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Populus euphratica, a Tolerant Model but Endangered Arborescent Species

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Populus euphratica is a most tolerant arborescent species to abiotic stress. It can adapt to extreme conditions, ranging from flood to atmosphere extremely dry, hot from + 54°C to - 45°C , and from normal soil to the soil with very high salt concentration (to 2 ~ 5%) although being a non-halophyte However, the natural stands of P. euphratica have been shrinking tremendously for the past decades and some populations are facing the fate of extinction. The preservation of existing resources should be carried out as a burning issue. In parallel, P. euphratica could be taken as a model plant to explore the molecular mechanism of abiotic-stress tolerance and to exploit its tolerant genes due to its smaller genome and easy molecular manipulation. The measures for preservation, germ-plasma exploitation, tolerance mechanism exploration and resource utilization were also discussed in this paper.

Key words *Populus euphratica*, abiotic stress, tolerance, preservation

Introduction

Populus euphratica Olivier belongs to the Family of *Salicaceae*, Order of *Salicacae*, Genus of *Populus* and Section of Turanga Bga. It remained as a relict plant left along the river banks of barren deserts through the Tertiary period of the Ancient Mediterranean epoch and has existed for about 3 — 6 million years[1]. Its distribution had ever stretched across three continents of Europe, Asia and Africa and the latitude between 0 N. to 47 N. At present, there are about: 590 thousand ha of P. *euphratica* forest worldwide, mainly distributed in 12 Counties although only a shadow of their former presence was found in some of them. Those Counties include China, the People's Republic Mongolia, Kazakhstan, Pakistan, India, Morocco, Turkey, Syria, Iraq, Iran, Spain Kenya. Its largest natural stands are concentrated in the Xingjiang Uygur Autonomous Region of China, as well as in Kazakhstan, and some large stretches of P. *euphratica* forast could be found there[2].

P. euphratica also has high ecological and economic value. The forest is a major factor in maintaining ecological condition in the desert area. It conserves water in oasis and wildlife habitat, and protects husbandry and agricultural crops as a natural screen. Besides, people use its wood to construct house, boats, and furniture and to make farm tools, musical instruments and handicrafts as well. Its leaves are one of the important forage for livestock during winter and spring. The excreted alkali can be used to produce edible soda. So P. *euphratica* was one of the basic necessities for the poor locals to live on.

1 Tolerance characteristics

P. *euphratica* remarkably stands out from poplars and other woody species due to its tolerance. It could adapt to condition extremes, ranging from hot to cold, flood to dry atmosphere, and could grow in the soil with high saline concentration although being a non-halophyte. It is the only arborescent tree species naturally distributed at the limit of barren desert or semi-barren desert worldwide.

On the temperature adaptation, P. *euphratica* could survive even in the harsh conditions where the temperature is quite unfavourable for plant inhabitation. For instance, on the river banks of Xilidali, Cu and Yili of Kazakhstan desert, where P. *euphratica* forest distributed, the atmosphere temperature could reach - 45°C, in winter and + 54°C in summer. In the world' s largest euphrates poplar distributed area of Northwest China, the temperature normally change from -39.8°C to 43. 6°C[2]. Moreover, in 1993, a scientific investigation team found a small

lined stand of euphrates poplar on hinterland of Great Taklimakan Desert, where the daily temperature could change from 43 ℃ at daytime to —6. 7 ℃ at night[2]. Under this condition, *P. euphratica* could live and multiply till now, indicating how tolerant it is to temperature extreme and changes.

P. *euphratica* has very strong capability to tolerate the atmosphere drought and tackle the ground water change. Normally, P. *euphratica* forests locate as the corridor-shoped natural belt along river banks or on the bed of discontinued rivers. There, the most distinct ecological characteristics are atmosphere drought and tremendous change on underground water table. For instance, in the P. *euphratica* distribution area around Takelamagan desert, the annual rainfall is only 37. 9 mm but annual evaporation 3769.6 mm. Seasonal precipitating causes the underground water table to change dramatically. Hence, P. *euphratica* has to deal with or adapt to the flood and drought in soil beside of dry atmosphere. As a result, it has developed an efficient mechanism to deal with periodical soil water flexion[3]. In the hinterland of Great Takalamagann desert, there is a small piece of lined P. *euphratica* forest, consisting of living trees and trees that died many years ago. Once people tried to dig out water there but failed. They found only dry sand even at a depth of 4 m. In Kuerle area, Xinjiang, China, the forestland of the Farm of 29th Regiment was almost flooded in the water with high mineral concentration of 10 g/L for 4 months every year, P. *euphratica* grew vigorously. In southern Xinjiang, P. *euphratica* planted as sheltbelts around the rice field grew quite well. In this areas, even the flood tolerance species, such as *Elaeagnus angustifolia, Populus mgra* var. thevestina. *Populus simonn* or other species could not grow.

Comparative studies revealed that the leaf anatomy structures of P . *euphratica* belong to mesophytes in general but some characteristics are biased to xerophyte, such as covered with wax, diverse shapes, and leathery, hard and thick tissue[4].

P. *euphratica* is a non-halophyte but bears a high salt tolerance[2]. According to an investigation (Table 1), the plants can grow vigorously in the soil with the saline content of 1. 33 to 2. 25 % in the top layer of 1 ~ 100 cm. When saline content is over 2 % , the biomass accumulation will be negatively affected and while over 5 % its growth is suppressed obviously and tree top will wither[5].

Table 1 Forest performance of *P. euphratica* on sandy soil containing different salinity

Location	Level of underground water (m)	Saline content in the soil of 1~100 cm (%)	Stand age (year)	Tree height (m)	Growth performance
Shaya	1.95	1.33	35	7.3	better
Luntai-1	3.65	2.25	35	8.3	better
Luntai-2	4.11	3.23	35	7.8	top Withered and sparse population

The adaptation to high-level saline and high pH of P. *euphratica* might attribute to its physiologic capability. Table 2 lists the saline content in vegetative organs of P. *euphratica* grown on the saline-alkali sand land[6]. The plants growing under high salt condition contain high concentration of ions and very high pH from 9.6 to 12. However, the mechanism of how the organ or cell deals with those high inside ions and pH is still unknown.

Table 2 Saline content of *Populus euphratica* vegetative organs

Vegetative Organ	Ash (%)	Salinity content (g/100 g fresh weight)				pH
		Total saline	Cl^-	SO_4^{2-}	CO_3^{2-}	
Lateral root	10.067	2.531	0.367	0.571	1.4187	10.6
Trunk	1.914	—	0.063	0.536	1.0698	9.6
Phloem of trunk	6.484	1.021	0.093	0.672	1.2664	11.8
Xylem of trunk	1.142	0.216	0.063	0.607	0.6280	9.5
Phloem of branch	8.076	1.600	0.084	0.536	1.4420	11.8
leaf	11.238	0.031	0.0765	1.250	1.7443	9.9

From the General Agricultural Exploration Bureau of Xinjiang, 1978

2 Endangered situation

The natural stands of *P. euphratica* were shrinking tremendously during the past decades. Many large areas of natural euphrate forest were destroyed or die away due to reclamation, denudation, grazing, and particularly reservoir building at the upper reaches of rivers. As the population increases, the local people have to damage it for their living. It is worrisome that the damage is still going on and being accelerated. In China, for example, the existing area of *P. euphratica* forest is no more than half of its area before the founding of new China[5]. It has become the most endangered species and was listed in China's Plant Red Book[7]. In the other part of world, the devastation of *P. euphratica* was even more serious and the natural forest is almost eliminated. *P. euphratica* is developing from formerly a vastly distributed species to one that faces the fate of extinction.

Fortunately, in some areas, due to the poor transportation and sparse population, some natural forests still remain undisturbed by mankind. It is common natural wealth for mankind and also an important gene plasma resource for conservation, research and utilisation. Therefore, protecting and preserving the limited resource and carrying out in-depth research have become a burning issue.

3 Limitations for the exploration and preservation

Although P. *euphratica* is a precious tolerant resource that has been attracting more and more attention, its research and application lagged greatly behind what it should be. Research outputs were quite limited and most of them were on the superficial investigations like ecology and physiological characteristics, so on and so forth[2]. This statue attributes not only to people's ignorance of its value and importance but also to this species itself. First, the existing stands mostly distribute in sparsely populated, poor and far-reach desert areas, so it is very difficult to reach this species; secondly, it is difficult to be propagated by conventional methods. The rooting rate of either hard or tender shoot is lower and unstable[8]. The main ways to raise *P. euphratica* plants are natural seedling and root-sucker regeneration, both being time-consuming with low efficiency. *P. euphratica* seeds are tiny and easy to lose its viability. Under normal room conditions, its viability declines to 31% after eleven days and 1% after one month[9]. In research practices, it is not easy to obtain enough identical plants to meet the experimental requirements. At last, it is normally incompatible with other Populus species when making hybridisation in breeding. All those mentioned above greatly limited the preservation, utilisation and exploitation of this tolerant germ-plasma.

However, in recent years, as application of the techniques of molecular biology and in vitro regeneration, the former limitations have been a history. Recent achievements on in-vitro micropropagation and molecular biology or biochemistry have shown the breakthrough[10]. Now, it is technically feasible to efficiently and scientifically preserve, exploit and use this treasure resource.

4 Perspectives

Considering the sharpdeclining of nature stands of P. *euphratica* forest, protection and preservation of the existing nature resources should be taken as a priority of concerning and rendered more management enforcement and scientific research. Since the natural P. *euphratica* is propagated by root-sucker or natural seedling, the genetic polymorphism in a population is quite uninformative. Therefore, in order to make a valid preservation and keep the maximum of genetic diversity, the genetic polymorphism should be discriminated. The available techniques of isozyme, RAPD, AFLP, FALP, microsatellite and so on could be employed as efficient technical tools. Based on the work of genetic polymorphism, some nature stands which contain the maximum variations are identified and those stands could be *in-situ* preserved as a form of nature protection zone to maintain underground water. Meanwhile, some individual precious germ plasma could be preserved *ex-situ* and in the forms of plant, organ, tissue or DNA at gene pool or at laboratory. Now, long-term preservation of DNA, tissue- and organ is technically possible at laboratory. The highly efficient and productive in-vitro regeneration system of *P. euphratica*[11] could serve as the critical technique to preserve and propagate the germ plasma.

It is a very important worldwide issue to understand the mechanism of plant tolerance to abiotic stress and further improve plant abiotic tolerance. P. *euphratica* is a non-halophyte and a mesophyte in

morphology but bears high tolerance to abiotic stress, and moreover, genus Populus have relatively small genome (2n=1.2 pg), 2) easy biotechnological manipulation, such as easy in-vitro regeneration and genetic transformation[12]. Therefore, P. *euphratic* might be a good arborescent model species for molecular mechanism exploration of abiotic stress tolerance and for tolerant gene exploitation. It is generally understood that plant tolerance to abiotic stress is governed by a molecular complexity, consisting of the process of detoxification, osmotic and ion homeostasis, and growth regulation. It involves the process of stress signal perception, transduction and induced gene expression[13]. Fortunately, advances in genomics, informatics, and functional genomics have made it technically feasible to dissect the complexity, clone related genes and gain a more complete understanding of genes regulating tolerance in a comprehensive way[14]. The outputs will be significant for both genetic improvement of plant tolerance to abiotic stress, particularly for woody species and plant tolerance theory.

As a tolerance arborescent forest species, P. *euphratica* could be directly used in afforestation in the ecologically severe area to combat land decimation and dissertation[15]. Moreover, *P. euphratica* could be applied as a tolerant rootstock. There have been some successful samples in that regard. In Northwest China, P. bolleana *is* a fast-growing and stem upstraight species, but more sensitive to salt stress. Through grafting P. *bolleana* on *P. euphratica*, the grafted plants showed both fast growthand salt tolerance. Productivity of the stands on the saline-alkali land was significantly improved.

The economic application of P. *euphratic* should be reviewed under modern technologies. It should be far beyond the traditional context of wood, livestock forage, soda and dye. Recent results have already shown the trace of its high value. It has been confirmed that the bark of P. *euphratica* contains very high phenolic glucosides and phenol acid[16]. Sap or extraction of P. *euphratica* were applied as an effective medicine for some human diseases like dyspepsia, hyperacidity and flatulence by the local doctors. The in-vitro cells proliferation of P. *euphratica* has been proved to have marvelous growth characteristics, such as resistance to rotator shear and tolerance to the flexion of medium constitution, and high biomass productivity[10], which were highly expected on molecular farming with plant cell[17].

P. *euphratica* is a natural treasure, we have full duty to preserve well this species and make it better serve human beings and the environment.

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