Seasonal Changes of Forest Ecosystem in an Artificial Forest of *Robinia pseudoacacia* in the Loess Plateau in China

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Abstract

*Robinia pseudoacacia* has been widely afforested in the Loess Plateau and has contributed to preventing erosion and sedimentation in the Yellow River. However, it has brought adverse effects such as deterioration of the native ecosystem and reduction of stream flow through excessive soil water use. This paper describes the seasonal changes of microclimate in an artificial forest of *R. pseudoacacia* by comparing it with a nearby native forest of *Quercus liaotungensis* in 2003. The results show that *R. pseudoacacia* tends to expose the forest floor and make a harsh environment for succession, which is exceedingly dry and hot, especially in spring when soil water is scarce and solar radiation is considerably strong.

Keywords: Black Locust, Ecosystem, Forest, Loess Plateau, Robinia, Yellow River

1. Introduction

The Yellow River, the second largest river in China, has been suffering from severe sedimentation. About 90% of all the sediment is provided from the Loess Plateau by soil erosion mainly due to successive deforestation and agricultural activity on steep slopes (Douglas, 1989). Thus, it became a pressing issue to overcome this situation and implement sustainable development in the Loess Plateau where the economy is backward and the ecosystem is vulnerable. In 1998, the Chinese government issued "National Ecological Environment Construction Plan" and launched a project called "Grain to Green Project" to convert farmland with a slope of over 25 degrees to forests or grassland (Fan, 2003). Although the forest coverage in the Loess Plateau is only 7.2%, which is 9.4% less than the average of the whole country, it has been gradually increasing (Lu, 2003, Cheng and Wang, 2002).

Black locust (*Robinia pseudoacacia* L.), native to North America, has been extensively planted in the southern Loess Plateau since 1960's and become the major tree species in the region (Wu and Liu, 2003). It has a great number of advantages such as drought tolerance, symbiotic nitrogen fixation, fast growth in youth, and high specific gravity. Consequently, it has been widely planted for a number of purposes such as reforestation of denuded land, soil improvement, the backbone of the agroforestry system and for a diverse range of products including paneling, firewood, livestock foliage and nectar (Boring and Swank, 1984; Bongarten et al.; 1992; Groninger et al., 1997; Feldhake, 2001; Swany et al., 2002; Wu and Liu, 2003; Wu et al., 2002; Lee et al., 2004), and become the third dominant planting tree in the world followed by eucalyptus and poplar. However, the expansion of the *R. pseudoacacia* has brought debates on adverse effects such as deterioration of the native ecosystem (Lee et al., 2004) and reduction of stream flow by excessive soil water use (Zhang, 1996; Gao et al., 2000; Shi and Li, 2001; Wen, 2002; He et al., 2003).

The work presented here is a part of the interdisciplinary researches on the ecosystem of an artificial forest of *R. pseudoacacia* in the Loess Plateau. This paper describes the seasonal changes of microclimate under the forest canopy of *R. pseudoacacia* in 2003.

2. Materials and Method

The study site is the Mt. Konglun near Yan'an, Shanxi Province (latitude 36°25.40'N, longitude 109°31.53'E) at an altitude of 1,353 m a.s.l. (Fig. 1). In the Loess Plateau, precipitation and forests gradually decrease northwestward, and Yan'an is on the forest-grassland zone (Cheng and Wan, 2002); mean annual precipitation and air temperature during 1982-2003
were 514mm and 10.2 °C respectively (Fig. 2).

Observation plots of 20 m x 20 m were set in an artificial forest of *R. pseudoacacia* and a native forest of *Quercus liaotungensis* at a distance of 150 m in 2002. An open space between them was set as a control plot. *R. pseudoacacia* is on the southeast-facing slope with a declination of 26 degrees. *Q. liaotungensis* and the open space are on the southwest-facing slope with a declination of 22 degrees.

The forest floor under *R. pseudoacacia* was almost bare and bright. On the other hand, the forest floor under *Q. liaotungensis* was relatively dark and covered with various shrubs, grasses and litters.

Interdisciplinary monitoring including ecology, physiology, meteorology, water and material circulations has been conducted since 2002. Concentrated observation has been conducted about three times a year.

### 3. Results and Discussion

Stand structure in the plots are shown in Table 1. *R. pseudoacacia* occupied about 93 % both in number and basal area, and *Q. liaotungensis* occupied about 28 % in number and about 54 % in basal area. *R. pseudoacacia* was about 25 years old while *Q. liaotungensis* was 40-50 years old in 2003. Almost 90 % of *R. pseudoacacia* was 10-15 cm in diameter of breast height (DBH) while DBH of *Q. liaotungensis* varied from 5 to 30 cm. These results indicate that *R. pseudoacacia* is an even aged artificial forest and succession was somehow restrained while *Q. liaotungensis* is a native natural forest with biodiversity.

Typical climatic features in the southern Loess Plateau are the cold dry winter and hot humid summer as shown in Fig. 2. Spring, especially April, is the most critical season for natural vegetation as well as rainfed crops. In spring, evaporative demand such as temperature, vapor pressure deficit (VPD) and solar radiation steeply increase while soil water is still scarce. Therefore, the soil surface easily dries up and exceedingly overheats in spring, which hinders the germination of vegetation.

Fig. 3 shows the seasonal changes of solar radiation above the canopy, precipitation in the open space, maximum soil surface temperature (\(T_{\text{max}}\)) of *R. pseudoacacia* and the difference of maximum soil surface temperature (\(\Delta T_{\text{max}}\)) between *R. pseudoacacia* and *Q. liaotungensis* in 2003. Precipitation from winter to spring was very scarce, and consequently the soil surface was quite dry. Solar radiation exceeded 20 MJ m⁻² from mid-March to around September. \(T_{\text{max}}\) of *R. pseudoacacia* increased from 0 °C in January to about 55 °C in April. It was constantly in the range 25 °C - 30 °C from May to August. It suddenly rose in September again, and then gradually fell towards winter. As can be seen in Fig. 3(d), \(T_{\text{max}}\) of *R. pseudoacacia* was almost identical to \(T_{\text{max}}\) of *Q. liaotungensis* in summer. On the other hand, \(T_{\text{max}}\) of *R. pseudoacacia* in the other seasons was similar to \(T_{\text{max}}\).
of the bare soil surface at the open space. These results indicate that the canopy of *R. pseudoacacia* does not shade the forest floor well except in summer, which induces harsh conditions for succession in spring, that are exceedingly dry and hot. On the other hand, it receives most of the sunlight for itself in summer when the soil water is replenished. These conditions could inhibit other vegetation from growing on the forest floor.

![Graphs](https://example.com/graphs.png)

**Fig. 3** Annual changes of some climatic factors in Mt. Konglou in 2003

These effects would be highly dependent on the canopy structure maintaining large gaps; vertically developed stems and complete defoliation. In addition to the canopy structure, human activities could also have an effect. Lee *et al.* (2004) reported that succession of *R. pseudoacacia* to native vegetation is often disturbed by frequent human activities, such as thinning and wood gathering, because these activities maintain large gaps. In the Loess Plateau, pasturage of sheep and goats could also disturb the succession and keep the large gaps. Thus, the ban of pasturage enacted in 2003 may affect the situation. Sign of environmental changes were seen in spring in 2004, but more investigation is needed to clarify the trend.

### 4. Conclusion

*R. pseudoacacia* has a canopy structure maintaining large gaps, which tends to expose the forest floor and make the soil surface exceedingly dry and hot in spring when soil water is scarce and evaporative demands become considerably strong. Human activities such as thinning, wood gathering and pasturage could have effects as indicated by Lee *et al.* (2004). Consequently, the ecosystem of the artificial forest of *R. pseudoacacia* is very harsh for succession and very poor in biodiversity.

Moreover, *R. pseudoacacia* tends to deplete deep soil water and expose the dieback symptom. It is unfavorable not only for the local ecosystem but also for the water resources because the runoff may be exceedingly reduced. As Liu and Ni (2002) pointed out, consumption of large amounts of water resources by forests may exaggerate the "Yellow River Dry-up Problem", which has occurred since 1972; the river failed to reach its mouth at the Bohai Bay 21 times out of 27 years.

Revegetation will change the ecosystem in multiple ways. Thus, careful and interdisciplinary investigations are strongly required especially where the ecosystem extends to large areas, such as in the Yellow River Basin. Change of local ecosystem will influence not only the regional ecosystem but also the global ecosystem. Therefore, long-term ecological researches such as those conducted by the International Long Term Ecological Research (ILTER) are crucial to maintain a healthy ecosystem on every level.

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