

# Photosynthetic Physiological Characteristics of *Gazania rigens* L. Under Drought Stress

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**Abstract.** To investigate the responses of photosynthetic physiological characteristics of *Gazania rigens* L. to drought stress, the changes of three cultivars ('Xingbai', 'XH' and 'Hongwen') photosynthetic values under drought stress were determined via LI-6400 portable photosynthesis analyzer (LI-COR, USA), and the relationships between photosynthesis and drought resistance of each cultivar were analyzed. The results showed that, three cultivars net photosynthetic rate ( $P_n$ ), stomatal conductance ( $G_s$ ), transpiration rate ( $Tr$ ), and light use efficiency ( $LUE$ ) value indicated the trend of decreasing gradually and there existed significant reduction in  $P_n$  and  $G_s$  values. There were extremely negative significant correlations between drought stress treatment days and  $P_n$ ,  $G_s$ ,  $Tr$ , water use efficiency ( $WUE$ ) and  $LUE$  values. A small amount of leaves began to turn soft and yellow after drought stress treatment for 10 days, but they could recover to grow quickly after rehydration. The  $P_n$  values of 'Hongwen' decreased quickly and changed in a large range, so it had a poor resistance; the  $P_n$  values of 'Xingbai' decreased slowly and changed in a small range, so it had a strong resistance; while the changes of their hybrids –'XH' were between its parents. This research would provide a theoretical basis for gazania resistance cultivar breeding and application in landscape.

## 1. Introduction

*Gazania* (*G. rigens* L.), with another name – treasure flower, belonging to Asteraceae family and *Gazania* spp., is a perennial herb and known for its beautiful flower shape and horticultural appeal. With the characteristics of evergreen, flowering in three seasons, dwarf, interesting flower shape, gazania can be used as potted plant, ground cover plant, flower border and so on [1]. Now it has been widely used in landscaping of the world.

Water is a vital factor that limits plant distribution and growth, and photosynthesis is directly influenced by water [2]. Photosynthesis is one of the main factors determining plants' biomass. Only



when plants keep high photosynthesis under stress can plants maintain its survival and development. Moreover, the ability to resistance is reflected by the values of photosynthesis [3]. Photosynthesis and the changes of the plant itself response the plant growth condition and stress resistance. The leaves of plants will close its stoma when subjected to drought stress, which leads to decrease photosynthesis rate [4].  $P_n$  and  $G_s$  values of shrubs and herbs decrease with the reduction of water, which is harmful for plant growth [5].

The photosynthetic physiological characteristics of plants in the Asteraceae family under drought stress were studied by many scholars. Research on Dahlia photosynthetic characteristics showed  $P_n$ ,  $Tr$ ,  $G_s$ ,  $WUE$  values decreased with the prolonged drought stress, while  $C_i$  values increased first and then decreased [6]. Compared with the control group, water stress decreased stomatal density on the surface of the leaf, as well as the  $G_s$  values and moisture loss; water stress reduced leaf values of  $P_n$ ,  $Tr$ ,  $G_s$  and other physiological indexes of *Flaveria bidentis* [7]. Influence of different degree of drought stress on the photosynthetic physiological characteristics and water use efficiency have been researched, which indicated ground-cover chrysanthemum belonged to cover plants with high drought resistance, and it was suitable to plant ground-cover chrysanthemum in the arid areas [8].

Deficit irrigation can improve plants' tolerance to stress. Previous studies on different gazania cultivars' drought resistance are mainly focused on physiological responses to drought stress, such as polyamines, antioxidant enzymes, isozymes, abscisic acid (ABA) and so on [9], while the study of photosynthetic characteristics under drought stress was not involved. Photosynthesis is one of the main performances of plant heterosis, and there exists heterobeltiosis in the hybrids photosynthesis capability, especially under the water stress condition [10]. In order to provide a theoretical basis for gazania resistance cultivar breeding and landscape plants low carbon maintenance, 'Xingbai', 'Hongwen' and their hybrid 'XH' were chosen as experimental materials. Photosynthetic physiological values of three cultivars under drought stress were determined via portable photosynthesis analyzer.

## 2. Materials and methods

### 2.1. Materials

'Xingbai', 'Hongwen' and their hybrid 'XH' were chosen as experimental materials. They were propagated in early May 2013 by cutting and these cuttings were transplanted to plastic pots after 30 days growing. Each pot had three holes and the pot volume is  $40 \times 30 \times 15 \text{ cm}^3$  with uniform substrate (Liangtu common soil for gardening, China) in it. There were 6 pots and every pot had 3 cultivars, 9 plants in total, with each cultivar having three plants. Then they were watered and fertilized with unified management for future experiment.

### 2.2. Methods

**2.2.1. Experimental design.** These pots were soaked fully in water at 3:00 PM for 20 minutes to get enough water on the day before the experiment. The treatments were as follows: these plants were in drought stress without watering in the whole experiment period. The artificial drought stress device frame was made of  $200 \times 100 \times 50 \text{ cm}^3$  aluminum alloy, the top of which was covered with transparent glass as other 4 sides of the device usually was open. These sides were covered only in this case that it

was rainy. In this way, it could not only simulate natural environment as much as possible to let wind and light in freedom but also prevent the interference caused by rainfall. Each treatment had three repeats and the first day of the experiment was chosen as control. Relative photosynthetic indicators were recorded respectively on the 1<sup>st</sup>, 4<sup>th</sup>, 7<sup>th</sup>, 10<sup>th</sup>, 13<sup>th</sup> and 16<sup>th</sup> day of drought stress experiment.

**2.2.2. Setting and determination of photosynthetic gas exchange parameters.** The second position leaves were chosen as experimental materials in each treatment, and photosynthetic characteristics like  $P_n$ ,  $G_s$ , intercellular  $\text{CO}_2$  concentration ( $C_i$ ), and  $Tr$  were determined via LI-6400 portable photosynthesis analyzer (LI-COR, USA). The parameters of the analyzer in this experiment are as follows: red and blue light inside the photosynthetic system was used to provide continuous and stable illumination; leaf chamber was  $2 \times 3$  cm in size and light intensity was  $1500 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ; flow rate of sample chamber was  $500 \mu\text{mol}\cdot\text{s}^{-1}$ . During determination, the atmospheric  $\text{CO}_2$  concentration was about  $400 \mu\text{mol}\cdot\text{mol}^{-1}$ , and the test time was 8:30-11:30 AM with the experimental temperature controlled at  $25\sim 27^\circ\text{C}$ .

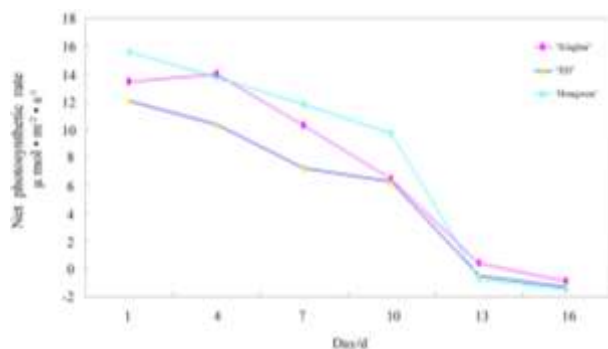
### 2.3. Data processing method

Use SPSS 17.0 (Statistical program for social sciences) and Microsoft Excel 2003 to analyze statics and map.  $WUE = P_n / Tr$ ,  $LUE = P_n / \text{Light intensity}$  to calculate  $WUE$  and  $LUE$  values [11]. And the data in this paper was mean values which were derived from three repeats.

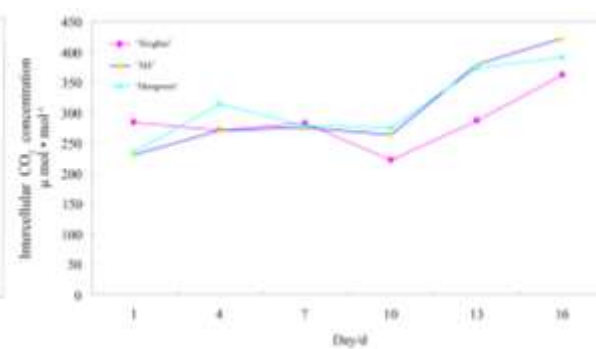
## 3. Results

### 3.1. Effects of drought stress on gazania $P_n$

Compared with the 1<sup>st</sup> day experimental values, 'Xingbai', 'XH' and 'Hongwen'  $P_n$  showed the trend of decreasing gradually with the prolonged drought stress (Figure 1), and  $P_n$  values decreased significantly from the days 10 to 13. Under the same treatment days, the values of 'XH' from days 1 to 10 were lower than its parents 'Xingbai' and 'Hongwen', while the values of 'XH' from days 10 to 16 were between its parents; the values of 'Hongwen' from days 1 to 10 were higher than 'Xingbai' and 'XH', while it decreased greatly than 'Xingbai' and 'XH' from days 10 to 13 and the value was  $10.51 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ; 'Xingbai', 'XH' and 'Hongwen' decreased  $14.31 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ,  $13.38 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ,  $17.02 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$  respectively compared with the 1<sup>st</sup> day of experiment.



**Figure 1.** Effects of drought stress on gazania net photosynthetic rate.



**Figure 2.** Effects of drought stress on gazania intercellular  $\text{CO}_2$  concentration.

### 3.2. Effects of drought stress on gazania *Gs* and *Tr*

With the prolonged drought stress, 'Xingbai', 'XH' and 'Hongwen' *Gs* showed the trend of decreasing gradually (Table 1). Under the same treatment circumstance, the values of 'XH' were between its parents' from days 4 to 13, and it didn't reach to significant level; the values of 'XH' were a slightly higher than its parents on the 16<sup>th</sup> day treatment; the three cultivars values reached to the lowest point on the 16<sup>th</sup> day treatment. What's more, 'Xingbai', 'XH' and 'Hongwen' decreased 185.45 mmol·m<sup>-2</sup>·s<sup>-1</sup>, 135.61 mmol·m<sup>-2</sup>·s<sup>-1</sup>, 258.85 mmol·m<sup>-2</sup>·s<sup>-1</sup> respectively compared with the 1<sup>st</sup> day value. However, the changes of three cultivars' *Tr* values were not the same. 'Xingbai' *Tr* showed the trend of decreased gradually while values of 'XH' and 'Hongwen' decreased firstly, then increased and decreased finally once again. Compared with the 1<sup>st</sup> day value, treatment values of the 16<sup>th</sup> day of the three cultivars reached to the lowest point, 'Xingbai', 'XH' and 'Hongwen' decreased 2.29 mmol·m<sup>-2</sup>·s<sup>-1</sup>, 2.17 mmol·m<sup>-2</sup>·s<sup>-1</sup>, 3.63 mmol·m<sup>-2</sup>·s<sup>-1</sup> respectively. It was obvious that the values of 'XH' were between or lower than its parents' under the same treatment.

**Table 1.** Stomatal conductance and transpiration rate of gazania under drought stress.

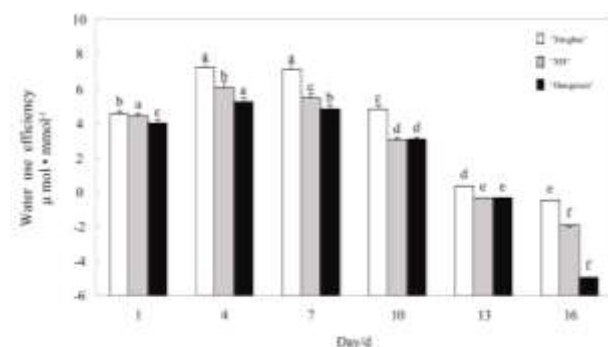
Treatment Days	<i>Gs</i> (mmol·m <sup>-2</sup> ·s <sup>-1</sup> )			<i>Tr</i> (mmol·m <sup>-2</sup> ·s <sup>-1</sup> )		
	'Xingbai'	'XH'	'Hongwen'	'Xingbai'	'XH'	'Hongwen'
1 d	214.22a	171.67a	272.96a	3.00a	2.84a	3.92a
4 d	133.46b	134.06b	224.07b	1.94b	1.71c	2.65c
7 d	97.14c	112.28b	173.95c	1.46bc	1.32e	2.45d
10 d	88.42d	114.11b	144.16d	1.34bc	2.08b	3.23b
13 d	64.06e	79.03c	123.58e	1.13bc	1.63d	2.26e
16 d	28.77f	36.06d	14.11f	0.71c	0.67f	0.29f

### 3.3. Effects of drought stress on gazania *Ci*

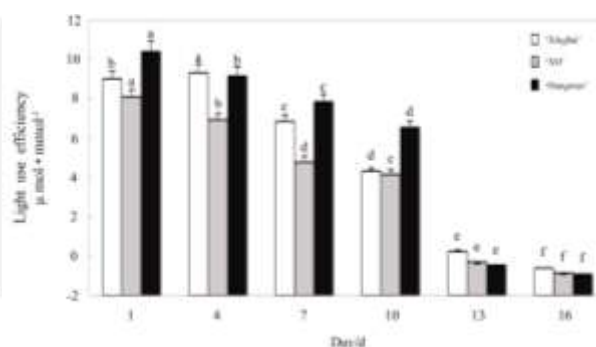
The changes of 'Xingbai' *Ci* was complex under drought stress, but the three cultivars showed the trend of increased firstly and then decreased, finally increased once again in the whole (Figure 2). The values of 16<sup>th</sup> day treatment were significantly higher than others' and values of 'Xingbai', 'XH' and 'Hongwen' increased 77.87 μmol·mol<sup>-1</sup>, 192.77 μmol·mol<sup>-1</sup>, 156.26 μmol·mol<sup>-1</sup> respectively compared with the 1<sup>st</sup> day treatment. The values of 'XH' *Ci* were between or lower than its parents' under the same treatment from days 1 to 10, while 'XH' values were higher than its parents from treatment days 10 to 16.

### 3.4. Effects of drought stress on gazania *WUE*

'Xingbai', 'XH' and 'Hongwen' *WUE* values increased first and then decreased with the prolonged drought stress (Figure 3). The values of three cultivars reached to the highest point under drought stress for four days. 'Xingbai', 'XH' and 'Hongwen' decreased 4.91 μmol·mmol<sup>-1</sup>, 6.31 μmol·mmol<sup>-1</sup>, 8.93 μmol·mmol<sup>-1</sup> respectively compared with the 1<sup>st</sup> day treatment. The values of 'XH' were between its parents' under the same treatment.



**Figure 3.** Effects of drought stress on gazania water use efficiency.



**Figure 4.** Effects of drought stress on gazania light use efficiency.

### 3.5. Effects of drought stress on gazania LUE

With the prolonged drought stress, 'Xingbai' LUE value increased on the day 4<sup>th</sup> treatment when the other three cultivars decreased gradually in general (Figure 4). 'Xingbai', 'XH' and 'Hongwen' decreased 9.54  $\mu\text{mol}\cdot\text{mmol}^{-1}$ , 8.92  $\mu\text{mol}\cdot\text{mmol}^{-1}$ , 11.35  $\mu\text{mol}\cdot\text{mmol}^{-1}$  respectively compared with the 1<sup>st</sup> day treatment. The values of 'XH' were between or lower than its parents under the same treatment. The three cultivars LUE values decreased significantly than others' and they decreased 4.00  $\mu\text{mol}\cdot\text{mmol}^{-1}$ , 3.84  $\mu\text{mol}\cdot\text{mmol}^{-1}$ , 6.01  $\mu\text{mol}\cdot\text{mmol}^{-1}$  respectively from days 10 to 13.

### 3.6. Correlationships of gazania photosynthetic indicators under drought stress

There existed a certain correlations among gazania photosynthetic indicators under drought stress (Table 2). The three cultivars  $P_n$ ,  $G_s$ ,  $Tr$ ,  $WUE$ ,  $LUE$  were extremely negative significance with drought days. There was no correlation between 'Xingbai'  $C_i$  and treatment days, while there existed extremely positive significance between 'XH', 'Hongwen'  $C_i$  and treatment days.

**Table 2.** Correlation of photosynthetic characteristics under drought stress.

		Day	$P_n$	$G_s$	$C_i$	$Tr$	$WUE$
'Xingbai'	$P_n$	-0.966**					
	$G_s$	-0.954**	0.853**				
	$C_i$	0.448	-0.480*	-0.375			
	$Tr$	-0.828**	0.729**	0.880**	-0.292		
	$WUE$	-0.776**	0.897**	0.567*	-0.612**	0.459	
	$LUE$	-0.966**	1.000**	0.853**	-0.480*	0.729**	0.897**
'XH'	$P_n$	-0.972**					
	$G_s$	-0.940**	0.924**				
	$C_i$	0.898**	-0.948**	-0.919**			
	$Tr$	-0.754**	0.725**	0.853**	-0.789**		
	$WUE$	-0.877**	0.915**	0.814**	-0.900**	0.514*	
	$LUE$	-0.972**	1.000**	0.924**	-0.948**	0.725**	0.915**
'Hongwen'	$P_n$	-0.944**					
	$G_s$	-0.960**	0.880**				

<i>Ci</i>	0.839**	-0.910**	-0.807**			
<i>Tr</i>	-0.810**	0.788**	0.882**	-0.868**		
<i>WUE</i>	-0.859**	0.909**	0.873**	-0.815**	0.825**	
<i>LUE</i>	-0.944**	1.000**	0.880**	-0.910**	0.788**	0.909**

\*\* significant differences at  $P < 0.01$  level; \* significant differences at  $P < 0.05$  level

#### 4. Discussions

Drought is the main abiotic stress factors limiting plant growth and high recuperative capacity of plants from drought damages is critical for plant survival during drought stress. The impact of drought on the plants photosynthesis and photosynthetic organs will strengthen with the increasing extent of drought stress. Drought stress reduce plant's photosynthesis, these results are consistent with it [12].

The three cultivars *Pn*, *Gs* and *LUE* decreased gradually while there was a short increasing time for *Ci*, *Tr* and *WUE*. The changes of *Pn* values were mainly influenced by two factors: stomata limit caused by partial stomata closing, and non-stomata limit caused by photosynthetic activity decreasing in mesophyll cells [13]. *Pn* value decreased while *Ci* value increased gradually from days 1 to 7, which indicated the reason that why *Pn* value was decreased was not the change of *Gs*, because the changed *Gs* would lead  $\text{CO}_2$  concentration to decrease. It was that non-stomata limit, such as increasing resistance of stomatal diffusion in mesophyll cells, decreasing of  $\text{CO}_2$  solubility, reducing affinity of Rubisco enzyme on  $\text{CO}_2$ , decreasing of RuBP regeneration or decreasing of key components stability for photosynthetic apparatus, hindering the usage of  $\text{CO}_2$  caused the accumulation of intracellular  $\text{CO}_2$  [14]. *Pn* value decreased and *Gs*, *Ci* decreased as well from treatment days 7 to 10, which indicated that the decrease of *Gs* limited the entrance of  $\text{CO}_2$  - stomata limit. *Ci* increased gradually from days 10 to 16, which manifested that the main reason causing *Pn* decreasing was non-stomata limit. Therefore, gazania *Pn* value is mainly influenced by stomata and non-stomata limits under drought stress. *WUE* is a stable indicator to evaluate the relation between carbon fixation and water consumption [15], and it can show water usage level meanwhile it limits the adaptability to stress [16].

Three cultivars *Tr* decreased gradually in general with the prolonged drought stress, which was the same as *Gs* changed. It is probably because that the decrease of *Gs*, *Tr* reduce water loss in plant body. *WUE* is determined by *Pn* and *Tr*. Moreover, *WUE* value increased first in this experiment from treatment days 1 to 4. *WUE* value showed the trend of decreasing gradually with the prolonged drought stress and this might be a kind of adaptability to drought stress. Meanwhile, the biggest value of *WUE* occurred on the 4<sup>th</sup> day treatment, which revealed that it is not necessarily the highest water use efficiency occurs in high field water-holding capacity condition. Moderate water deficit will improve the plant water utilization rate.

#### 5. Conclusion

There exists extremely significant changes between *Pn*, *Gs*, *Tr*, *WUE*, *LUE* and treatment days, so it can be an indicator to evaluate the photosynthetic characteristics response of gazania to drought stress. According to the values and the general trends of different measured variables under drought stress,

we can select cultivar(s) with strong resistance and high ornamental value to enrich the landscape architecture.

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