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RESEARCH ARTICLE

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Testing research for assessing suitability of multi-species of trees introduced in habitats in hilly and gully areas of Loess Plateau

Abstract To enrich resource of species, 105 arbor species (25 genera, 15 families) were introduced to the hilly and gully areas on Loess Plateau. By acclimation and selection, more than 90 tree species (12 genera, 8 families) were identified as fine species, including trees suitable for sloping fields such as *Pinus sylvestri* var *mongolica*, *Pinus tabulaeformis*, *Platycladus orientalis*, and *Robinia pseudoacacia,* trees suitable for gully bottoms such as *Populus davidiana*, *Populus diversifolia*, and *Salix cheilophila* and non-timber trees such as *Prunus armeniaca*, *Ziziphus jujuba* and *Prunus persica*. For those fine trees, habitat conditions and regularity of requirement of water and fertilizers were studied and then habitat ranges were given. From research results, it could be seen that *Robinia pseudoacacia* consumed more water, but it could improve the content of organic matters in soil; by contrast, *Pinus tabulaeformis* and *Platycladus orientalis* consumed less water and were suitable for dry sloping fields; species of apricot were suitable for sunny or semi-shady sloping fields with good conditions of water and fertilizer; species of pear were suitable for both shady sloping fields and sunny sloping fields; species of Chinese date were suitable for sunny sloping fields.

Keywords Loess Plateau, introduction of arbors and assessment, suitable habitats

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1 Introduction

On Loess Plateau, soil and water loss was severe due to the fact that vegetation was thin and fine trees were scarce there (Cui et al., 2003). Therefore, many testing researches had been carried out to restore vegetation and promote reconstruction of ecosystem and they testified that converting farmlands into forests and grasslands to increase vegetation coverage was an important measure to reduce soil and water loss (Bond and Willis, 1969; Sharpley, 1987). However, because of the inclement ecological conditions, survival rate of planted trees was low and consequently, profit from planting such trees was also little (Hou and Han, 1996), which affected the enthusiasm of local inhabitants to converting farmlands into forests. In recent years, people in various regions had been active in introducing trees to earn a better benefit.

To avoid blindness and unnecessary economic loss in introducing trees, 105 tree species (25 genera, 15 families) of water conservation forestry and non-timber forest had been introduced in succession since 1989. More than 90 species (12 genera, 8 families) suitable for local areas were selected as fine trees by acclimation and selection. Their habitat conditions and regularity of the requirement of water and fertilizers were studied and then suitable habitat ranges were presented for them in local areas. All such work enriched the resource of the tree species of forests.

2 Study area

Field experiments were conducted in Wuding River basin in Mizhi County. The altitude of this site ranged from 900 to 1,300 m and the climate type was warm-temperate drought zone where annual average temperature was 8.8°C, absolute highest temperature was 38°C, absolute lowest temperature was –25°C, and 160 days were without frost per year. With an annual average of 421.4 mm, rainfalls mainly occurred in July, August and September; the sum of rainfalls in these three months occupied 65% of the total annual rainfall. The aridity degree was 1.14. In testing area, the soil was typical Loess soil, whose profile development was not evident, soil mass was homogeneous and finally, soil aeration was good. Some chemical parameters for soil sampled from layer 50 cm deep were respectively organic matter 2.31 g/kg, total N 0.43 g/kg, total P 2.1 g/kg, total K 1.83 g/kg, and pH 8.35.

3 Materials and methods

Tree species were introduced from similar ecological regions such as Inner Mongolia, Gansu, shanxi, and Qinghai. For each tree cultivar, the number of plants was not less than 150 and seedlings were 2 years of age, with hale situation of growth and basically identical size. In the Spring of 1989, these trees were planted in six types of habitats, that is, hilltops, slow shady sloping fields and sunny sloping fields (gradient≤15°), steep shady sloping fields and sunny sloping fields (gradient≥20°), and those gully bottoms. For water conservation forest and non-timber forest, the planting densities were 2 m×2 m and 3 m×3 m respectively. The preparation area of each kind of tree was 0.07 hm^2. In the first year after planting, irrigation rate was 30 kg for each plant, once every 10 days and 3 times totally. To exercise their adaptability to drought, the irrigation rates were reduced gradually in the following years.

The planting sites were prepared as following. Trees for water conservation forest were planted on hilltops and steep sloping fields by pit planting. Filled with mature soil, each pit was 110 cm in and 80 cm in depth. On steep sloping fields (gradient≥20°), trees were planted in large fish-scale pits 110 cm in diameter. On those sloping fields with gradients from 15° to 20°, trees were mainly planted by pitting on level terrace and inverse-slope terrace with different width at different sites. In bottom fields, trees were planted by normal method with pits 110 cm in diameter.

To record phonological stage and growth of introduced trees, from 1990 to 2000, water content in soil layers 50–150 cm below habitat surface was measured four times by using Time Domain Reflectometry (TDR) on the 10th of each month in the period from June to September, which was the active growing period. Then, the average of four values was calculated. Yield of non-timber forest determined by weighting and timber volume of arbor forest measured with a plastic ruler was taken as assessment criterion of their suitability.

4 The assessment criterion of suitability

Combining with growing characteristics of various tree species in local area, this assessment criterion of suitability had referred to suitability assessment criterion based on land output of World Food and Agricultural Organization and adaptability assessment criterion on tree species induced to Loess Plateau (Zhang et al., 1996). In this criterion, suitability of different trees for local environment was defined as three degrees based on annual income for non-timber forest and timber volume for arbor forest. S_1-highly suitable: on the one hand, soil had no obvious restriction on trees; on the other hand, those trees had strong resistance to disadvantageous condition and could live normally; finally, annual profit was more than 10%. S_2-moderately suitable: soil had restriction on trees to certain extent; trees had moderate resistance to disadvantageous condition and could finish their growth periods; annual profit was less than 10%. S_3-unsuitable: soil had obvious restriction on tree species introduced and those trees could not finish their growth periods (Zhang et al., 2002).

5 Results and discussion

5.1 Relationship between growth of tree species induced and habitats

5.1.1 Family Pinaceae

Seven species (four genera) of family Pinaceae were introduced. *Cedrus deodara*, *Larix olgensis,* and *principis-rupprechtii*, *Picea meyeri* died because of drought and coldness, which meant the failure of introduction. For genus *Pinus*, only three species survived. In these three species, *Pinus densiflora* grew badly and *Pinus sylvestri* var. *mongolica* and *Pinus tabulaeformis* grew best on shady sloping fields. Although they could also survive on hilltops and slow sunny sloping fields, they grew slowly on such sites, which could be seen for 20 years, the cumulative volume of timber was just 28–30 m^3/hm^2 and timber volume of a single plant was just 0.05 m^3 (Table 1).

5.1.2 Family Cupressaceae

Three species (three genera) of family Cupressaceae were introduced. *Juniperus rigida* and *Platycladus orientalis* grew best and *Sabina chinensis* took the second place. For habitats, hilltops and steep sloping fields were best for such trees and gully bottoms usually led to their death (Table 1).

5.1.3 Family Salicaceae

Sixteen species (two genera) of family Salicaceae were introduced. Introduction of *Populus ussuriensis*, *Salix fragilis*, *Salix babylonica,* and *Salix limprichtii* failed because these tree species could not adapt to coldness in winter and drought in spring and summer in local area. At present, 11 species of these two genera survived, including *Populus davidiana*, *Populus diversifolia*, *Salix cheilophila* and so on. Survival trees grew best on habitats with good condition of water content such as slow shady sloping fields and gully bottoms. By contrast, they mostly died in steep sloping fields and slow sunny sloping fields. On hilltops, they could not survive (Table 2).

Table 1 The growth condition of pine and cypress in this area

Family	Genus	Species	Hilltop		Slopes: 15°–25°		Slopes: ≥25°		Gully bottoms		Suitability assessment
			Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	
Pinaceae	*Pinus*	*Pinus sylvestris*	0.004	39.1	0.054	67.0	0.004,9	63.0	Death	124.0	Suitable for slow sloping fields
		Pinus tabulaeformis	0.005	42.1	0.057	67.0	0.059	63.0	Little survival	114.0	Suitable for slow sloping fields
Cypressaceae	*Juniperus*	*Juniperus rigida*	0.006,1	41.0	0.012	67.0	0.009	61.0	Death	104.0	Suitable for sloping fields and hilltops
	Platycladus	*Platycladus orientalis*	0.064	41.0	0.014	68.0	0.011	61.0	Death	107.0	Suitable for sloping fields and hilltops
	Sabina	*Sabina chinensis*	0.006,7	42.0	0.017	68.0	0.012	61.0	Death	114.0	Suitable for sloping fields and hilltops

Timber volume was growing stock of single plant 13 years of age and these were all the same in this text.

Table 2 The growth condition of poplar and willow in this area

Genus	Species	Hilltop		15°–25° Sloping fields		≥25° Sloping fields		Bottom of hill		Suitability assessment
		Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	Timber volume /m^3	Soil water /($g\cdot kg^{-1}$)	
Populus	*P. davidiana*	Death	37.1	0.010	68.0	0.008	61.1	0.021	114.0	Suitable for gully bottoms and slow slopes
	P. diversifolia	Little survival	39.0	0.013	67.1	0.007	59.4	0.023	108.0	Suitable for gully bottoms and slow slopes
	P. hopeiensis	Death	39.0	0.012	67.5	0.007	61.3	0.021	117.0	Suitable for gully bottoms and slow slopes
	P. opera	Death	38.0	0.014	67.1	0.009	61.4	0.021	104.0	Suitable for gully bottoms and slow slopes
	P. simonii	Death	42.0	0.013	66.4	0.008	61.3	0.023	106.0	Suitable for gully bottoms and slow slopes
	P. alba var. *pyramidalis*	Death	40.0	0.009	67.0	0.008	61.2	0.022	114.0	Suitable for gully bottoms and slow slopes
	P. pekinensis	Death	40.0	Death	—	—	60.8	0.032	109.0	Suitable for gully bottoms
Salix	*S. cheilophila*	Death	39.0	Death	66.3	Death	60.7	0.034	113.0	Suitable for gully bottoms
	S. gordejevii	Death	38.0	Death	64.1	Death	61.4	0.032	109.0	Suitable for gully bottoms
	S. chienii	Death	39.0	Death	63.7	Death	60.9	0.027	109.0	Suitable for gully bottoms
	S. matsudana	Death	38.1	Death	64.3	Death	60.9	0.034	114.0	Suitable for gully bottoms

5.1.4 Family Rosaceae

One hundred and sixteen non-timber cultivars of 19 species (ten genera) of family Rosaceae were introduced and 48 cultivars of 8 genera have survived till date after ten years of introduction and acclimation.

Thirty-seven cultivars of genus *Malus* were introduced. Their suitable habitats were level platform fields whose soil water content was 6.7–10.0 g/kg. For each of three cultivars such as Qinguan and Jinguan apple, ten years of yield was as high as between 8,000 and 22,500 kg/hm^2. Rates of profit from them were all above 10%; therefore, they were highly suitable. For each of the three cultivars, that is, Hongyu, Red Fuji, and Xinhongxing apple, ten years of yield ranged from 5,000 to 8,000 kg/hm^2 and rates of profit from them were 15%–18.5%; however, their qualities were not good due to severe dryness in summer in this area and consequently, they were moderately suitable in local area.

Five species of genus *Prunus* were introduced, among which peach (*P. persica* Batsch) had 49 cultivars and apricot (*P. armeniaca* L.) had 12 cultivars. Now, there existed 12 cultivars of peach and 10 cultivars of apricot, which grew well on slow sloping fields (10°≤gradient≤20°) with good condition of water and fertilizer. For each of the three cultivars of peach, that is, Dajiubao peach, Bumuzaosheng peach, Doukoudahong peach, ten years of yield was 7,000–8,000 kg/hm^2. For each of the four cultivars of apricot, that is, Dahuang apricot, Cao apricot, Hulu apricot, and Mei apricot, ten years of yield was 9,500–10,500 kg/hm^2. Annual rates of profit from such seven cultivars above were all above 10%, and so they were highly suitable.

Seventeen cultivars of genus *Pyrus* were introduced and they grew best on the level platform fields. Among these cultivars, Dangshan pear grew best followed by Xue pear and Ya pear. Ten years of yield of each cultivar above was 8,000–12,000 kg/hm^2. Annual profits from them were all above 15%, and so they were highly suitable. Because of sufficient sunlight and heat, these sites were fine for growth of mixed fruit trees, especially trees of genus *Prunus* and genus *Pyrus*, fruits of which contained high amount of sugar, appeared with fine colors, and were all of high quality.

5.1.5 Family Leguminosae

Four species (four genera) of family Leguminosae were introduced, among which *Albizzia julibrissin* and *Gleditsia japonica* failed in introduction because their trees all died due to coldness in winter in these areas.

Robinia pseudoacacia was the main tree species of water conservation forest and its trees grew well on slow sloping fields and shady sloping fields with gradient more than 25°. Although they could still grow on sunny sloping fields with gradient more than 25°, they grew slowly and their timber volume was too small, that is, so called “grow into forest but not produce timber”. This phenomenon was mainly due to the soil water content being just 43 to 49 g/kg in this area. With 15 years of timber volume up to 0.011 m^3, *Sophora japonica* was highly suitable for yards besides those gullies.

5.1.6 Family Rhamnaceae

Eleven cultivars of genus *Ziziphus* of family Rhamnaceae were introduced and they were highly suitable for slow sloping terrace fields with soil water content between 54.0 and 63.0 g/kg. With a high yield for ten years from 12,000–15,000 kg/hm^2, *Ziziphus jujuba* Mill. cv. Spineless was most suitable and annual profit from it was above 20%, which made it the main tree species of non-timber forest in this area.

5.1.7 Family Moraceae

Twenty-two cultivars of two species of genus *Morus* of family Moraceae were introduced. Three cultivars grew relatively well, that is, Panqing, Moyu of species *Morus alba* L., and Mongolia mulberry of species *Morus mongolica* Schneid. Resisting to drought and coldness, they grew well in the fields below slow slopes; in these fields, soil water content of habitats should be not less than 60 g/kg. Particularly, survival rate of such cultivars planted by means of furrow could be 98% or higher, so they could also reduce soil and water loss observably, while they produced profit. All these facts indicated that they were highly suitable.

5.1.8 Family Simarubaceae

One species of genus *Ailanthus* of family Simarubaceae was introduced, that is, *Ailanthus altissima Swingle*. Having a strong ability to live through winter, it grew well in local area, especially in yards and middle or the lower parts of hills. In these sites, it grew very quickly, which made it a relatively fine tree species for timber and 13 years of timber of a single plant could be up to 0.023 m^3. Therefore, it was highly suitable but unfortunately, it was not suitable for forestation in large area.

Other trees introduced included *Metasequloia glyptostroboides* of family *Taxodiaceae*, *Juglans regia* of family *Juglandaceae*, *Ostryopsis davidiana* of family *Betulaceae*, *Quercus liaotungensis* of family *Fagaceae*, *Ulmus pumila* of family *Ulmaceae*, *Eucommia ulmoides* of family *Eucommiaceae*, *Paulownia tomentosa* of family *Scrophulariaceae,* and so on. They all failed to survive in various habitats because they could not adapt to the chillness of winter and drought of spring in local area. Therefore, they were not suitable for introduction.

5.2 The requirement of introduced trees on water and fertilizer

In this research, CK (*Setaria italica*) was taken as the reference point. In the condition that fertilizations for trees and reference crop were basically identical, by selecting trees growing in slow sloping fields as testing object, the average consumptions of water and fertilizer of different tree species were determined annually after defoliation in fall from 2000 to 2004 (Table 3).

Table 3 The water and nutrient of the soil different trees grow on (g/kg)

Species	Trees age /year	Soil layer: 0–50 cm					Soil layer: 50–100 cm					Soil layer: 100–150 cm				
		Water content	N	P	K	Organic matter	Water content	N	P	K	Organic matter	Water content	N	P	K	Organic matter
Setaria italica (CK)		45.6	0.047	2.01	1.31	2.93	45.1	0.29	2.10	1.21	1.10	43.0	0.22	2.00	1.23	1.01
Pinus sylvestris var. *mongolica*	13	48.6	0.037	3.37	1.71	3.45	33.5	0.34	3.20	1.55	3.14	33.6	0.41	3.21	1.42	2.03
Robinia pseudoacacia	13	40.2	0.41	3.28	1.84	4.47	31.8	0.37	3.17	1.66	3.22	32.4	0.21	3.20	1.47	2.12
Prunus armeniaca L.	13	41.8	0.39	2.10	1.34	3.33	31.7	0.28	2.31	1.6	3.07	36.7	0.24	2.21	1.25	2.13
Prunus persica Batsch	13	42.6	0.37	2.02	1.41	3.30	34.3	0.20	1.90	1.24	3.07	35.2	0.27	2.10	1.29	2.41
Platycladus orientalis	13	49.6	0.45	3.31	1.62	4.35	49.5	0.33	3.17	1.51	3.90	41.3	0.37	3.16	1.43	2.10

From Table 3, it can be seen that contents of N in active layer 0–50 cm deep of root systems of non-timber forest were relatively low and they declined much in layer 50–100 cm deep, which indicated that natural loss of N was relatively little and this element was adsorbed relatively efficiently. By contrast, there was no significant difference between contents of N in layer 0–50 cm deep and layer 50–100 cm deep in water conservation forest, which indicated that N was adsorbed relatively little. Additionally, a non-timber forest consumed more P and K than a water conservation forest.

In the meantime, water conservation forest could improve efficiently the content of organic matter in soil, which could be seen from that in the layer 0–50 cm deep, the contents of organic matter 4.47 and 4.35 g/kg respectively in forest of *Robinia pseudoacacia* and *Platycladus orientalis* were higher than reference 2.93 g/kg by 52.5% and 48.3% respectively, which indicated that water conservation forest helped to improve soil structure. However, *Robinia pseudoacacia* consumed much water and content of water 40.2 g/kg in soil 0–50 cm deep was 13.4% lower than reference 45.6 g/kg. *Pinus sylvestris* var. *mongolica* and *Platycladus orientalis* consumed relatively little water and contents of water in forests of such two trees were 6.6% and 8.1% higher than reference respectively. As a whole, water conservation forest could improve soil structure and conserve water, which was in accordance with the viewpoint of Doyle et al. (1975, 1977).

5.3 The assessment of suitability of introduced species for habitats

5.3.1 The assessment of suitability of non-timber tree species for habitats

The assessment of suitability of species of trees of non-timber forest was carried out in five kinds of habitats, that is, gully bottom, slow sloping field, steep sloping field, shady side, and sunny side. All cultivars of genus *Prunus*, *Pyrus*, and *Malus* grew not well on steep sloping fields. More than 20 cultivars of peach and apricot grew well on sunny sides of slow sloping fields and gully bottoms, but they did not grow well on shady sides. Seventeen cultivars of pear grew well on both shady sides and sunny sides of slow sloping fields, which indicated that they were eugenic species of trees in local area. Although all cultivars of genus *Malus* could grow on slow sloping fields, their fruits were not of high quality and there was significant difference between fruit quality of years abundant in rainfall and fruit quality of years short of rainfall, which indicated that they were not eugenic species of trees in local areas.

5.3.2 The assessment of suitability of arbor species for habitats

The assessment of suitability of species of arbor forest in habitats was carried out by measuring in different habitats timber volumes of four species of locally mainly planted trees, that is, *Robinia pseudoacacia*, *Populus simonii*, *Pinus tabulaeformis*, and *Salix matsudana* (Table 5).

Table 4 The output value and rate of profit of the different fruit trees

Species	Habitats	Area /hm^2	1998–2000			Assessment
			Output /(kg·hm^{-2})	Value of output /(yuan·hm^{-2})	Profit /%	
Prunus persica	Gully bottom	0.60	5,134	6,268	20.47	Highly suitable
Batsch	Slow sunny sloping field	0.60	6,140	12,280	25.41	Highly suitable
	Slow shady sloping field	0.60	2,314	4,628	15.60	Highly suitable
Pyrus bretschneideri	Gully bottom	0.50	7,149	10,783	24.47	Highly suitable
	Slow sunny sloping field	0.56	6,124	9,186	21.64	Highly suitable
	Slow shady sloping field	0.60	7,231	10,846	25.63	Highly suitable
Prunus armeniaca	Gully bottom	0.50	1,213	2,426	17.54	Moderately suitable
	Slow sunny sloping field	0.47	1,875	3,750	20.62	Highly suitable
	Slow shady sloping field	0.70	986	1,872	12.70	Unsuitable
Malus pumila	Gully bottom	0.75	4,756	4,756	14.15	Moderately suitable
	Slow sunny sloping field	0.63	4,104	4,104	19.67	Moderately suitable
	Slow shady sloping fields	0.55	908	2,090	10.16	Unsuitable

From Tables 4 and 5, it can be seen that habitats had significant influence on the growth of trees. Benefits from the same tree species may be very different due to the difference of habitats. For example, trees of non-timber forest were suitable for slow sloping fields, *Robinia pseudoacacia* and *Pinus tabulaeformis* were suitable for hilltops and steep sloping fields and finally, *Populus simonii* and *Salix matsudana* were suitable for bottoms of sloping fields and gully bottoms with high content of water in soil.

Table 5 The economic benefit of arbors forest

Species	Habitat	Age /year	Storage timber /(m^3·hm^{-2})	Value of output /(yuan·hm^{-2})	Assessment
Robinia pseudoacacia	Sunny slope	13	14.2	2,840	Moderately suitable
Populus simonii	Shady slope	13	28.0	5,600	Highly suitable
	Gully bottom	13	45.8	9,160	Highly suitable
Salix matsudana	Slope	13	10.1	2,020	Unsuitable
	Gully bottom	13	46.5	9,300	Highly suitable
Pinus tabulaeformis	Hilltop	13	15.7	3,140	Moderately suitable
	Slope	13	5.97	5,373	Highly suitable

6 Conclusion

Some tree species of water conservation forest were all suitable for local area, such as *Salix matsudana*, *Populus simonii, Populus hopeiensis,* and *Populus opera* of family Salicaceae, *Robinia pseudoacacia* and *Sophora japonica* of family Leguminosae, *Ailanthus altissima* swingle of family Simaroubaceae, *Platydadus orientalis*, *Juniperus rigida*, *Sabina chinensis* of family Cupressaceae, *Pinus sylvestri* var. *mongolica* and *Pinus tabulaeformis* of family Pinaceae, *Morus alba* L, *Moyu* and *Morus mongolica* Schneid of family Moraceae and so on. However, due to the significant difference between different habitats, there should be scientific match of various tree species according to their habitat conditions. For example, trees of family Salicaceae and Moraceae that liked water should be planted in such areas abundant in soil water as bottoms of sloping fields and sides of gullies. Trees of family Leguminosae, Pinaceae and Cupressaceae that resisted well to drought should be planted as trees of water conservation forest to protect slopes in steep sloping fields and hilltops and at the same time, planting them should be combined with some measures of water conservation engineering, especially *Pinus sylvestri* var. *mongolica*, which had a strict requirement on habitat. Trees of this species grew well on shady sloping fields with a gradient less than 20° and by contrast, it could not grow well on gully bottoms and sloping fields with a gradient more than 20°.

Most non-timber cultivars of species of pear, peach, apricot, and apple of family Rosaceae and Chinese date of family Rhamnaceae etc. adapted to local ecological environments and they are main non-timber trees in local area. Particularly, most cultivars of apricot, Chinese date, and pear resisted well to drought, had high quality, and produced considerable profit. All these made them suitable for local area. However, they should be planted in slow sloping fields with good conditions of water and fertilizer, among them Chinese date on sunny sloping fields, apricot on sunny sloping fields, and semi-shady sloping fields and pear on both shady and sunny sloping fields. In planting them, irrigation and fertilizing should be carried out according to different dates.

Resisting to drought and tolerating barrenness, trees of family Leguminosae could be planted on steep sloping fields with gradient more than 20°. In such habitats, water content was low because it was difficult for rainfall water to filter into soil, and so density of forestation with trees of family Leguminosae should not be too high and in plantation, such trees should also be matched with trees consuming less water such as *Platydadus orientalis* to form mixed forest.

In the precondition that trees introduced could survive, habitat conditions and the change of water, air and heat in microenvironment should be considered in planting, because gradients of slopes were large and gullies were deep in the hilly and gully areas on Loess Plateau, which made microenvironments diverse and soil water contents significantly different.

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