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LIGHT RESPONSE OF *SHEPHERDIAARGENTEA* 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 pumilacv. 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, 2200μmol·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*<200μmol·m^{-2}·s^{-1})was did linear regression analysis to get *LCP* and apparent quantum yield (*α*) (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 μmol·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 20.187μmol·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), on the contrary, *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 6.483μmol·m^{-2}·s^{-1}, indicating the strongest point of the ability to use low light.

Response of apparent quantum yield(*α*)to *SWC**α* is also an important indicator of the ability to use low light of plant There was a significant upward trend in *α* 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 *α* 0.0547. When *SWC* was in the same, *S. argentea* was of stronger photosynthetic capacity than *H. rhamnoides* as *α* 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* 1830μmol· $m^{-2}\cdot s^{-1}$; *H. rhamnoides* 2050 μmol·$m^{-2}\cdot s^{-1}$) 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*: *Tr-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 0-400μmol·$m^{-2}\cdot s^{-1}$, *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 400μmol·$m^{-2}\cdot s^{-1}$, *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 400-2000μmol·$m^{-2}\cdot s^{-1}$, 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 *WU*E.

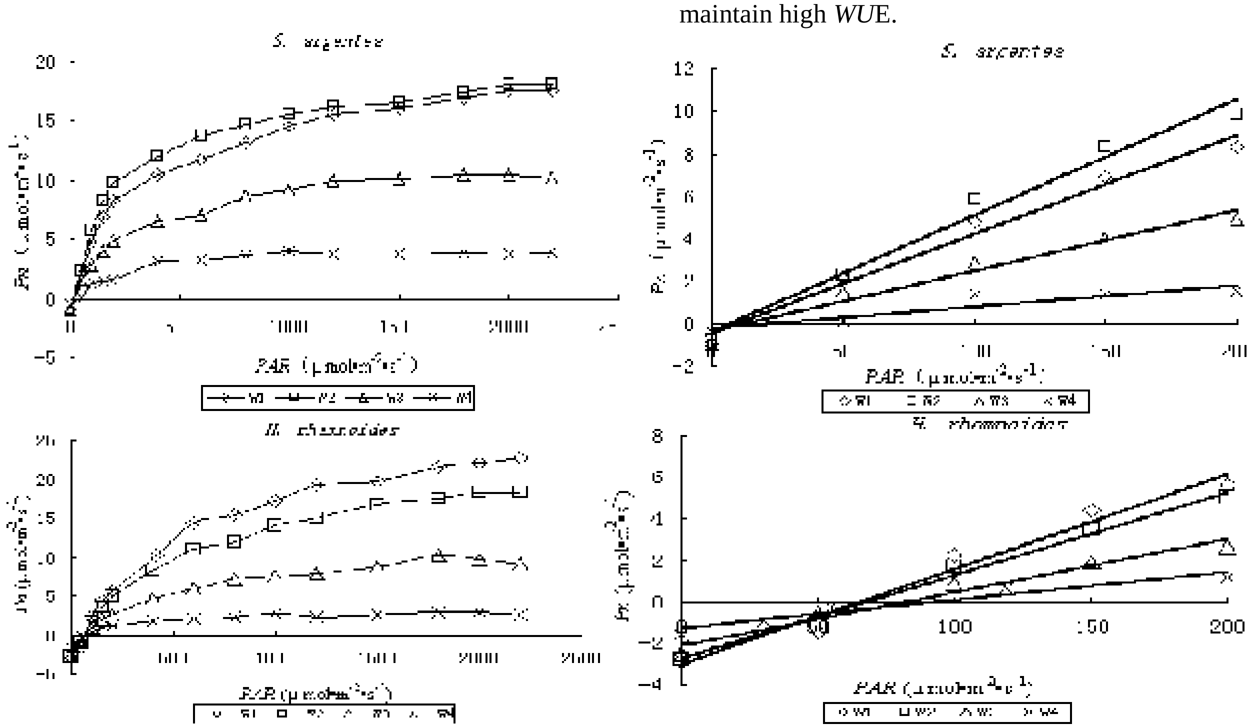

Figure 1. Response of *Pn* to *PAR* of *H. rhamnoides* and *S. argentea* seedlings under different soil moisture conditions

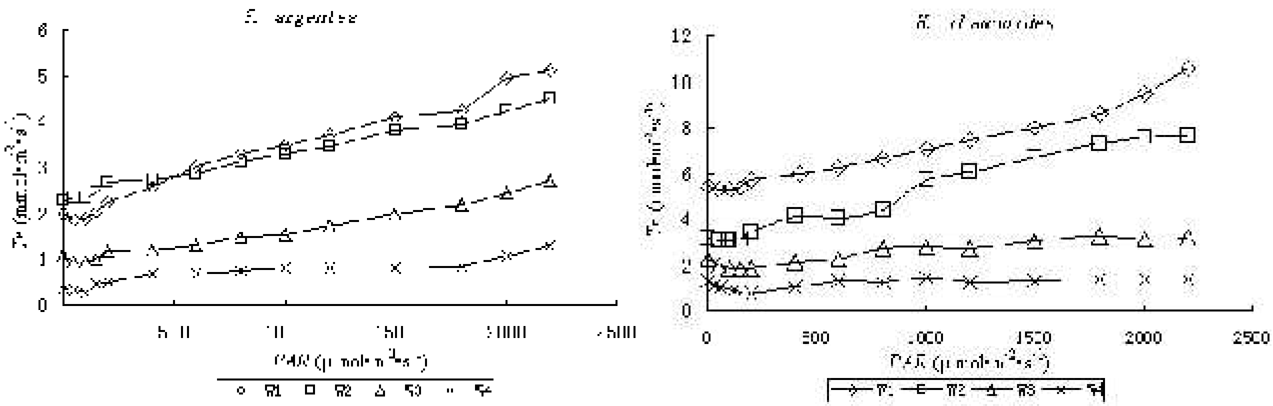

Figure 2. Response of transpiration rate (*Tr*) to *PAR* of *H. rhamnoides and S. argentea seedlings* under different soil moisture conditions

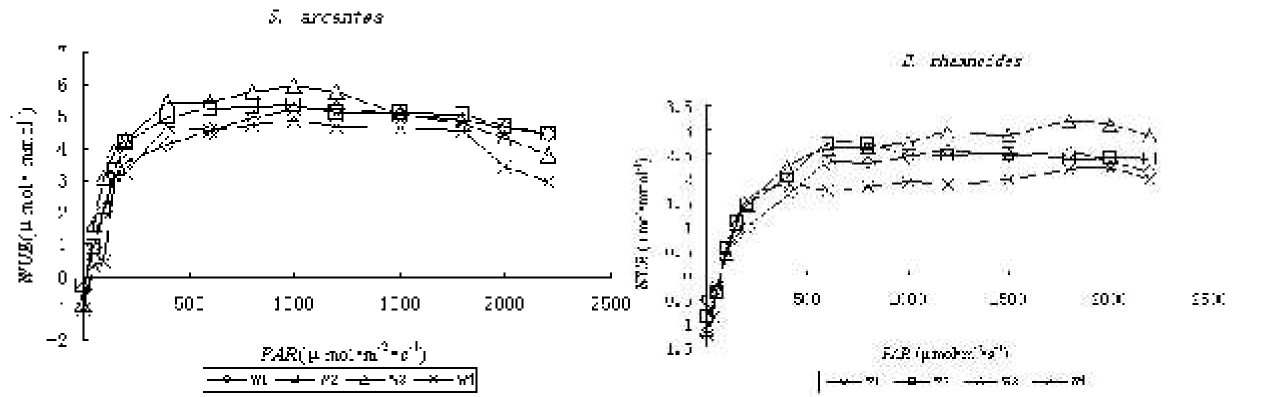

Figure 3. Response of water use efficiency (*WUE*) to *PAR* of *H. rhamnoidesand S. argenteaseedlings* under different soil moisture conditions

Table1. Response of *Pn*to *PAR* of *S. argentea* under different *SWC* as determined by regression equation: y = *P*n, x = PPFD

SWC	Regression equation	*Pnmax* (μmol·m^{-2}·s^{-1})	*LSP* (μmol·m^{-2}·s^{-1})	*LCP* (μmol·m^{-2}·s^{-1})	*α*
W1	$y = -0.000005x^2 + 0.0172x + 2.6861$	17.4781	1720	9.7457265	0.0468
W2	$y = -0.000005x^2 + 0.0183x + 3.4425$	20.187	1830	6.48263254	0.0547
W3	$y = -0.000004x^2 + 0.0119x + 1.3693$	10.21993	1487.5	12.645614	0.0285
W4	$y = -0.000002x^2 + 0.0053x + 0.4208$	3.93205	1325	22.6923077	0.0112

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

SWC	Regression equation	*Pnmax* (μmol·m^{-2}·s^{-1})	*LSP* (μmol·m^{-2}·s^{-1})	*LCP* (μmol·m^{-2}·s^{-1})	*α*
W1	$y = -0.000007x^2 + 0.0257x - 0.6317$	22.95723	1835.714	65.5512	0.0459
W2	$y = -0.000006x^2 + 0.0205x - 0.542$	20.4705	2050	68.43812	0.0404
W3	$y = -0.000004x^2 + 0.0122x - 0.6376$	8.6649	1525	82.41245	0.0257
W4	$y = -0.000002x^2 + 0.005x - 0.604$	2.521	1250	114.4085	0.0104

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 (α) 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 α 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 *WU*E. 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.

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