LIGHT RESPONSE OF SHEPHERDIA ARGENTEA AND HIPPOPHAE RHAMNOIDES SEEDLINGS UNDER DIFFERENT SOIL MOISTURE CONDITIONS

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ABSTRACT

In alpine region of Loess Plateau, by using Li-6400 portable photosynthesis system, light response of gas exchange parameters in S. argentea and H. rhamnoides seedlings under different soil moisture conditions was analyzed. The results showed that Pn, Tr and WUE of the two shrub species were both increased with an increase of the PAR. With continued increase of the PAR, Pn and WUE of S. argentea and H. rhamnoides seedlings declined but Tr still increased. With the increase of soil water content (SWC), Pn, Tr of both two shrub species increased, while WUE increased first, then declined after arriving at the maximum under mild water stress condition (W2). When SWC was in the same, light compensation point (LCP) of S. argentea was lower than that of H. rhamnoides obviously, light saturation point (LSP) and efficiency of light energy utilization of S. argentea were higher than those of H. rhamnoides, and the apparent quantum yield (α) in the leaves of S. argentea was higher than that of H. rhamnoides. So compared with H. rhamnoides, photosynthetic capacity of S. argentea was stronger at low PAR. Contrastive analysis indicated that under severe water stress condition (W4) H. rhamnoides was easier to be stressed by high PAR. The capacity utilization ratio of low PAR and WUE in S. argentea was higher than that of H. rhamnoides. Thus, it is concluded that the drought-tolerant productivity of S. argentea seedlings was stronger than that of H. rhamnoides seedlings.

Keywords: net photosynthesis rates, transpiration rate, water use efficiency, light response.

INTRODUCTION

Drought and strong light are the major influencing factors on plant growth. They play an extremely important role in plant growth, survival and the formation of productivity. The lack of water limits the growth and development of plant and light is also one of the most important and most influential environmental factors on plant photosynthetic apparatus (Zhang et al., 2000; Zhou et al., 2002; Li et al., 2005). In alpine region of Loess Plateau, to do establishment of vegetation, we must first solve the core problem how to maintain the basic water demand for the normal growth and development of plant (Wei et al., 1998; He et al., 1998), and select light-resistant plant species. Muhtar (2009) studied the effect of water stress on plant biomass and several physiological characters of Elaeagnusoxycarpa Schlecht seedlings with pot method. Wang and Yang (2000) studied Malus pumilauc. Goldspur for the purpose of improving WUE with pot experiment. And there were a lot of studies about the effect solar radiation on photosynthesis of different photosynthetic pathways plant. However, the results obtained were all under fixed light intensity or natural lighting conditions, such as the study of Zhang (2005). Currently, the study of the dynamic response of photosynthesis physiological characteristics in different habitats of plant to different light intensity (Guo, 2009) became research focus of plant physiological ecology. So there has been many research about the effect only soil moisture or light intensity on plant, but the research combining light intensity with soil water stress was only a few. This article was the study on response of the physiological parameters to light radiation of S. argentea and H. rhamnoides under different soil moisture conditions in loess plateau region Datong, Xining, Qinghai Province. Hippophaerhamnoides belongs to Hippophae of Elaeagnaceae, and it has many characteristics, such as cold-resistant, drought-resistant, poor soil-resistant, anti-sandstorm and wide adaptability. So far, the existing research has mostly focused on the relationship between H. rhamnoides’ physiological process of photosynthesis and environmental influencing factors (Tang et al., 2006; Tang et al., 2007; Zhu et al., 2007), and little has been done in studying the response of physiological parameters to PAR. Shepherdiaargentea, introduced in 2002 from the United States, belongs to Shepherdia of Elaeagnaceae, and it is good specie for soil and water
conservation and sand-fixing with many characteristics, such as cold-resistant, drought-resistant, fast growing and strong root system. However, in China, there have been few studies focusing on the physiological characteristics of *S. argentea* (Qin et al, 2009). Therefore, in order to provide a theoretical basis and scientific guidance for the selection of tree species and effective utilization of water, by using Li-6400 portable photosynthesis system, light response of the physiological parameters to light radiation of *S. argentea* and *H. rhamnoides* 2-year old seedlings under different soil moisture conditions was studied.

**MATERIALS AND METHODS**

**Experimental design:** *S. argentea* and *H. rhamnoides* 2-year old seedlings were obtained from the experimental base (latitude36°56′N, longitude101°46′E and altitude 2475m) of Research Institute of Forestry, Qinghai Academy of Agriculture and Forestry, China. In May 2012, the seedlings of *S. argentea* and *H. rhamnoides* were planted in plasticpots (one per pot), irrigated with adequate water to ensure their survival and normal growth. By using TDR soil moisture meter and BP-3400 precision balance (accuracy 0.1), soil water content (mass water content) of seedlings was set and divided into four levels: W1 was the treatment with sufficient water, and SWC was above 21.5%; W2 was the treatment with mild water stress, SWC was between 14.35%~21.5%; W3 was the treatment with moderate water stress, SWC was between 7.2%~14.35%; W4 was the treatment with severe water stress, SWC was below 7.2%. After SWC levels were set, seedlings were all covered with plastic film to prevent evaporation of soil moisture. Each level had four replicates, and SWC of each replicates was measured with TDR soil moisture meter every 5 days. Proper amount of water could be added so as that SWC of each replicates maintained at an appropriate level.

**Observation Method:** 9:00am-11:00am, July 27, 2012 (partly cloudy), when the external environment relatively stable, *Pn, Tr* and *WUE* of the seedlings under different soil moisture conditions were all measured by Li-6400 portable photosynthesis system. 4 healthy leaves per seedling which were in the upper part of seedling were selected as measured leaves, and the average of six stable data from different positions of each leaf was record. Simulating *PAR* with Li-6400-02B red and blue light radiation, gradients were set as follows: 0, 50, 100, 150, 200, 400, 600, 800, 1000, 1200, 1500, 1800, 2000, 2200 mol·m$^{-2}$·s$^{-1}$.

**Statistical analysis:** *WUE* of leaves was calculated with the ratio of *Pn*/ *Tr* (Gao et al, 2007). *LSP* was obtained by drawing *Pn-PAR* curves, and the initial part of the *Pn-PAR* curves (*PAR*<200 mol m$^{-2}$·s$^{-1}$)was did linear regression analysis to get *LCP* and apparent quantum yield (*a*). (Institute of Plant Physiology Shanghai Institutes Chinese Academy of Sciences, 1999; Li *et al*, 2005; Guo *et al*, 1999).

**RESULTS**

**Response of *Pn* to *PAR*** Under different soil moisture conditions, the responses of *Pn* of the two shrub species to *PAR* were all in the form of quadratic curves(Figure 1). When *PAR* was in the range of 0~500 mol m$^{-2}$·s$^{-1}$, there was a marked and progressive increase in *Pn* of the two shrub species with the increase of *PAR*. When *PAR* increased further, the increasing rate of *Pn* decreased, and after *PAR* reached the certain value *LSP*, the *Pn-PAR* curves flattened. With the increase of SWC, *Pn-PAR* curves of *S. argentea* rose gradually, and arrived at the maximum 20.187 mol m$^{-2}$·s$^{-1}$ under mild water stress (W2), then declined, which showed that mild water stress was good for the increase of *Pn* of *S. argentea*. *Pn-PAR* curves of *H. rhamnoides* continued to rise with the increase of SWC. Under severe water stress (W4), *Pn-PAR* curves of the two shrub species were flattened all the time, and there was no significant fluctuation, but *Pn* of *S. argentea* was higher than that of *H. rhamnoides*on the whole.

In the sufficient water supply (W1), *Pn*of *H. rhamnoides* was higher than that of *S. argentea* (Tab.1 and 2), indicating that the photosynthetic capacity of *H. rhamnoides* was stronger relatively. Under severe water stress (W4), *Pn* of *S. argentea* was higher than that of *H. rhamnoides*, so *S. argentea*had stronger photosynthetic capacity at the moment.

**Response of *LCP to SWC*** *LCP* is an important indicator of the ability to use low light of plant, and the smaller *LCP* is, the stronger the ability to use low light is (Feng *et al*, 2009). With the increase of SWC, *LCP* of *H. rhamnoides* showed a downward trend (Tab.1 and 2), implying their growing ability to use low light; *LCP* of *S. argentea* decreased first and then increased, and under mild water stress (W2) it reached the minimum 6.483 mol m$^{-2}$·s$^{-1}$, indicating the strongest point of the ability to use low light.

**Response of apparent quantum yield(*a*) to SWC** *a* is also an important indicator of the ability to use low light of plant. There was a significant upward trend in *a* of the two shrub species with the increase of SWC (Tab.1 and 2), which indicated their growing ability to use low light. But *S. argentea* seedlings under mild water stress (W2) had the highest *a* 0.0547. When SWC was in the same, *S. argentea* was of stronger photosynthetic capacity than *H. rhamnoides* as *a* of *S. argentea* was higher than that of *H. rhamnoides*.

**Response of *LSP to SWC*** *LSP* of the two shrub species both increased first and then decreased with the increase
of SWC (Figure 1, Tab.1 and 2), and reached the maximum (S. argentea 1830 mol m⁻²·s⁻¹; H. rhamnoides 2050 mol m⁻²·s⁻¹) under mild water stress (W2), which illustrated the ability to use strong light of the two shrub species both increased first and then decreased. Under severe water stress (W4), the two shrub species had the lowest LSP compared with the LSP the two shrub species had under other water conditions, and on the other hand LSP of S. argentea was lower than that of H. rhamnoides. So neither of the two shrub species was of good ability to use strong light. Moreover, the ability to use strong light of H. rhamnoides was worse than that of S. argentea.

Response of Tr to PAR

Curves of the two shrub species were almost the same under different soil moisture (Figure 2). With the increase of SWC, Tr increased. In W1, W2, W3 treatments, Tr of S. argentea and H. rhamnoides both had balanced increase with the increase of PAR, indicating the effect of units of PAR on Tr of the two shrub species was almost the same, and strong light did not cause obvious increase of Tr. In the W4 treatment, Tr increased only a little with the increase of PAR, which was mainly due to stoma, the main channel of water vapor loss, which closed to the minimum level because of severe water stress.

Response of WUE to PAR

WUE, which is an indicator used to describe plant carbon dioxide fixation by per unit water, in other words the output of plant, depends on the ratio of Pn/Tr, and it also determines the level of drought-tolerant productivity of plant (Gong et al, 2007).

When SWC was in the same, WUE of S. argentea was higher than that of H. rhamnoides obviously (Figure 3). Under different soil moisture conditions, WUE-PAR curves of the two shrub species were similar. When PAR was in the range of 0-400 mol m⁻²·s⁻¹, WUE increased significantly with the increase of PAR, as the increase in Pn with PAR was much higher than the increase in Tr; When PAR was higher than 400 mol m⁻²·s⁻¹, WUE did not stop increasing with the increase of PAR until reached the maximum under moderate water stress (W3), but the rate of increase decreased, then WUE decreased with the increase of PAR, as the increase in Pn with PAR was less than the increase in Tr.

The maximum of WUE was generally not obtained in the sufficient water supply, but obtained under moderate water stress (Shan, 1996). WUE of the two shrub species both increased with the increase of SWC, reaching the maximum under moderate water stress (W3), and then declined with the increase of SWC. Under moderate water stress (W3), Pn and Tr of the two shrub species both decreased, but Tr dropped more, so WUE could keep at a high level when PAR was in the range of 400-2000 mol m⁻²·s⁻¹, which illustrated that under moderate water stress, the two shrub species could adapt to water and other environmental changes through their own physical conditioning, so as to maintain high WUE.

In summary, when SWC was in the same, WUE of S. argentea was higher than that of H. rhamnoides, and moderate water stress is good for the two shrub species to maintain high WUE.
Figure 2. Response of transpiration rate (Tr) to PAR of H. rhamnoides and S. argentea seedlings under different soil moisture conditions

Figure 3. Response of water use efficiency (WUE) to PAR of H. rhamnoides and S. argentea seedlings under different soil moisture conditions

Table 1. Response of \( Pn \) to PAR of S. argentea under different SWC as determined by regression equation: \( y = Pn, x = PPFD \)

<table>
<thead>
<tr>
<th>SWC</th>
<th>Regression equation</th>
<th>( P_{nmax} ) (( \text{μmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} ))</th>
<th>( LSP ) (( \text{μmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} ))</th>
<th>( LCP ) (( \text{μmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} ))</th>
<th>( \alpha )</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>( y = -0.000005x^2 + 0.0172x + 2.6861 )</td>
<td>17.4781</td>
<td>1720</td>
<td>9.7457265</td>
<td>0.0468</td>
</tr>
<tr>
<td>W2</td>
<td>( y = -0.000005x^2 + 0.0183x + 3.4425 )</td>
<td>20.187</td>
<td>1830</td>
<td>6.4826324</td>
<td>0.0547</td>
</tr>
<tr>
<td>W3</td>
<td>( y = -0.000004x^2 + 0.0119x + 1.3693 )</td>
<td>10.21993</td>
<td>1487.5</td>
<td>12.645614</td>
<td>0.0285</td>
</tr>
<tr>
<td>W4</td>
<td>( y = -0.000002x^2 + 0.0053x + 0.4208 )</td>
<td>3.93205</td>
<td>1325</td>
<td>22.6923077</td>
<td>0.0112</td>
</tr>
</tbody>
</table>

Table 2. Response of \( Pn \) to PAR of H. rhamnoides under different SWC as determined by regression equation: \( y = Pn, x = PPFD \)

<table>
<thead>
<tr>
<th>SWC</th>
<th>Regression equation</th>
<th>( P_{nmax} ) (( \text{μmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} ))</th>
<th>( LSP ) (( \text{μmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} ))</th>
<th>( LCP ) (( \text{μmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} ))</th>
<th>( \alpha )</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>( y = -0.000007x^2 + 0.0257x - 0.6317 )</td>
<td>22.95723</td>
<td>1835.714</td>
<td>65.5512</td>
<td>0.0459</td>
</tr>
<tr>
<td>W2</td>
<td>( y = -0.000006x^2 + 0.0205x - 0.542 )</td>
<td>20.4705</td>
<td>2050</td>
<td>68.43812</td>
<td>0.0404</td>
</tr>
<tr>
<td>W3</td>
<td>( y = -0.000004x^2 + 0.0122x - 0.6376 )</td>
<td>8.6649</td>
<td>1525</td>
<td>82.41245</td>
<td>0.0257</td>
</tr>
<tr>
<td>W4</td>
<td>( y = -0.000002x^2 + 0.0053x - 0.604 )</td>
<td>2.521</td>
<td>1250</td>
<td>114.4085</td>
<td>0.0104</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Through the measurement of gas exchange parameters and WUE, adaptability of the two shrub species to different soil moisture was analyzed, and this study provided a theoretical basis and scientific guidance for the selection and planting in alpine region of Loess Plateau. But this study carried out by pot experiments,
and due to the differences between environment of potted seedlings and the microclimate of stand, even if under the same soil moisture conditions, root development, the sun radiation, temperature and humidity of potted seedlings were still inconsistent with the microclimate of stand, so the application of the results of this study still need to combine with the actual situation of stand.

When the absorbed light energy exceeds its requirement, the excess excitation would produce light inhibition and reduce the efficiency of photosynthesis (Li, 2004). The coexistence of light and water stress will break the chloroplast photosynthetic CO$_2$ fixation and absorption of light energy balance (Sun et al., 2006), resulting in excess of light energy accumulation which would aggravate photo inhibition and damage light system (Yang et al., 2002; D’ambrosio et al. 2006). The study showed that variation of PAR had significant impact on Pn, Tr and WUE of the two shrub species. With the increase of PAR, Pn increased gradually, and after PAR reached a point, light saturation point (LSP), Pn varied only a little and the Pn-PAR curves flattend. Under sufficient water supply condition, Pn of *H. rhamnoides* was higher than that of *S. argentea*, so *H. rhamnoides* had stronger photosynthetic capacity relatively. Under severe water stress condition, on the contrary, Pn of *S. argentea* was higher than that of *H. rhamnoides*, so *S. argentea* had stronger photosynthetic capacity relatively.

LSP and LCP are two main indexes reflecting the light characteristics of plant. (Leng et al., 2000). Plant with low LCP and high LSP have strong adaptability to adapt light environment (Yang et al., 2005). In this study, when SWC was in the same, LCP of *S. argentea* was lower than that of *H. rhamnoides* obviously, so the ability to use low light of *S. argentea* was higher than that of *H. rhamnoides*. LSP of the two shrub species both increased first and then decreased with the increase of SWC, illustrating the ability to use light of the two shrub species increased first and then decreased. Under severe water stress (W4), LSP of *S. argentea* was lower than that of *H. rhamnoides*, indicating *S. argentea* had stronger ability to use strong light than *H. rhamnoides*.

Apparent quantum yield ($\alpha$) of the two shrub species both increased with the increase of SWC, which indicated their growing ability to use low light. And when SWC was in the same, *S. argentea* was of stronger photosynthetic capacity than *H. rhamnoides* as $\alpha$ of *S. argentea* was higher than that of *H. rhamnoides*.

The growth and development of plants and various physiological activities are closely related with the water. This study showed that, With the increase of SWC, WUE of the two shrub species both increased first, and arrived at the maximum under moderate water stress (W3), then decreased, indicating that moderate water stress was good for the two shrub species to maintain high WUE. When SWC was in the same, WUE of *S. argentea* was higher than that of *H. rhamnoides*, so *S. argentea* had strong photosynthetic capacity relatively, which showed that the drought-tolerant productivity and water-saving capacity of *S. argentea* seedlings were stronger than that of *H. rhamnoides* seedlings.

**Conclusion:** Pn, Tr and WUE of the two shrub species were closely related with the PAR and SWC. Under severe water stress, compared to the two shrub species, *H. rhamnoides* was more vulnerable to strong light than *S. argentea*, and low-light capability, Pn and WUE of *S. argentea* were all higher than those of *H. rhamnoides*, indicating *S. argentea* had much stronger adaptability to adversity, such as strong light, drought.

**REFERENCES**


