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Full Length Research Paper

Improving the eco-environment in the western-China by applying local tree species: Issues and implications for global arid areas

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Local tree species would perform an important role in forestation, because they have more advantages than exotic species in terms of the physiological and adaptation aspects. In this article, we discussed some main factors which affect the drought resistance of trees and depict some anti-drought characteristics and mechanisms of some local species. These factors include osmoregulation, antioxidant system, transpiration and the shape and structure of trees. At the same time, we also make some suggestions and discussions for the application of typical local tree species in the west-China for improving regional, national and international environmental quality.

Key words: Loess Plateau, local tree species, soil water, drought resistance, osmoregulation, environmental management, arid and semiarid areas.

INTRODUCTION

The west-China is a very important area for the strategic position of China, which includes 12 provinces (Figure 1). The population of there is about 28.8 percentage of the Chinese population, but the area is 71.4% of the total area of China. The situation of geographic and eco-environment in this area is very complex and diverse, representing main zone of China. In the north-west area, drought or semiarid is the mainly characteristic of this area. And there are mainly deserts and grasslands. At the same time, some forests and mountainous regions are there, but the vegetation was destroyed very seriously, especially in Loess Plateau (Figure 1). Loess Plateau is a typical area where the drought and soil erosion had long been a major problem (Ceulemans and Deraedt, 1999; Jiang and Guo, 1996a, b; Du et al., 2007; Gupta et al., 1998). In the south-west area, there are subtropical zones and tropical zones. And the climate is very humid. Qinghai-Tibet Plateau is there, in addition, some mountains, forests and agricultural areas are distributed widely in this area (Han et al., 1994, 2003; Hu et al., 1999; Jiang and Guo, 1996a, b; Li et al., 1995). The vegetation in west-China is not only the basic sources for local people' living but also the most important factor for the eco-environment adjusting and protecting and the releasing of the climate cataclysm. Because there are lots of disadvantages, for example, drought, cold, gale, strong ultraviolet radiation, steep terrain, strong salinization and

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Abbreviations: SOD, superoxide dismutase; **POD**, peroxidase; **CAT**, catalase; **MDA**, malondialdehyde; **Vc**, vitamine C; **Ve**, vitamine E; **GSH**, reduced glutathione.

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Figure 1. The provinces of the West-China and the location of Loess.

man-made destruction. The eco-environment is on the stage of the critical line of physiology and ecology and the system of ecology and biodiversity is very fragile. In addition, Because of drought and high temperature, the area of desertification is still enlarged gradually every year. Since the western-development in China though the government made great efforts to improve it in resent years, the Eco-environment is not satisfactory in the west-China. In some regions, the governments make great effort to plant exotic species, which indeed beautify the environment, but only the partial regions can be covered. Additionally, the cost is very high and the survival rate is very low, even exotic species destroy the local ecosystem by appearing in the form of small-old trees. However, local tree species have been adapted to the local climate and environment and the vitality is very strong. Planting local tree species have more advantages than planting exotic species in the context of ecological adaptation and evolution (Ceulemans and Deraedt, 1999; Dai et al., 1999; Du et al., 2007; Li et al., 1995; Greenwood et al., 1985; Guo and Tian, 1998; Lo Gullo, 1986; Xia et al., 2000; Xu et al., 2000; McVicar et al., 2007; Mishra and Singal, 1993).

CURRENT QUESTIONS AND ANALYSIS

In order to ameliorate the quality of eco-environment and improve the level of local people's living standard, many governments take a lot of measures to do it. They mainly plant new trees to maintain the water in soil to resist the drought. In fact, some measures are not producing expectant results. The survival of trees is very low and the survival part may be not the available. Sometimes, it would bring some undesirable phenomena, the soil dried layer, for example. It has two reasons about it.

First, in order to build a beautiful environment, some local governments plant many new trees species without considering their applicability. In fact, some new species which were planted in the western region need more water than the local soil moisture to maintain its living.

Second, only one species was planted in some regions, which is not good to maintain the water in soil and protect the biodiversity.

The external manifestation of plants was determined by its genes and the environment. It is also true of the drought resistance of plants. As we all know, water is the basis of life. For plants, it is not an exception. In these drought regions, the growth of plants is very sensitive to the water content in soil. The growing and developing of plants are affected by drought, which may affect the whole course of growing, including the external shape and inner structure. Different plant species have different suitability for adverse environment. And the property of plants is the important factor for the utilizing of water. So the choice of plant species for forestation in drought regions is critical. According to the discussion about the anti-drought mechanism done by Turner and Kramer, there are two types of the drought resistance. Delayed dehydration (High water potential drought resistance) and Patience dehydration (Low water potential drought resistance) (Li and Zhai, 2000; Li and Zhang, 1993). *Pinus tabuliformis, Pinus syluestriformis, Pinus sylvestris var. mongolica, Pinus armandii franch., Pinus bungeana* Zucc.ex Endl. and *Larix principis-rupprechtii* Mayr could belong to the first type and the second type includes *Platycladus orientalis* (Linn.)Franco, *Ulmus pumila, Populus euphratica* Oliv. and *Tamarix ramosissima* Ledeb. etc (Moreno and Cubera, 2008; Nie et al., 1991). The following factors may mainly decide the drought resistance of trees.

Osmoregulation

Osmoregulation is the important mechanism for the drought resistance of plants. Osmoregulation is the active regulation of the osmotic pressure of bodily fluids to maintain the homeostasis of the body's water content, which keeps the body's fluids from becoming too dilute or too concentrated. Osmotic pressure is a measure of the tendency of water to move into one solution from another by osmosis. In the drought region, plants mainly have their osmotic pressure to absorb more water from environment to maintain their normal metabolism. Two ways can be used to regulate osmotic pressure: water loss and solute increase. But only increasing the solute could be the osmoregulation. The solute includes two kinds: inorganic salt, K^+, Na^+, Cl^-, NO^{3-}, absorbed from environment and organic substance (soluble sugar, free amino acids and betaine) synthesized by organisms. They could be used as the physiological index of the ability of osmoregulation (Ren et al., 2007; Shao et al., 2006). It is reported that more proline could be accumulated in the anti-drought plants than the ordinary plants, for example, *Citrus reticulata* Banco, *Ammopiptanthus mongolicus (Maxim.)* Cheng f. and *Hippophae rhamnoides Linn* (Shao et al., 2006; Shao et al., 2007; Shao et al., 2008). Gu et al. (1986) found that the content of soluble sugar in the seedling of *Acer truncatum Bunge* would be increase gradually with the drought become more and more serious. Yang et al. (1997) found that *Aopulus tomentosa* carr triploid clones could improve the osmoregulation and maintain its osmotic pressure with the drought intensified.

There are no specific osmoregulation organs in higher plants. The intake and loss of water are by means of those internal and external factors which affect the rate of transpiration. Certain plants develop methods of water conservation. Xerophytes are plants in dry habitats such as deserts which are able to withstand prolonged periods of water shortage. Succulent plants such as the cactus have water stored in large parenchyma tissues. Other plants have leaf modifications to reduce water loss, such as needle-shaped leaves, sunken stomata and thick, waxy cuticles as in the pine. The sand-dune marram grass has rolled leaves with stomata on the inner surface.

Antioxidant system

In free radical theory of injury, the production and elimination of free radicals and active oxygen are very common in the cells of plants. One of the harm of drought for plants is that active oxygen would be produced in the plant cells. With the increase of active oxygen, it could harm the protein, nucleic acid, saccharide and lipid in cells. But active oxygen would not start lipid peroxidation directly, which must be produced by some OH through some reactions and then started to trigger lipid peroxidation and to destroy the structure of biological membrane (Shao et al., 2008; Shao et al., 2008; Shao et al., 2008; Shen et al., 2000; Wang, 2003; Wang et al., 1989). MDA is the primary product of the lipid peroxidation, which can be used as the index of lipid peroxidation. In general, the drought resistance is better, the content of MDA and the lever of lipid peroxidation is lower. Some enzymes can eliminate the active oxygen. There is a close relationship between the drought resistance and the ability of eliminating the active oxygen in plants. SOD is an important enzyme for eliminating the active oxygen in plants, which is usually distributed in chloroplast, mitochondria and cytoplasm. In drought condition, the activity of SOD and the ability of anti-oxygen are directly related (Yan et al., 1999; Yang et al., 1997; Zhang, 2003). It can be proved in *Pinus sylvestris var. mongolica Litv., Pinus koraiensis Sieb. et Zucc., Hippophae rhamnoides Linn., P. cathayana* and *Acer truncatum Bunge* (Sperry and Tyree, 1988; Seel et al., 1992; Sperry and Tyree, 1990; Zhang, 2001). Xia et al. (2000) found that *Pinus sylvestris var. mongolica* Litv. could increase the active of SOD apparent to resist drought. But the content of MDA still increased. It was proved that SOD would not resist drought completely. Two kinds of substance in plants to control the eliminating

of active oxygen are enzymes (SOD, POD, CAT and others) and anti-oxygen substance (Vc, Ve, GSH and others), which eliminate the active oxygen in cooperation. With the decline of SOD activity in serious drought, the ability to eliminate the active oxygen would be feeble, which causes the content of MDA to rise rapidly. This indicates that the drought have exceeded the limit of drought resistance. Jiang and Guo (1996a) found that the content of POD in species of high drought resistance would be increased at the beginning and declined afterwards in serious drought. At the same time, the content would maintain the high density. The activity of CAT would be declined, but the extent is smaller in the species of high drought resistance than the common species.

MDA is the primary product of the lipid peroxidation, whose content and transparency of cell membrane are directly related. MDA is can be one index of the transparency of cell membrane or extent of injury. SOD may be the enzyme, which could be evaluated the drought resistance of different species (Yang et al., 1997; Zhang, 2003; Sperry and Tyree, 1988; Seel et al., 1992; Sperry and Tyree, 1990; Zhang, 2001; Zhao and Zhao, 2002).

Transpiration

Transpiration is a process that water was evaporated from plants to environment, which is a significant factor to affect the water consumption of plants. Most water absorbed by trees was consumed by transpiration. So studying the efficiency of transpiration can reflect the property of water consumption of plants and the drought resistance. Han et al. (1994) found that the arrangement of water consumption of local tree species in the western China from high to low is: *Robinia pseudoacacia L.* > *Populus* > *Caragana Korshinskii* Kom. > *Hippophae rhamnoides* Linn. > *Platycladus orientalis* (Linn.)Franco > *Pinus tabulaeformis* Carr. At the same time*, Hippophae rhamnoides Linn.* has higher water use efficiency (Shao et al., 2006). The water consumption is very different among different plants and in different time. Wang (2003) found that the difference of water consumption of four local trees species is very large in the whole growing reason through systematic investigations [(Shao et al., 2008). At the same time, evidence of the relationship between leaf area and evapotranspiration has been provided by several authors (Sperry and Tyree, 1990; Zhang, 2001; Zhao and Zhao, 2002). So transpiration is the critical factor for the selecting of trees species in forestation in this fragile region.

The shape and structure of trees

In drought regions, trees have special shape to resist drought evaluated by the environment. At the same time, the hydraulic architecture of trees is an important factor that affects the drought resistance (Wang et al., 1989; Yan et al., 1999; Yang et al., 1997; Zhang, 2003; Sperry and Tyree, 1988; Seel et al., 1992).

The hydraulic architecture is the manner formed from different structure morphology and water absorption and transport for adapting the special environment. Tree can change its hydraulic architecture to affect the obstruction of water transport and the demand of water, which can take deep effect for water transport and balance. In general, the vessel of ring-porous wood is long, and the caliber is big, so the obstruction of water transport is very small, which could produce the phenomenon of cavity and embolish easily. The water transport happened in small area with fast speed. In the diffuse-porous wood, the vessel is short and the caliber is small, the probability of produced the phenomenon of cavity and embolish between the ring-porous wood and the coniferous tree. The water transport happened in big area with low speed. In the coniferous tree, there is only tracheid in the woodiness. The unit of tracheid is small and has cross-walls. So the obstruction is very big, but it cannot produce the phenomenon of cavity and embolism. The water transport of the coniferous tree happened in big area, but the speed is lower. The phenomenon of cavity and embolish reflect the ability of water stress of tracheid. At the same time, the ability of recover after the phenomenon is very important for plant living. They reflect the drought resistance of tracheid (Xu et al., 2000; McVicar et al., 2007; Mishra and Singal, 1993; Li and Zhai, 2000; Li and Zhang, 1993). Many researchers deem that the species of drought resistance have strong ability to resist the cavity and embolism of tracheid (Nie et al., 1991; Ren et al., 2007; Shao et al., 2006). The coniferous trees have lower water potential threshold than broad-leaved trees. So the coniferous trees have strong ability to resist the cavity and embolism of tracheid compared to the broad-leaved trees, which have good drought resistance.

The anatomy and function are the basis for trees to adapt the drought environment. The floss and calthrop in the surface of plants could increase the area for radiating to avoid injury for the surface by sunshine. Some plants have wax in their surface to decrease the water evaporation. The spiracles in some plants are in the leaves to decrease water loss. In air region, the species which have well-developed roots have advantages to living. The feature of xeromorphy of leaf can reflect the ability of drought resistance. It is demonstrated that the symbol of strong drought resistance include leaf thickness, developed palisade tissue, high thickness rate of palisade and sponge tissue, thickness cuticles , thickness epithelial layer, sank spiracle and developed epidermal hair. Dai et al. (1999) found that the scale leaf of *Platycladus orientalis* (Linn.) Franco has high drought extent. And the ratio of stoma under the scale leaf is about 75 - 85%. The epidermal cell is small and the cell wall is thickness. Through study difference of the density of stoma, the thickness of epidermis and the depth of substomatic

Table 1. Partial promising local tree species in the west-China and their characteristics.

Name	Characteristic
Ammopiptanthus mongolicus (Maxim.) Cheng f.	Special structure in root, stem, leaf to resist drought; the seedling can resist cold of -20.9℃
Populus euphratica Oliv.	Bear drought, low temperature, salt-marsh and flooded; resist wind; have strong applicability
Elaeagnus angustifolia L.	Like sunny; not bear drought; bear moderate salt-marsh
Populus pruinosa Schrenk	Resist hight temperature of 42.7℃ and low temperature of -40℃; bear atmospheric drought
Haloxylon ammodendron (C. A. Mey.) Bunge	Bear high temperature, chilliness and salt; bear atmospheric drought and soil drought; deep root
Tamarix chinensis	Bear damp; salt-marsh; arid
Salix matsudana Koidz.	Bear drought and low temperature; strong sprout; develop root; deep root in soil; have endophyte in root
Hippophae rhamnoides Linn.	Develop root; bear drought, arid and salt-marsh
Platycladus orientalis (Linn.) Franco	Bear drought and arid; strong sprout; able grow in acidic; neutral; calcareous and low salt-marsh soil
Robinia pseudoacacia L.	Bear drought; growing fast; not sensitive for PH of soil
Pinus tabulaeformis Carr.	Deep root; like sunny; resist arid and wind; able grow normally in -25℃
Caragana Korshinskii Kom.	Develop root; bear drought; low temperature and high temperature; have strong ability to fix sand
Populus tomentosa Carr	Deep root; develop root; strong sprout; growing fast; not bear severe drought; bear low salt-marsh
Pinus sylvestris var. mongolica Litv.	Deep root; bear drought and low temperature; resist wind
Acer truncatum Bunge	Deep root, Bear low temperature; resist wind; not bear dry hot and strong sunshine; resist SO2 and HF; can adsorb dust
Quercus mongolicus Fisch.	Strong applicability; bear fire, drought, arid and low temperature; low temperature limit is -50℃ ,deep root;

chamber among the isogenesis, they found the features of the scale leaf from north are very outstanding (Shen et al., 2000; Sperry and Tyree, 1988; Zhao and Zhao, 2002). In addition, the root and stem could affect the drought resistance of plants. Li et al. (1995) found that *Atriplex Canesccns Fames* had extreme drought resistance, which can adapt the drought desert in the north-west China through their anatomical structure of leaf and stem.

Through the evolution in thousands of years, plants have developed many important anti-drought mechanisms, especially for the local tree species. So they may be the best choice to be planted in these special environments. In Table 1, there are some local tree species, which are often used in forestation. From it, we can know that every one has its own characteristics to adapt to terrible conditions.

SUMMARY

Local tree species have lots of advantages compared with exotic species. There are different local tree species in different regions, which have different anti-drought mechanisms. In order to adapt the special environment, the gene and morphology of trees have changed gradually. Therefore, forestation with local tree species is the wise choice to batter the environment, which can not only low the cost, but also enhance the survival rate.

In fact, there are a lot of local tree species in the western China. But many of them are not utilized by people due to the lack of knowledge of their physiology and biochemistry. In order to build a green west-China, we must make more efforts to exploit the local tree species.

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Plateau

Notes: The west-China includes 12 Provinces (Xinjiang,

Gansu, Qinghai, Tibet, Ningxia, Shaanxi, Sichuan, Chongqing, Guizhou, Yunnan, Guangxi, Inner Mongolia), Loess Plateau region mainly includes Ningxia and Shaanxi.

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