Which is the Best Model for Describing Light-response Curves in two *Bergenia* Species

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Abstract
Photosynthetic responses to light environment can be useful measurements to determine favorable habitat conditions for the conservation and cultivation of medicinal species. The eight models are used to explore the best model for describing light-response curves in two Bergenia species. The results show that the light-response curves of Bergenia tianquaninsis and Bergenia purpurascens were best described by the modified exponential model, the Pmax and Rd calculated by the modified exponential model were more accurate than those calculated by other models in two Bergenia. This model may be widely applicable to light-response curves of other Bergenia species.
Keywords: BERGENIA, LIGHT-RESPONSE CURVES, MODLES

1. Introduction

Genus *Bergenia*, flowering plant in the family Saxifragaceae, is the source of drug bergenin. They are distributed in central Asia and the Himalayan region[1]. The genus comprises ten species namely, seven species are distributed in China, there are *Bergenia tianquanensis*, *Bergenia emeiensis*, *Bergenia purpurascens*, *Bergenia scopulosa*, *Bergenia crassifolia* Fritsch, *Bergenia pacumbis*, *Bergenia stracheyi* Engl.[2],which is a perennial herb, 1 to 2 feet tall with thick, stout, creeping rootstock and bears spirally arranged rosette of leaves 6–35 cm long and 4–15 cm broad [1,3]. The rhizome o f *Bergenia* is a well–known and widely used traditional Chinese medicine (TCM) [4,5]. Because of their higher Medicinal value, resulting the natural resources of medicinal *Bergenia* species have been declining dramatically due to overharvesting and curtailment of habitat over the past several decades, and the plants have become more scarce recently.

There are few research about *Bergenia*, the work for *Bergenia* mainly focused on analysis of chemical constituents, optimization of extraction methods[1,4,5].

There is no report on other areas in the literature, but measuring light-response curves are very important to assess optimal habitat conditions for growth and the conservation of species, which have been useful in cultivation[6,7]. In order to investigate the light-response curves, some mathematical models for describing light-response curves have been reported, The most extensively applied model is Nonrectangular hyperbola model, Rectangular hyperbola model, Modified rectangular hyperbola model, Exponential model, Modified exponential model [8,9].

The *Bergenia tianquanensis* and *Bergenia purpurascens* that belonging to the *Bergenia* are used to measure the light-response curves, we want to know (1) which is best model for *Bergenia* among five extensively applied models? (2) which are optimal photosynthetic parameters in best model respectively?

2. Materials and methods

2.1. Experimental situation

The experiment was conducted in experimental field of China West Normal University (30°49′N, 106°04′E), with main purple soil conditions at 300 m in altitude. Belonging to subtropical humid monsoon climate, mean annual temperature and mean annual precipitation are 15.8-17.8°C, and 980-1150mm, respectively.

2.2. Experimental materials and methods

The plants belonging to two species of *Bergenia* (*Bergenia tianquaninsis* and *Bergenia purpurascens*) were transplanted into the experimental field at China West Normal University for a year of acclimation, and then they were used as materials in this experiment. In growing period, ten individual plants were selected from each species to measure their light-response curve by using the portable photosynthesis system Li-6400 (LI-COR, Lincoln, USA), with leaves illuminated at the PAR 600 μmol·m^{-2}·s^{-1} until equilibration, and the flow rate set as 500 μmol·s^{-1}. The relative humidity and temperature in the chamber were controlled at 65%±5% and 25±0.95°C, respectively.

2.2.1. Determination of diurnal variation of photosynthesis

For each plant, six well growing leaves were measured individually, from 7:00 to 19:00 in the sunny day, to obtain the net photosynthetic rate (Pn) and other photosynthetic parameters. The correlation was analyzed among the photosynthetic parameters.

2.2.2. Determination of light-response curve

In light-response, CO_2 cylinders to be provided carbon source and used CO_2 mixer to inject a stable 395±4.14 μmol·mol^{-1} CO_2 concentration, the net photosynthetic rates (Pn) were determined at seventeen gradually levels of photosynthetically avaible radiation (PAR)[10]. Light-response curve models with reference to Dias-Filho[9].

2.3. Ways of processing light-response curve data

The data obtained from light-response curves were divided into two groups**.** The measured data included the seventeen levels of PAR 0-2000 μmol·m^{-2}·s^{-1}, and counted the average values of Pn. One group included 14 levels of PAR belong 0-1200 μmol·m^{-2}·s^{-1} were used to fit with five models. Pn values obtaining from the best fit of each model were called fitted values, and parameter estimation was completely using the nonlinear regression module of SPSS 19.0 (SPSS Inc., Chicago.IL, USA). R^2 was taken as measures for the quality of the fit.

3. Results

In *B. tianquanensis*, R^2 values of the five models were equal or greater than 0.931, Photosynthetic parameters computed by these models were contrasted with the measured values (Table 1), and the photosynthetic parameters obtained by these models showed little difference comparing with the measured values. The LCP of modified exponential model was close to the measured values. The LSP can not been calculated by Exponential model 1 and Nonrectangular hyperbola model. The LSP of rrectangular hyperbola model 2 and modified exponential model were close to the measured values. The Pmax and Rd of modified exponential model was close to the measured values. So, the light-response curves of *B. tianquanensis* was best described by the modified exponential model, which implied it good fit to the measured values.

In *B. purpurascens*, R^2 values of the five models were equal or greater than 0.925, Photosynthetic parameters computed by these models were contrasted with the measured values (Table 2). The LCP of nonrectangular hyperbola model and modified exponential model was close to the measured values. The LSP can not been calculated by Exponential model 1 and Nonrectangular hyperbola model. The LSP of exponential model and modified exponential model

Table 1. Comparison of photosynthetic parameters calculated by the fitted formulations and measured values in *B. tianquaninsis*

Parameters	R^2	LCP	LSP	Pmax	Rd	AQY
Measured values	--	≈14.071	≈599.220	8.039	-0.878	--
Exponential model 1	0.998	13.004	--	7.466	0.752	0.060
Exponential model 2	0.998	13.004	907.923	7.464	-1.115	0.056
Exponential model 3	0.998	13.004	907.890	7.469	-0.751	0.050
Modified rectangular hyperbola model	0.999	14.964	1353.837	8.064	1.134	0.079
Rectangular hyperbola model 1	0.931	12.100	495.893	7.786	-1.437	0.0381
Rectangular hyperbola model 2	0.930	15.441	617.870	7.788	1.326	0.095
Nonrectangular hyperbola model	0.977	15.041	--	7.428	0.913	0.063
Modified exponential model	0.999	14.792	559.070	8.049	-0.942	0.067

Table 2. Comparison of photosynthetic parameters calculated by the fitted formulations and measured values in B. purpurascens

Parameters	R^2	LCP	LSP	Pmax	Rd	AQY
Measured values	--	≈35.641	≈800.540	7.715	-1.821	
Exponential model 1	0.993	33.644		7.976	0.504	0.056
Exponential model 2	0.993	33.644	816.789	7.780	-1.701	0.046
Exponential model 3	0.993	33.644	907.890	7.780	-0.751	0.050
Modified rectangular hyperbola model	0.994	32.189	992.732	7.845	1.108	0.074
Rectangular hyperbola model 1	0.925	8.060	540.710	8.208	-1.092	0.032
Rectangular hyperbola model 2	0.979	8.031	533.880	7.797	2.122	0.0893
Nonrectangular hyperbola model	0.955	35.313		7.858	1.425	0.041
Modified exponential model	0.997	36.505	766.307	7.676	-1.823	0.055

were close to the measured values. There were little difference in the Pmax of eight models. The Rd of modified exponential model was close to the measured values. So, the light-response curves of *B. purpurascens* was best described by the modified exponential model, which implied it good fit to the measured values.

4. Conclusions

The light-response curves of *B. tianquaninsis* and *B. purpurascens* were best described by the modified exponential model, especially when light intensity is beyond light saturation point, and the Pmax and Rd calculated by the modified exponential model were more accurate than those calculated by other models in *B. tianquaninsis* and *B. purpurascens*.

This model may be widely applicable to light-response curves of other *Bergenia* species. The photosynthetic parameters of *B. tianquaninsis* obtained by the modified exponential model are: LCP 14.792μmolm^{2}s^{-1}, LSP 559.070 μmol m^{2}s^{-1}, Pmax 8.039 μmol(CO_2)m^{2}s^{-1}, RD -0.942 μmol(CO_2)m^{2}s^{-1} and AQY 0.063, respectively. The photosynthetic parameters of *B. purpurascens* obtained by the modified exponential model are: LCP 36.505μmolm^{2}s^{-1}, LSP 766.307 μmol m^{2}s^{-1}, Pmax 7.676 μmol (CO_2) m^{2}s^{-1}, RD -1.823μmol(CO_2)m^{2}s^{-1} and AQY0.055, respectively. According to the efficiency ranges of AQY (0.03-0.07), the AQY of two *Bergenia* in the modified exponential model can meet the standard, which are 0.063 and 0.055, respectively. And the AQY and LSP show the two *Bergenia* species are shade tolerant plants. The two *Bergenia* have similar habits in natural conditions, which live in the damp rocks.

Acknowedgments

This work was supported by the Open Fund for Science and technology department of Sichuan province(No.466426) and the Scientific Research Foundation of China West Normal University (No. 421452).

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Design of the Quasi-diffuse Vacuum Arc Source with Cold Cathode in Vacuum Arc Deposition

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Abstract
The work proposed design principles and program of a compact and efficient quasi-diffusion arc source with cold cathode. Movement of arc spot was controlled through diode rotating transverse magnetic field covering the entire target surface, with adjustable frequency and strength. Meanwhile, manufacture of arc source and discharge testing were conducted according to the design principles and program. Results show that: large collective arc spot were gradually decomposed into dispersive arc spot lines with increasing rotation frequency and intensity of transverse magnetic field; arc spot lines gradually pervaded on the entire target surface, presenting morphology of dispersive arcs, thus greatly reducing power density of arc spot. Meanwhile, purified plasma with high density was extracted through axial-focusing guiding magnetic field, thus improving transport efficiency of plasma. In cold cathode target, the quasi-diffusion arc source program had achieved strong disperse arc state fully distributing on the entire target surface, without the need to heat target to high temperature. Through quasi-diffusion arc with cold cathode, discharge types and working stability of arc spot was greatly improved; corrosion uniformity and utilization of target was enhanced to reduce emission of MPs; transmission efficiency of plasma was improved, expanding application of vacuum arc deposition technology.
Keywords: DIODE ROTATING TRANSVERSE MAGNETIC FIELD, ARC SOURCE OF QUASI-DIFFUSION ARC WITH COLD CATHODE, AXIAL-FOCUSING GUIDING MAGNETIC FIELD, MPS, ARC DISCHARGE