American Journal of Plant Sciences, 2018, 9, 1630-1645
http://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Research on Light Response Curve Fitting Model of Four Chamaenerion Plants on the Serzilla Mountains

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How to cite this paper: Wan, L.S., Xing, Z., Chang, X.Y., Liu, J. and Zhang, G.R. (2018) Research on Light Response Curve Fitting Model of Four Chamaenerion Plants on the Serzilla Mountains. *American Journal of Plant Sciences*, **9**, 1630-1645.
https://doi.org/10.4236/ajps.2018.98118

Received: May 25, 2018
Accepted: July 9, 2018
Published: July 12, 2018

Abstract

In order to study the applicability of different light response models to the photoresponse curves of four species of Chamaenerion, four species of Chamaenerion collected from Serzilla were used as test materials. Four common photosynthetic models were used to fit the photosynthetic response curve of the leaves. The results show that: 1) The effect of different photosynthetic response models on photosynthetic response curve of the genus chromasia was different. The fitted value of the correction model of right angled hyperbola was closest to the measured value, the R2 was 0.998, and RE was 0.216. 2) In terms of fitting the photosynthetic parameters, the initial quantum efficiency, light compensation point and dark respiration rate were suitable for fitting with non-right angle hyperbolic model. In terms of fitting the photosynthetic parameters, the initial quantum efficiency, light compensation point and dark respiration rate were suitable for fitting with non-right angle hyperbolic model. 3) The photosynthetic characteristics of *C. angustifolium* subsp. circumvagum reflect the negative response to high altitude radiation. Under strong radiation, the photosynthetic rate, apparent quantum efficiency, and light saturation point are low. On the other hand, *C. conspersum* has a positive response to high altitude radiation. *C. angustifolium* and *C. latifolium* has a higher light compensation point and higher light saturation point, but it is also positive for high altitude radiation. The response is only a choice of light intensity at different elevations, which also explains the distribution of *C. angustifolium* and *C. latifolium* in the salmonella with a single elevation, habitat, and slope.

Keywords

Alpine Plant, Chamaenerion, Optical Response Curve, Right Angle Hyperbolic Correction Model

1. Introduction

The plant chamaenerion is a medicinal ornamental plant for ecological restoration [1] [2] [3], has very high application value and has gradually become the hot spot in research on modern botanical drug [4] [5] [6] [7]. Now the response curve fitting models of the photosynthetic light are diversified. The four frequent models include rectangular hyperssions model, nonrectangular hyperssions model, exponential function model and modified model of rectangular hyperbola. The rectangular hyperssions model, nonrectangular hyperssions model and exponential function model can be used to fit an asymptote without an extreme, which cannot resolve the plant saturation intensity and maximum net photosynthetic rate by using the model equations [8] and can not reflect the light suppression phenomena after the plant reaches the saturation intensity [9]. The nonrectangular hyperssions includes the curve's curvature θ and approximates to the measured value in case of data fitting [10]. The corrected rectangular hyperssions model includes the coefficient β and γ, so it not only fits the light saturation point and light compensation point and computes the solution of the maximum net photosynthetic rate, but also roughly ensures that the fitted values and computed values approximate to the measured values highly.

Some bad weathers such as low temperature, drought, strong radiation and strong winds exist in the Tibetan Plateau, so the plants in this area feature distinct physiological and ecological adaptation [11] [12]. The strong radiation in the Tibetan Plateau will easily affect photosynthesis of the plants. When the altitude increases, the flavone content will increase in the plants, so the alpine plants have the radiation resistance stronger than that of the low-altitude plants [13]. For response to the illumination radiation intensity, the photosynthetic rate of some plants [14] [15] will become strong with growth of the radiation and these plants can actively utilize the light energy. The photosynthetic rate of some plants [16] [17] will become weak with growth of the radiation in order to avoid damage to the leaves under the strong light and enter the preventive status. Some persons [18] [19] think that this phenomena is caused by low temperature. In addition, the light saturation point and light compensation point of the alpine plants are lower than those of the low-altitude plants [16].

Therefore, identifying the photosynthesis light response curve of the alpine plants is significant for research on the photosynthetic characteristics of the alpine plants [20]. Four frequent light response modes are used to fit the light response data of four chamaenerion plants in this paper, the applicability of several light response modes is discussed, and some basis are provided for reasonable cultivation and scientific management of four chamaenerion plants.

2. Materials and Methods

2.1. Overview of Experimental Site

The experiment was conducted in the Tibetan Featured Flower Research and development Center of the National Flower Engineering Technology Research Center. The experiment site is located in the rare and endangered garden plant cultivation base of Tibet Agriculture & Animal Husbandry University in Bayi Town, Bayi District, Nyingchi City. It is located in the lower reaches of the Niyang River, with an altitude of 2970 m. It belongs to the warm and humid climate in Southeast Tibet with annual average temperature of 8.6˚C, the average temperature of the hottest month of 15.6˚C, the average temperature of the coldest month of 0.2˚C, the extreme maximum temperature of 30.2˚C, the extreme minimum temperature of −15.3˚C, ≥10˚C accumulated temperature of 2 225.7˚C and frost-free period of 177 d. There is no month with monthly average temperature of ≤ 0˚C throughout the year. The number of days with daily average temperature of ≥ 10˚C is 159.2. The average annual rainfall is 634.2 mm. The distribution of precipitation is uneven throughout the year, mainly in June-September (71.6%). The average relative humidity, humidity coefficient, maximum snow thickness, annual hail days, annual thunderstorm days, annual strong wind (wind speed ≥ 17.0 m/s) days, annual sunshine hours, sunshine percentage, average atmospheric pressure and temperature coefficient are 71%, 1.01, 11 cm, 2.8 d, 28.3 d, 7.6 d, 1 988.6 h, 46%, 70.6 kPa and 8.3, respectively. The late frost appears latest in early May, and the early frost appears earliest in late September [21]. The experimental site is open, and free from shading, and the lighting, ventilation and irrigation conditions are good.

2.2. Test Materials

The test materials include some perennial plants such as *C. angustifolium*, *C. angustifolium* subsp. Circumvagum, *C. conspersum* and *C. latifolium* in the Serzilla Mountains, Linzhi, Tibet Autonomous Region. After the test materials are cultivated and survive at the Tibet characteristic flowers and plants R&D center of the National Flowers and Plants Engineering Technology R&D center, they will be tested in the flower season.

2.3. Collection Method of Light Response Curve

The photosynthesis test is measured inside the greenroom at the Tibet Characteristics Flowers and Plants R&D Center of the National Flowers and Plants Engineering Technology Research Center. The test is performed at AM 9:00 ~ 11:30 in which the weather is clear. The Li-6400 portable photosynthesis instrument (LiCior Inc., Lincoln, USA) is sued. The fitting LED red and blue light source leaf room is used for automatic measurement of photosynthesis-light response curve in the open gas circuit. The photosynthesis photon flux densities are 2000, 1800, 1600, 1400, 1200, 1000, 800, 600, 400, 200, 100, 50, 25 and 0 μmol·m^{-2}·s^{-1}. The CO_2 density of the gas source is set as 400 μmol·mol^{-1} in case of measurement. The left room temperature 25˚C ± 0.5˚C, the air flow is 500 μmol·s^{-1}. The mature leaves with the normal form of the middle and up part and without plant diseases and insect pests are selected. 3 robust plantlets are selected for each plant. 1 leaf is measured for each plantlet. Measurement is performed three times.

2.4. Light Response Curve Model

2.4.1. Light Response Model and Parameter Fitting

Now the light response curve models are diversified. Four typical response models are selected for this test, including rectangular hyperssions model, modified model of rectangular hyperbola, nonrectangular hyperssions model and exponential function model.

The mathematical expression of the rectangular hyperssions model [22] is described as follows:

$$P_n(I) = \frac{\alpha I P_{\max}}{\alpha I + P_{\max}} - R_d \tag{1}$$

In this equation, $P_n(I)$ is the net photosynthesis rate, I is the photosynthesis photon flux density, α is the initial gradient of the light response curve, $P_{\max}$ is the maximum net photosynthetic rate and R_d is the dark respiration rate.

The modified model of rectangular hyperbola [23] [24] for the plant photosynthesis to the light response is expressed as follows:

$$P_n(I) = \alpha \frac{1-\beta I}{1+\gamma I} I - R_d \tag{2}$$

In this equation, α is the initial gradient of the light response curve, β and γ are the coefficient, I is the photosynthesis photon flux density, R_d is the dark respiration, and the saturation intensity I_{sat} is:

$$I_{sat} = \frac{\sqrt{(\beta+\gamma)/\beta - 1}}{\gamma} \tag{3}$$

The maximum net photosynthetic rate $P_{\max}$ is expressed as follows:

$$P_{\max} = \alpha \left(\frac{\sqrt{\beta+\gamma} - \sqrt{\beta}}{\gamma} \right)^2 - R_d \tag{4}$$

The nonrectangular hyperssions model [25] is expressed as follows:

$$P_n(I) = \frac{\alpha I + P_{\max} - \sqrt{(\alpha I + P_{\max})^2 - 4\theta\alpha I P_{\max}}}{2\theta} - R_d \tag{5}$$

In this equation, $P_n(I)$ is the net photosynthesis rate, I is the photosynthesis photon flux density, θ is the curve curvature, α is the gradient of the plant photosynthesis to the light response curve in case of $I = 0$, namely the initial gradient of the light response curve, which is also called as the initial quantum efficiency.

P_{max} is the maximum net photosynthetic rate and R_d is the dark respiration rate.

The exponential equation [26] of the plant photosynthesis to the light response given by Bassman and Zwier is expressed as follows:

$$P_n(I) = P_{max}\left(1 - e^{-\alpha I/P_{max}}\right) - R_d \tag{6}$$

In this equation, the definitions of $P_n(I)$, α, P_{max}, R_d and I are same as the above definitions.

2.4.2. Calculation of Characteristic Parameters of the Light Response Curve

The initial quantum efficiency, maximum net photosynthetic rate and dark respiration rate of different chamaenerion plants in Serzilla Mountains can be obtained via photosynthesis model fitting. The linear regression is performed for the net photosynthesis rate data under the low photosynthesis photon flux density (≤200 μmol·m^{-2}·s^{-1}). The intersection point between the regressive line and X axis (P_n = 0) is the light compensation point. The intersection point with $y = P_{max}$ is the light saturation point. For modified model of rectangular hyperbola, light saturation point and maximum net photosynthetic rate can be calculated by using the Equation (3) and (4). For the exponential function model, the light saturation point is the corresponding photosynthesis photon flux density [27] [28] of 0.9 P_{max} or 0.99 P_{max}.

2.5. Data Processing

The Excel is used for statistical analysis and plotting of the data.

To further test precision of the fitting data and actual measured photosynthesis parameter, RE (the relative error) [29] is defined:

$$RE = \left|y_t - \hat{y}_t\right| / y_t$$

In this equation, y_t is the measured values and y_t is the fitting value. Smaller RE indicates that the fitting value approximates to the measured values.

3. Results and Analysis

3.1. Fitting and Comparison of Light Response Curve

Shown as the **Figure 1**, the rectangular hyperssions model, nonrectangular hyperssions model, exponential function model and modified model of rectangular hyperbola are used to fit the photosynthesis light response curves of four chamaenerion plants on the Serzilla Mountains. Four models can fit the photosynthesis data of four test materials well and the coefficient R^2 is between 0.964 and 0.999. The pure photosynthesis rate of *C. angustifolium*, *C. angustifolium* subsp. Circumvagum and *C. latifolium* will significantly reduce with growth of the photosynthesis photon flux density, namely light suppression phenomena. The rectangular hyperssions model can accurately reflect such phenomena. The photosynthesis fitting values of a model for different plants are similar to the

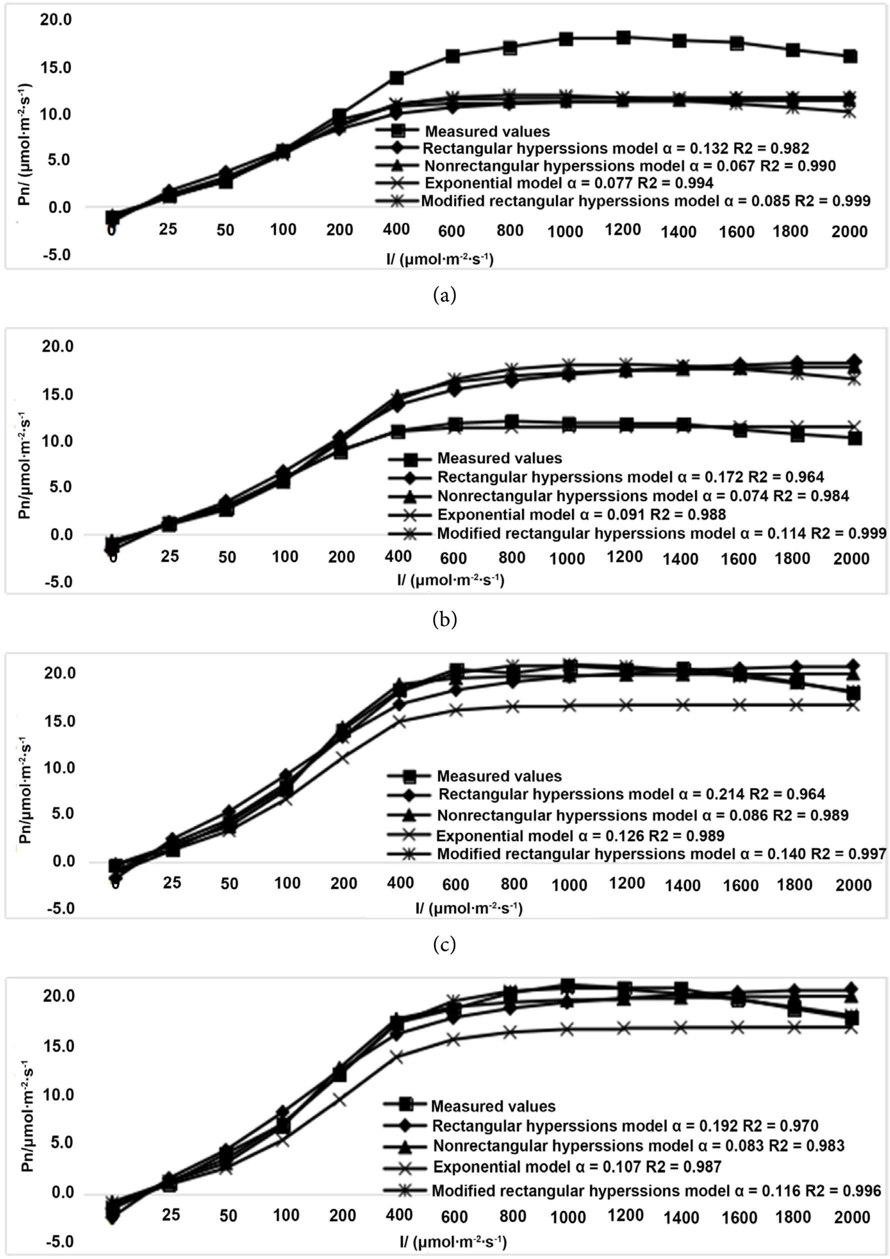

Figure 1. Photosynthetic-photoresponse curves of four species of *Chamaenerion* plants fitted by different models.

measured values under weak light conditions. When the photosynthesis photon flux density is more than 200 μmol·m^{-2}·s^{-1}, the exponential model fitting value is always smaller than the measured values and fitting values of other models. The diagram also shows that the fitting curves of the high determination coefficient are not much overlapped with the measured value curves.

It is known from Table 1, R^2 (0.998) of the modified model of rectangular hyperbola is the maximal determination coefficient, followed by R^2 (0.989) of exponential function model and R^2 (0.987) of nonrectangular hyperssions

Table 1. Photosynthetic parameters and their data of four species of *Chamaenerion* plants fitted by four models.

Model	Species/vari-eties	Dark respiration rate	Light compensation point	Light saturation point	Maximum net photosynthetic rate	R^2	R^2 average value	RE	RE average value
Rectangular hyperssions model	*C. angustifolium* subsp. *circumvagum*	1.602	10.560	292.380	13.788	0.964	0.970	0.359	0.616
	C. angustifolium	1.677	13.758	408.400	21.332	0.982		0.393	
	C. conspersum	1.947	9.852	333.600	25.298	0.964		1.345	
	C. latifolium	2.346	13.506	377.330	25.210	0.970		0.366	
Nonrectangular hyperssions model	*C. angustifolium* subsp. *circumvagum*	0.829	11.243	259.490	12.232	0.984	0.987	0.242	0.306
	C. angustifolium	0.675	10.086	359.710	18.750	0.990		0.311	
	C. conspersum	0.346	4.048	283.790	21.513	0.989		0.275	
	C. latifolium	0.799	9.660	326.080	21.739	0.983		0.396	
Exponential model	*C. angustifolium* subsp. *circumvagum*	1.099	12.673	333.981	11.231	0.988	0.989	0.189	0.373
	C. angustifolium	1.051	14.105	405.842	17.346	0.994		0.241	
	C. conspersum	1.057	8.600	326.787	21.062	0.989		0.733	
	C. latifolium	1.067	10.262	426.734	20.478	0.987		0.329	
Modified model of rectangular hyperbola	*C. angustifolium* subsp. *circumvagum*	1.183	11.090	844.411	11.872	0.999	0.998	0.063	0.216
	C. angustifolium	0.916	11.095	1147.728	17.797	0.999		0.064	
	C. conspersum	1.151	8.519	965.082	22.073	0.997		0.617	
	C. latifolium	1.299	11.620	1023.592	21.388	0.996		0.121	
The measured values	*C. angustifolium* subsp. *circumvagum*	1.047	11.848	800.000	11.862				
	C. angustifolium	1.092	11.504	1200.000	18.062				
	C. conspersum	0.427	4.931	1000.000	21.888				
	C. latifolium	1.470	15.946	1000.000	23.067				

model. The minimal determination coefficient of the modified model of rectangular hyperbola is 0.970. The determination coefficient indicates that four models can better fit photosynthesis light response curves of four chamaenerion plants. The fitting effect of four models are ranked from high to low as follows: modified model of rectangular hyperbola, exponential function model, nonrectangular hyperssions model and rectangular hyperssions model.

From the relative error average value, the minimal RE average value of the modified model of rectangular hyperbola is 0.216, followed by RE (0.306) of nonrectangular hyperssions model and RE (0.373) of exponential function model. The rectangular hyperbola model has the maximal relative error average value and its RE average value is 0.616. The relative error indicates that the similarity between the fitting values of four models and the measured values are ranked from high to low as follows: modified model of rectangular hyperbola, nonrectangular hyperssions model, exponential function model and rectangular hyperssions model.

To compare the determination coefficient and relative errors, the similarity between the fitting effect and fitting values of four models and the measured values complies with certain law and is not consistent, so R^2 can only describe that the fitting degree of the model is higher, but it cannot guarantee that the fitting results are consistent with the measured value [30].

3.2. Comparison of Light Response Characteristic Parameters of Different Chamaenerion Plants

3.2.1. Apparent Photosynthesis Quantum Efficiency and Initial Quantum Efficiency

The apparent photosynthesis quantum efficiency is also called as the quantum efficiency under the light intensity, measures the utilization capability of the plants to the low-light quantum density and is also the basic parameter to reflect the plant light energy utilization and photosynthesis material productivity [31]. The line equation is used to fit the light response data under the weak light intensity (≤200 $\mu mol \cdot m^{-2} \cdot s^{-1}$) to get initial gradient, which is called as the apparent photosynthesis quantum efficiency [32]. Research on the light response characteristics of four chamaenerion plants on the Serzilla Mountains indicates that the apparent quantum efficiencies of four chamaenerion plants [33] are 0.0473 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (*C. angustifolium* subsp. Circumvagum), 0.0529 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (*C. angustifolium*), 0.0760 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (*C. conspersum*) and 0.0677 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (*C. latifolium*).

It is known from **Table 2**, To compare the initial quantum efficiency for fitting of four models with the apparent quantum efficiency, the minimal average value of the relative error RE obtained from the fitting values of the nonrectangular hyperssions model is 0.299, which is far less than that of other models. The initial quantum efficiency of the nonrectangular hyperssions to compare the initial quantum efficiency for fitting of four models with the apparent quantum efficiency, the minimal average value of the relative error RE obtained from the fitting values of the nonrectangular hyperssions model is 0.299, which is far less than that of other models. The initial quantum efficiency from the nonrectangular hyperssions model approaches to the apparent quantum efficiency most. The initial quantum efficiency from the rectangular hyperssions model is far higher than the apparent quantum efficiency. The nonrectangular hyperssions model can better reflect the light energy utilization efficiency of four chamaenerion plants under the low light intensity on the Serzilla Mountains. The relative errors between the initial quantum efficiency and apparent quantum efficiency of models of different plants show that the fitting effect of four models for one plant is ranked from high to low as follows: *C. latifolium*, *C. angustifolium* and *C. conspersum*. The fitting values of *C. angustifolium* subsp. Circumvagum is very different from the measured values.

Table 2. The relative error between the fitting value of initial quantum efficiency and the appwerent quantum efficiency of different models of light response parameters of four species of *Chamaenerion.*

Model	*C. angustifolium* subsp. *circumvagum*	*C. angustifolium*	*C. conspersum*	*C. latifolium*	Average value
Rectangular hyperssions model	2.630	1.501	2.162	1.520	1.953
Nonrectangular hyperssions model	0.569	0.272	0.264	0.092	0.299
Exponential model	0.928	0.454	0.863	0.405	0.662
Modified model of rectangular hyperbola	1.419	0.612	1.066	0.528	0.906
Average value	1.386	0.710	1.089	0.636	—

3.2.2. Maximum Net Photosynthetic Rate

The maximum net photosynthetic rate fitted by four models are compared with the measured values. The RE in the Table 3 shows that the average RE value of the modified model of rectangular hyperbola is 0.024 and its fitting value approximates to the measured value much. The fitting effect of the maximum net photosynthetic rate shows that the modified model of rectangular hyperbola can show the most accurate maximum net photosynthetic rate of four chamaenerion plants on the Serzilla Mountains in the four light response curve fitting models, followed by the nonrectangular hyperssions model. The difference between the fitting values of the rectangular hyperssions model and the measured values is maximum. For the fitting effect of four models to the maximum net photosynthetic rate of same plants, the minimal RE of the relative errors of *C. conspersum* is 0.055. The RE value of *C. angustifolium* subsp. Circumvagum is 0.062. The RE value of *C. angustifolium* is 0.068. The RE value of the *C. latifolium* is 0.084. On the whole, the fitting effect of the fitting model of four light response curve is very accurate.

3.2.3. Light Saturation Point

From the RE values in the Table 4, when the fitting light saturation point of four models are compared with the measured values, the fitting value of the modified model of rectangular hyperbola approximates to the measured value much and its average RE value is 0.039. From the fitting effect of the light saturation point, the modified model of rectangular hyperbola can show the most accurate light saturation points of four chamaenerion plants on the Serzilla Mountains, followed by the exponential function model. The difference between the fitting values of the nonrectangular hyperssions and the measured value reaches the maximum. The REV values of the exponential function model, rectangular hyperssions model and nonrectangular hyperssions mode are similar and are far bigger than the RE value of modified model of rectangular hyperbola. For the fitting effect of four models for the light saturation point of same plant, the RE value of the relative errors of the *C. latifolium* is 0.473, which is similar to that of the *C. angustifolium* subsp. Circumvagum (RE is 0.487). The RE value of the *C. angustifolium* is 0.516 and is similar to that of *C. conspersum* (RE value is 0.523).

Table 3. The relative error between the maximum net photosynthetic rate fitting value and the measured value of light response parameters of four species of *Chamaenerion*.

Model	*C. angustifolium* subsp. *circumvagum*	*C. angustifolium*	*C. conspersum*	*C. latifolium*	Average value
Rectangular hyperssions model	0.162	0.181	0.156	0.093	0.148
Nonrectangular hyperssions model	0.031	0.038	0.017	0.058	0.036
Exponential model	0.053	0.040	0.038	0.112	0.061
Modified model of rectangular hyperbola	0.001	0.015	0.008	0.073	0.024
Average value	0.062	0.068	0.055	0.084	—

Table 4. The relative error between the fitting value of Light saturation Point and the measured value in different models of four species of *Chamaenerion.*

Model	*C. angustifolium* subsp. *circumvagum*	*C. angustifolium*	*C. conspersum*	*C. latifolium*	Average value
Rectangular hyperssions model	0.635	0.660	0.666	0.623	0.646
Nonrectangular hyperssions model	0.676	0.700	0.716	0.674	0.692
Exponential model	0.583	0.662	0.673	0.573	0.623
Modified model of rectangular hyperbola	0.056	0.044	0.035	0.024	0.039
Average value	0.487	0.516	0.523	0.473	—

3.2.4. Light Compensation Point

When the fitting light compensation points of four model are compared with the measured value, from the RE values in the Table 5, the average RE value of the nonrectangular hyperssions model is 0.187 and its fitting value approximates to the measured values much. From the fitting effect of the light compensation point, the nonrectangular hyperssions model can better reflect the light compensation point of four chamaenerion plants on the Serzilla Mountains, followed by the modified model of rectangular hyperbola. The difference between the fitting value of the rectangular hyperssions and the measured is maximum. For fitting effect of different light response curve fitting models to the light compensation point of same plants, the minimal RE value of the relative errors of the *C. angustifolium* subsp. Circumvagum is 0.073, the RE value of the *C. angustifolium*RE is 0.145. The RE value of the *C. latifolium* is 0.294. The RE value of the *C. conspersum* is 0.662.

3.2.5. Dark Respiration Rate

The RE in the Table 6 shows that the fitting dark respiration rate of the nonrectangular hyperssions mostly approximates to the measured value in the four models.

The average RE value is 0.309. To compare the relative errors of the dark respiration rate of different plant models, the fitting effect of four models for same plant is ranked from high to low as follows: *C. angustifolium* subsp. Circumvagum,

Table 5. The relative error between the fitting value of Light compensation Point and the measured value in different models of four species of *Chamaenerion.*

Model	*C. angustifolium* subsp. *circumvagum*	*C. angustifolium*	*C. conspersum*	*C. latifolium*	Average value
Rectangular hyperssions model	0.109	0.196	0.998	0.153	0.364
Nonrectangular hyperssions model	0.051	0.123	0.179	0.394	0.187
Exponential model	0.070	0.226	0.744	0.356	0.349
Modified model of rectangular hyperbola	0.064	0.036	0.728	0.271	0.275
Average value	0.073	0.145	0.662	0.294	—

Table 6. The relative error between the fitting value of dark respiration rate and the measured value in different models of four species of *Chamaenerion.*

Model	*C. angustifolium* subsp. *circumvagum*	*C. angustifolium*	*C. conspersum*	*C. latifolium*	Average value
Rectangular hyperssions model	0.530	0.536	3.560	0.596	1.306
Nonrectangular hyperssions model	0.209	0.382	0.189	0.457	0.309
Exponential model	0.049	0.037	1.476	0.274	0.459
Modified model of rectangular hyperbola	0.130	0.161	1.696	0.116	0.526
Average value	0.230	0.279	1.730	0.361	—

C. angustifolium and *C. latifolium*. The difference between the fitting value of *C. conspersum* and the measured values is maximum. The nonrectangular hyperssions model can better show respiration role of the chamaenerion plant on the Serzilla Mountains under the dark environment.

4. Conclusion

Study on the selection of photo-response curve fitting model for four species of *Chamaenerion* in Serzilla Mountains, the results show that: 1) The effect of different photosynthetic response models on photosynthetic response curve of the genus chromasia was different. The fitted value of the correction model of right angled hyperbola was closest to the measured value, the R2 was 0.998, and RE was 0.216. 2) In terms of fitting the photosynthetic parameters, the maximum net photosynthetic rate and the light saturation point are suitable for fitting with the right-angle hyperbolic modified model. 3) The photosynthetic characteristics of *C. angustifolium* subsp. circumvagum reflect the negative response to high altitude radiation. Under strong radiation, the photosynthetic rate, apparent quantum efficiency, and light saturation point are low. On the other hand, *C. conspersum* has a positive response to high altitude radiation. *C. angustifolium* and *C. latifolium* has a higher light compensation point and higher light saturation point, but it is also positive for high altitude radiation. The response is only a choice of light intensity at different elevations, which also explains the distribution of *C. angustifolium* and *C. latifolium* in the salmonella with a single elevation, habitat, and slope.

5. Discussion

Four chamaenerion plants on the Serzilla Mountains are significant in medical applications such as antibiosis and antiphlogosis, antianxiety, tumor growth inhibition and anti-aging, regional ecological restoration such as burning, cutover land, roadside landslide and retaining wall edge, urban garden greening and ecological restoration construction. Their photosynthetic characteristics shall be further studied. It has important realistic significance for reasonable development and protection of chamaenerion plant resources in Tibet.

From fitting of photosynthesis parameters in this research, the maximum net photosynthetic rate and light saturation point are applicable to fitting of the modified model of rectangular hyperbola. The photosynthesis parameters fitted by the modified model of rectangular hyperbola are matched with the measured values, which is recognized and extensively applied by the researchers in most research on the light response fitting models and is well validated in this research. The modified model of rectangular hyperbola is recommended to study the photosynthesis light response data of the plants. The modified model of rectangular hyperbola is most suitable for fitting of the photosynthesis light response curves for four chamaenerion plants on the Serzilla Mountains, so the fitting values of modified model of rectangular hyperbola are used as the photosynthesis parameters (except apparent quantum efficiency) of four chamaenerion plants on the Serzilla Mountains. The fitting values are described as follows: the fitting value of the *C. angustifolium* apparent quantum efficiency is 0.0529 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the maximum net photosynthetic rate is 17.797 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light saturation point is 1147.728 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light compensation point is 11.095 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the dark respiration rate is 0.916 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the *C. angustifolium* subsp. Circumvagum apparent quantum efficiency is 0.0473 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the maximum net photosynthetic rate is 11.872 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light saturation point is 844.411 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light compensation point is 11.090 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the dark respiration rate is 1.183 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the *C. conspersum* apparent quantum efficiency is 0.0760 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the maximum net photosynthetic rate is 20.073 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light saturation point is 965.082 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light compensation point is 8.519 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the dark respiration rate is 1.151 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the *C. latifolium* apparent quantum efficiency is 0.0677 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the maximum net photosynthetic rate is 21.388 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light saturation point is 1023.592 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the fitting value of the light compensation point is 11.620

μmol·m^{-2}·s^{-1} and the fitting value of the dark respiration rate is 1.299 μmol·m^{-2}·s^{-1}.

The light is the important environment factor to affect photosynthesis. The wide-range adaptation to the light shows that the plants have stronger adaptability to the environment. The plants with the lower light compensation point and higher light saturation point have stronger adaptability to the light environments. The plants with the higher light compensation point and lower light saturation point have weaker adaptability to the light environments [31]. The *C. conspersum* has lower light compensation point, higher light saturation point, higher net photosynthesis rate and wider illumination range in the research and is nearly distributed at different altitudes on the east and west slopes on the Serzilla Mountains. Such performance is similar to the Rheum tangutiCum [14], *Kobresia humilis* [15] and *Polygonum viviparum* L. [34] which have the active response to the strong radiation on the plateau. The *C. angustifolium* subsp. Circumvagum has higher light compensation point, lower light saturation point, narrow illumination adaptation range and photosynthesis feature of the shade-demanding plants. The photosynthetic characteristics of the *C. angustifolium* subsp. Circumvagum show passive response to the stronger radiation on the plateau and has lower photosynthesis rate, lower apparent quantum efficiency and lower light saturation point under the strong radiation. The *C. angustifolium* and *C. latifolium* has higher light compensation point and light saturation point, so they have weak adaptability to the light environment, but they have active response to the strong radiation on the plateau and can select the radiation with different light intensities at different altitudes. It can explain why the *C. angustifolium* and *C. latifolium* are distributed narrowly on the Serzilla Mountains. From the view of the light environment acclimation and adaptation, the plants on the plateau are difficult to grow in the areas with lower altitude and lower light intensities. The *C. angustifolium*, *C. angustifolium* subsp. Circumvagum and *C. latifolium* have significant suppression phenomena. The *C. conspersum* is most suitable for the applications under the high light intensities in Tibet. The daily change of photosynthesis and response to different CO_2 concentrations shall be further studied for four plants. Research on response to different CO_2 concentrations aims at the influences of the global weather change (CO_2 concentration and temperature increase) to the alpine plant photosynthesis and further derives their influences on other aspects in the Tibet plateau.

The alpine plant indicates the mountain plants growing on the high mountain tree line and higher and snow line. Now the research on the photosynthetic characteristics of the alpine plants mainly focuses on the North Pole and tundra zone and the research on the alpine plant at the middle and low latitude is missing [35]. The research on the photosynthesis of the chamaenerion plant on the Serzilla Mountains supplements research on the photosynthesis research of the alpine plants at the middle and low latitude. The research on the photosynthetic characteristics of the alpine plants in the Tibet plateau shows the following law: With growth of the altitude or effective photosynthesis radiation intensity, the photosynthetic characteristics parameters of the plant will grow or reduce. Some scholars [36] think that it may be caused by the survival regulation mechanism of the plant or be caused by consideration of single factor in research. The research on the photosynthetic characteristics of the alpine plants shall integrate interactive role or main component role of multiple environmental factors.

Acknowledgements

This study was financially supported by follow fund: Research on Tibet resources plant information system based on Android (2015XZ01G28); Comprehensive study on the diversity and landscape application techniques of *Chamaenerion* in Tibet (QC2015-43); Collection and utilization of medicinal flower resources in Tibet.

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