Scant light Disaster Index Determination of Strawberry in Greenhouse

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Abstract. In northern China, the sunlight deficiency in the greenhouse is serious during the late autumn and winter. The main purpose of this study is to determine the scant light disaster index of strawberry in greenhouse. In terms oftwo experiments in a farmer's greenhouse we measured the net photosynthetic rate (Pn), chlorophyll content (ChlC), yield, fruit sugar content, and the growth of strawberry under different condition of sunlight shortage. Based on analysis of expremental data, the scant light disaster grade index of two strawberry varieties in greenhouse were identified. The results provide scientific basis for early warning of scant light disaster and guiding the farmers to manage disaster on strawberry production in greenhouse.

1. Introduction

Strawberry enjoys the "fruit Queen" reputation with the characteristics of lovely color, rich nutrition and others [1]. In the fields of facility agriculture and sightseeing leisure agriculture, it is favored by customers and far outstrips other fruits in recent years.

Light and temperature play important roles in plant growth especially in greenhouses, affecting the dry mass distribution and the final yield of plants [2-3]. With the shading days increasing, the effect on morphology, dry-matter partitioning, and photosynthetic response of grapevines in the greenhouse was aggregated [4]. As a sun-loving plant [5], strawberry is negatively affected bysunless weathers in many aspects such as leaf photosynthesis, yield and fruit quality [6-7]. Shading stress also has important effects on the photosynthesis characteristic and chlorophyll fluorescence characteristic of strawberry [8-11].

In the north of China, sunlight deficiency is a serious problem in greenhouse agriculture during late autumn and winter, mainly resulting from less sunshine weathers such as cloud, rain, snow, fog, haze and so on [12-15]. According to our observations, since November 6,2015,the scant light disastrous weather had lasted for nearly one month in Zhengzhou area of Henan province, which hindered the plant growth, led to low production and quality and being late in the market, and brought heavy losses to the farmers. Thus, it is significant to investigate the relationship between the duration of scant lighting and the disaster degree of strawberry production in greenhouse, which will

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help to make an early alerting according to weather forecasts.

Few studies have focused on the grading index of the scant light disaster. In this paper, by detecting the adverse effect of scant light on net photosynthetic rate (Pn), chlorophyll content (ChlC), yield, fruit sugar content, and the growth of strawberry, we aimed to determine the scant light disaster grade index of strawberry in the greenhouse, so as to make an early warning and guide the famers to manage disaster on strawberry production in greenhouse.

2. Materials and methods

The experimental greenhouse locates in the yellow river farm (Zhengzhou, Henan province, China, 34°54'N, 113°36'E, and 96.0 m elevation), running east to west and facing the south. The dimensions of the greenhouse are 75.0 m length, 8.1 m width , and 3.8 m height. It is comprised of semi-circular metal tubing, and covered with a low density polyvinylchloride (PVC) plastic. Experiments were conducted from January to February in 2015 and 2016 respectively, during the flowering and fruiting period of strawberry (Figure 1).

Figure 1. The panoramic view (a) and the interior view (b) of the greenhouse.

In this study, two strawberry varieties were chosen for 2015 and 2016 experiment, respectively. One variety is 'Red strawberry', with the characteristics of tall plant height, big fruit, high sugar content, heavy fragrance, good quality but slightly lower yield, being planted in 2015, which is the mainstream variety which is popular in the current market in China. The other strawberry cultivar is 'sweet Charlie', being planted in 2016,featured by strong vigor, high yield, tolerance to storage and transportation, medium quality, slightly acid. As the main planting variety, it accounts for more than 80% of total planting area in Henan province .

Black shading nets with 20% light transmittance were used to cover the plants, which made the treatments enjoyed the similar light intensity to the overcast condition.

The experiment in 2015 included 7 treatments: under the shading condition for 3 days (d), 5 d, 7 d, 10 d, 13 d, 16 d, respectively, and the control group (under the natural weather condition). The experiment in 2016 included 9 treatments: under the shading condition for 5 d, 7 d, 10 d, 13 d, 16 d, 19 d, 22 d , 26 d respectively,and the control group (Table 1). Both of the experiments were composed of 10 plants for each process.

Table 1. Experimental design of 2015 and 2016 in the greenhouse.

Year	Variety	Treatment
2015	Red strawberry	shading condition(3 d, 5 d, 7 d, 10 d, 13 d, 16 d) control group
2016	Sweet Charlie	shading condition(5 d, 7 d, 10 d, 13 d, 16 d, 19 d, 22 d , 26 d) control group

We measured the Pn of plant leaves with portable photosynthesis-fluorescence measurement system (LI-6400XT, USA), measured the ChlC with portable chlorophyll meter (SPAD-502Plus), measured the sugar content of the ripe fruit with portal sugar meter, and counted the amount of fruits for each plant, 5 random plants per treatment. All these jobs mentioned above were done from 9 to 11 in the morning.

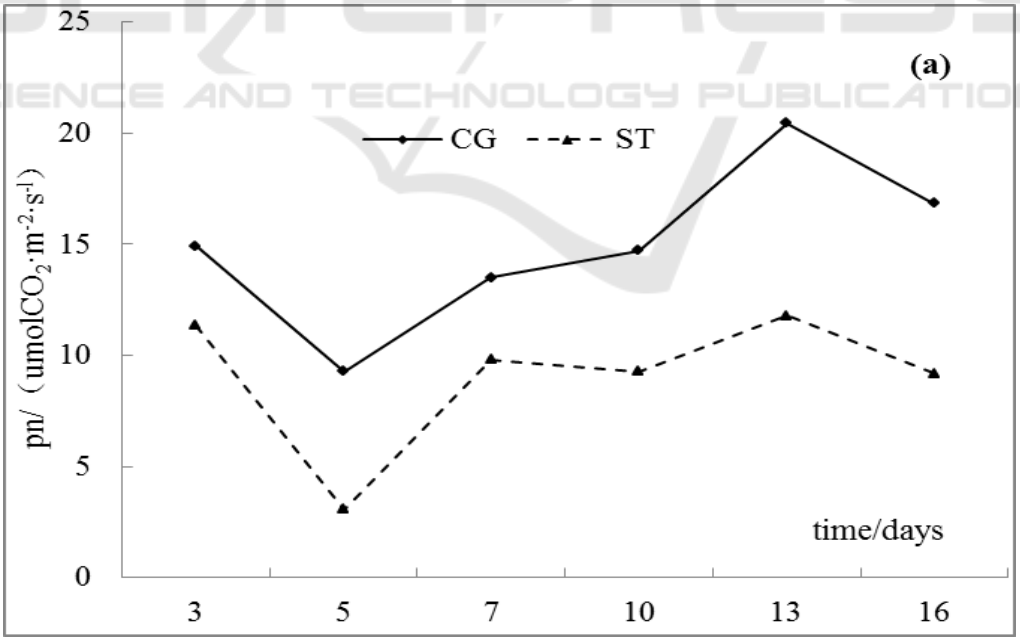
The Duncan method was used for multiple comparisons evaluated at $p<=0.05$.

3. Results

3.1. Effects of scant light on Pn of strawberry leaves in greenhouse

Characteristics of Pn were shown in Figure 2. The figure indicated that (1) the Pn value of plant leaves under the shading conditions was significantly lower than that of control group (CG). (2) The difference of Pn value was relatively large between the two varieties.

Shading resulted in the decline of photosynthetic rate. As a result, the accumulation of photosynthetic product was less, which affected the vegetative growth of plant.



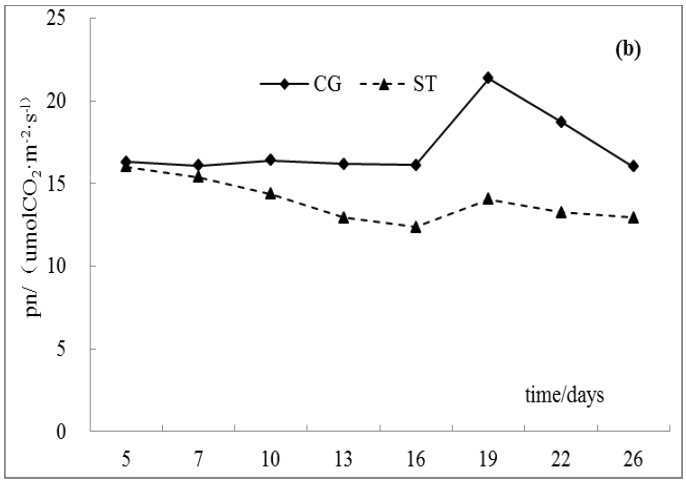


Figure 2. The Pn of strawberry leaves. a illustrates the Pn of 'Red strawberry' leaves in 2015, b illustrates the Pn of 'Sweet Charlie' leaves in 2016. CG (control group), ST (shading treatment).

3.2. Effects of scant light on ChlC of strawberry leaves in greenhouse

Characteristics of ChlC were shown in Figure 3. The figure indicated that (1) The ChlC began to decrease after 7 days scant light in 2015,and it expressed a sharply decline after 10 days shading. (2) The ChlC began to decrease after 19 days scant light in 2016. (3) Two sets of experimental data presented the similar characteristic, that was, the ChlC rose first and then fell. However, turning point of 'Sweet Charlie' was much later than that of 'Red strawberry', indicating that :

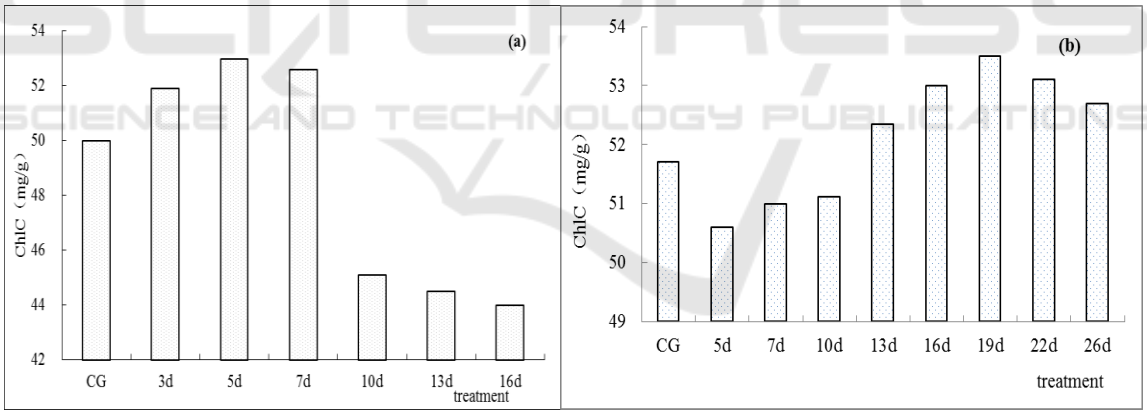


Figure 3. The ChlC of plant leaves. a illustrates the ChlC of 'Red strawberry' leaves in 2015, b illustrates the ChlC of 'Sweet Charlie' leaves in 2016.

3.3. Effects of scant light on sugar content of strawberry in greenhouse

Table 2 showed that (1) It made no difference to the soluble solids content (SSC) of fruit within 3 days scant light. (2) After more than 3 days scant light, the SSC of fruit was lower than that of CG. (3) There was no ripe fruit after more than 16 days scant light. (4) Compared to CG, the difference was significant on the SSC after 7 d, 10 d, and 13 d scant light, indicating that scant light more than 7 days affected the SSC of 'red strawberry' obviously.

Table 2 also indicated that (1) The SSC of strawberry fruit under each scant light treatment was lower than that of CG. (2) Comparing to CG, the difference of SSC was significant after more than 10 days scant light, but not of 5 days or 7 days treatment, indicating that scant light more than 10

days affected the SSC of ‘sweet Charlie’ significantly.

Table 2. Effects of different treatments on the sugar content of strawberry in the greenhouse.

‘Red strawberry’ (2015)			‘Sweet Charlie’ (2016)		
Treatment	SSC /°Brix	Compared with CG/%	Treatment	SSC/ °Brix	Compared with CG/%
CG	12.5d		CG	8.3 c	
3 d	12.5d	0			
5 d	12.1d	-3.2	5 d	8.1 c	-2.4
7 d	11.4c	-8.8	7 d	8.0 c	-3.6
10 d	9.4b	-24.8	10 d	7.3 b	-12.0
13 d	7.5a	-40.0	13 d	6.8 b	-18.1
16 d			16 d	5.2 a	-37.3
			19 d	4.5 a	-45.8
			22 d	4.4 a	-47.0
			26 d	4.4 a	-47.0

3.4. Effects of scant light on strawberry yield in greenhouse

Table 3 demonstrated that (1) The fruit number of scant light treatment was obviously less than that of CG. It made a reduction of 7.1%, 9.3%, 9.8%, 24.6%, 60.7% and 83.1% respectively after the scant light of 3 d, 5 d, 7 d, 10 d, 13 d and 16 days respectively. (2) Comparing to CG, the difference of fruit number was significant after the scant light of 10 d, 13 d and 16 days respectively, but it was not significant after the scant light of 3 d, 5 d and 7 days, illustrating that low light more than 7 d affected the fruit number of ‘red strawberry’ obviously.

Table 3 also showed that (1) There was a slight increase in the fruit number after 5 days scant light, the value was 2.6%, this might be caused by the difference of individual samples. This also revealed that there was no effect on fruit number within 5 days scant light. (2) It made a reduction of 4.7%, 2.6%, 17.7%, 15.6%, 20.3%, 37.0% and 44.81% respectively after the scant light from 7 days to 26 days. (4) Compared with CG, the difference of fruit number was significant after 13 days shading, indicating that more than 13 days scant light affected the fruit number of ‘sweet Charlie’ significantly.

A comparison of fruit number on the two varieties revealed that (1) The fruit number of ‘red strawberry’ was less than that of ‘sweet Charlie’ for all the treatments. (2) The fruit number of ‘red strawberry’ decreased greatly with the increase of scant light days, indicating that the disaster resistance ability of ‘red strawberry’ was less than that of ‘sweet Charlie’.

Table 3. Effects of different treatments on the fruit number of strawberry in the greenhouse.

‘Red strawberry’(2015)			‘Sweet Charlie’(2016)		
Treatmen	Fruit /number	Compared with CG/%	Treatment	Fruit /number	Compared with CG/%
CG	18.3d		CG	19.2 c	
3 d	17.0d	-7.1			
5 d	16.6d	-9.3	5 d	19.7 c	2.6
7 d	16.5d	-9.8	7 d	18.3 c	-4.7
10 d	13.8c	-24.6	10 d	18.7 c	-2.6
13 d	7.2b	-60.7	13 d	15.8 b	-17.7
16 d	3.1a	-83.1	16 d	16.2 b	-15.6
			19 d	15.3 b	-20.3
			22 d	12.1 a	-37.0
			26 d	10.6 a	-44.8

3.5. Effects of scant light on plant growth in greenhouse

The 'red strawberry' growth observations in 2015 were as follows: (1) there was almost no effect on the growth of 'red strawberry' within 7 days scant light. (2) The effect was slight on the growth between 7 and 10 days scant light, with the symptom of yellow leaves and less ripe fruit. (3) When the low light spanned 11 to 13 days, the phenomenon of leaves turning yellow was serious, the flower and fruit number was little, stems, leaves and fruits began to mildew. (4) The scant light spanning 14 to 16 days made it so worse that stems and leaves turned yellow and dried seriously, no flower, no fruit. These injuries could not be recovered.

The strawberry 'sweet Charlie' growth observations in 2016 were as follows: (1) there was almost no effect on the growth of 'sweet Charlie' within 10 days shading condition. (2) The effect was slight on the growth between 10 and 19 days scant light. (3) The scant light spanning 20 to 26 days didn't seem make a significant influence on the growth, but through careful observation, we found that most of the stem base had got black and rotten.

Two years experimental observations allowed us to conclude that (1) 7 days scant light made no significant effect on the two strawberry varieties growth. (2) More than 14 days scant light made 'red strawberry' injured that could not be recovered, but it made a great effect on the 'sweet Charlie' strawberry until 20 days scant light, this indicated that 'sweet Charlie' has the stronger resistant ability than 'red strawberry'.

4. Conclusions and discussion

Based on two sets of experiment, it is revealed that the scant light condition significantly influenced the strawberry on the Pn, ChlC, fruit number, sugar content and the growth. Two varieties had the different resistant ability: the anti-disaster capacity of 'sweet Charlie' was stronger than that of 'red strawberry'.

By analyzing the influence of scant light on the Pn, ChlC, fruit number, sugar content and the growth of strawberry, we identified the scant light disaster grade index of strawberry in the greenhouse. The grade index of 'red strawberry' was mild disaster (1-6 days), moderate disaster (7-10 days), and severe disaster (more than 10 days). The sunless disaster indicator of strawberry cultivar 'sweet Charlie' was light disaster (1-9 days), medium disaster (10-19 days),and heavy disaster (more than 19 days).

In production, based on the weather forecast, sunless forewarning can be made to help the farmers to manage the scant light disaster in greenhouse.

In this study, the ChlC rose first and then fell, which may be the adaptive response of plant to low light stress [16]. The ChlC increased when the light intensity decreased, which was beneficial to improve the plant leaves' ability of absorption and utilization of low light and scattered light [17-18]. But after a long period of shading, the photosynthetic products decreased, the respiratory consumption was still at a high level, which caused the cell damaged, physiological metabolism was blocked, so the ChlC began to decrease [19].

Ferree and Stang [20]reported that shading reduced the strawberry production during the flower formation, Demirsoy *et* al [21] also reported that the strawberry yield was significantly reduced by shading during the flower initiation period. These were in agreement with our observations.

The recovery experiment after shading haven't been carried out yet. In future study, different recovery treatments can be designed to observe and measure correlation indexes of the strawberry after shading.

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