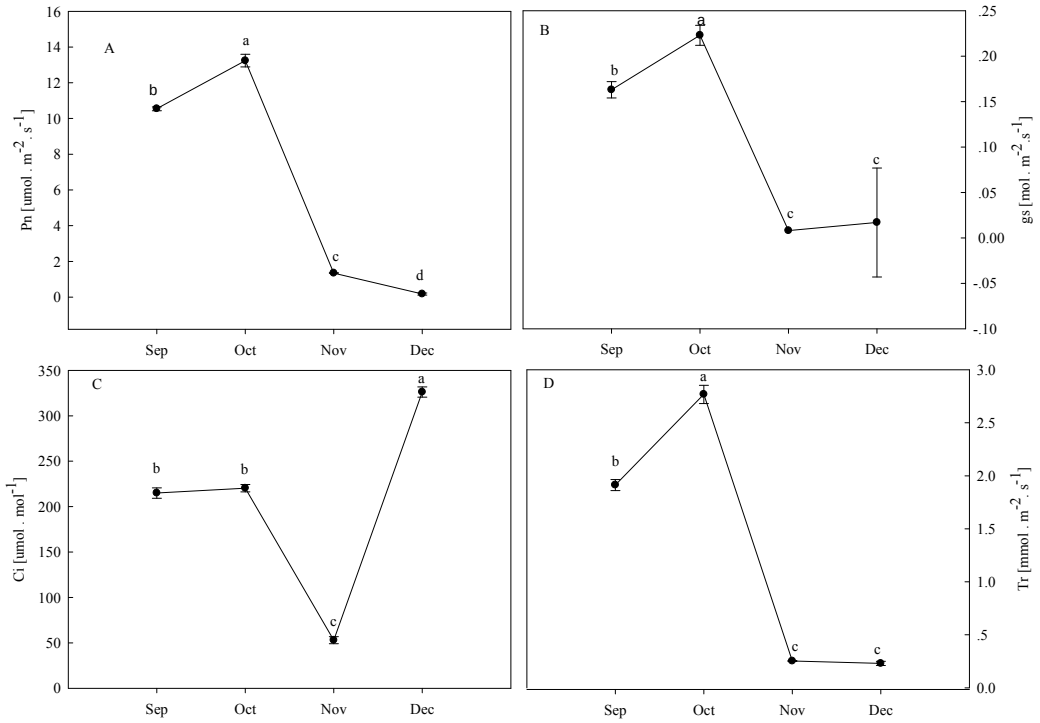

Figure 1 : Seasonal changes of gas exchanges parameters in *J.* curcas L. were pot-grown from September to December. Significant differences are indicated by different letters (*P* <0.05).

Seasonal changes in chlorophyll fluorescence parameters

Seasonal changes in the Fo and Fv/Fm of the *J. curcas* from September to December are shown in Figure 2. There were no significantly changes in Fv/Fm from September to November (Fv/Fm ranged from 0.819 to 0.784, data not shown), Whereas, Compare with the other three months, Fv/Fm was decreased significantly with the decline of the temperature of day in December and reduction in Fv/Fm decreased from 71.92% after one month, to 71.40% after two months, and 70.66% after three months (Figure 2 B). With the progress of days, ΦPSII, qP and NPQ tended to decrease. The value of ΦPSII regularly decreased from 0.713 ± 0.01 (in September) to 0.096 ± 0·03 (in December) during the growing season. NPQ increased significantly from September to October, remained stable from October to November and decreased significantly to December (Figure 2 E). qP, however, was significantly decreased in *J.* curcas after growing field experiment with the coming of winter, which was decreased by 9.73%, 8.77%, 63.12(Figure 2 F).

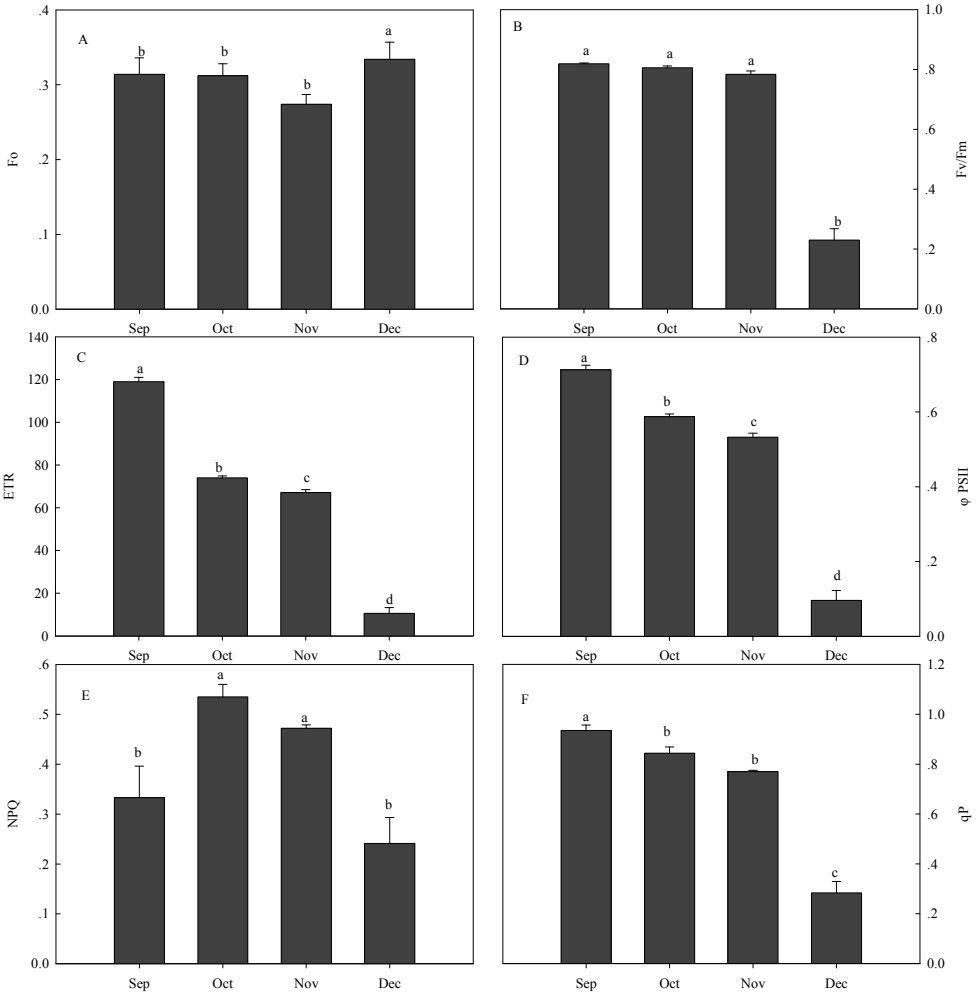

Figure 2 : Seasonal variations of chlorophyll fluorescence for *J. curcas* L.. The values given are mean values ± SEM (standard error of mean) of four replicates. The values of histograms under different lowercase letters are significantly different at *P* <0.05.

Seasonal changes in leaf pigment content

Figure 3. shows seasonal dynamics of chlorophyll *a, b* and cartenoid content in *J*atropha curcas, calculated per fresh weight, in the period from September to December. The Chl *a* and Car synthesis started earlier than that of Chl *b*. It can be seen that the highest Chl *a* and Car content in *J*atropha curcas was observed in September. In December, Chl *a* content decreased about 4.79 %. The Chl *b* content changed more drastically during October and remained at that constant level until November and rapidly increase in December as the same level as September. Car, however, was opposite trend compared with Chl *b*.

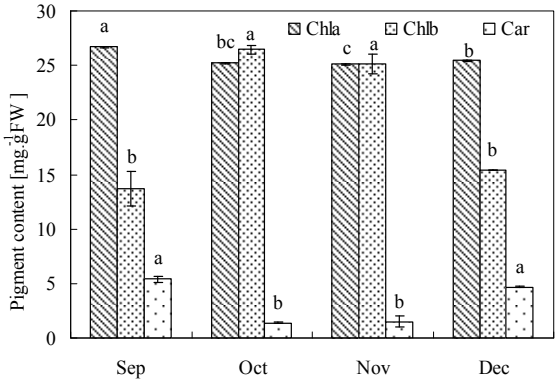

Figure 3 : Seasonal dynamics of chlorophyll a, b and carotenoid content in *J. curcas* L. Data are represented as mean ± standard errors (n = 4).

Seasonal changes in antioxidant systems

Data for two antioxidant enzymes′ activities are shown in Figure 4, which indicate a significantly increase in activity of POD from September to December. In October, the activity of SOD increased almost one times and then decreased hardly one times and remained at constant level until December.

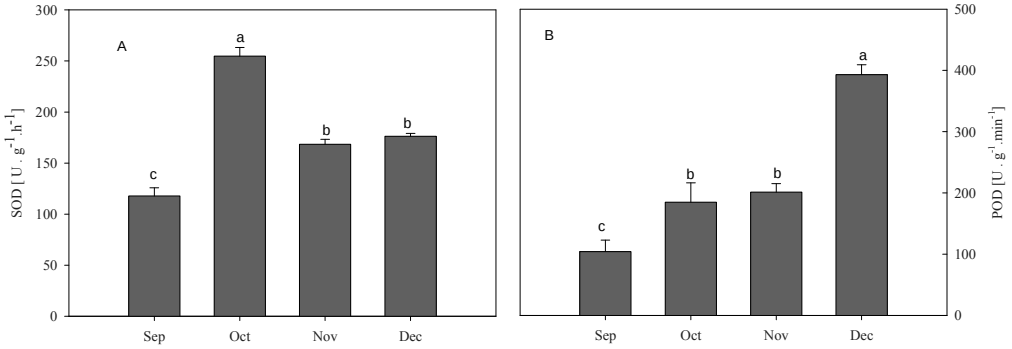

Figure 4 : Seasonal changes in the activities of antioxidant enzymes for *J. curcas* L. seedling leaf. Each value represents the mean ± standard errors of four months.

Discussion

Temperatures were very different between seasons by an automatic meteorological station placed in the study site, and photosynthetic parameters such as Pn, gs, Ci and Tr were strongly influenced by these seasonal changes in temperature. It was reported that the declines in photosynthesis observed at cold temperatures have been attributed to several possible causes among which is a photoprotective mechanism in photosystems by energy dissipation, the loss of enzymatic activities participating in the Calvin cycle, the stomatal closure which compromises gas exchange and CO_2 fixation[7]. Thus, it is most probably the temperature dependence of gs, Ci and Tr, which causes the drop in photosynthesis. In September and October, values of Fv/Fm before dawn were within the optimal range (0.80-0.83 found in unstressed leaves of higher plants) showing the good physiological state of plants[8]. Even during the November, Fv/Fm ratio did not fall below 0.75 (0.784±0.01), suggesting therefore that potential decreases in that ratio should be attributed to photoprotection,. Also, *J. curcas* leaves should have had an increased capacity to dissipate excess excitation energy, as indirectly inferred from their lower ΦPSII under the low temperature conditions. Together, these data suggest that a reduced susceptibility to low-temperature-induced photoinhibition plays a role in the cold-tolerance of photosynthesis in *J.* curcas L. Growth at a cold winter led to an obvious decrease in the indicated chlorophyll fluorescence parameters, showing chronic photoinhibiton.

Leaf chlorophyll content stands out as being both sensitive to environmental conditions and having a very strong influence on leaf optical properties[9]. As a consequence of the different pigment compositions of their photosynthetic apparatus, the variation in leaf pigment (chlorophyll and carotenoid) content in plants is because of these factors. Our results reveal that photosynthetic pigments experience strong seasonal changes in *J. curcas* from autumn to winter. These changes are probably controlled by various external factors and internal factor, most likely the low temperature and leaf thickness. Lower chlorophyll content under low temperature could be attributed to the rate of chlorophyll degradation in comparison to the rate of synthesis[10].

CONCLUSIONS

Taking into account the *J. curcas* are deciduous, shedding the leaves in dry season for December or January, and the climate of research region belong to humid climate, we only study the photosynthetic characteristic of *J. curcas* from September to December. According to the experiment, we found that there were significantly decreased all photosynthetic parameters entering winter climate conditions, but the values of Pn remain above zero before the leaves were fallen, and some protective enzyme to reduce and/or tolerate photooxidative stress in winter. Combine with the *J. curcas* can survive in suboptimal conditions, and also overwinter the climate of Mianyang regions (data were not shown). Thus, we concluded that *J. curcas* can adapt to the climate of Mianyang region through acclimation of cold adaptation.

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