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RESEARCH ARTICLE

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A model for vertical distribution of fine roots in *Robinia pseudoacacia* plantations on the Loess Plateau

Abstract Based on a detailed investigation of vertical distributions of fine roots in *Robinia pseudoacacia* plantations at the Ansai Soil and Water Conservation Station, Shaanxi Province, a model was developed for the deep distribution of fine roots of *R. pseudoacacia*, which reflects the growth of fine roots affected by the mixed process of infiltration water and deep soil water. The maximum depth of the distribution $h_{\max}$ and the depth of the highest fine root density (FRD) h_p were determined and the maximum depth of infiltration water supplied for fine root growth h_q could also be calculated, h_q was considered as the approximate boundary between infiltration water and deep soil water in support of the growth of fine roots. According to the model, the soil water of *R. pseudoacacia* woodland in the profile could be classified into three layers: the first layer from the soil surface to h_p was the active water exchange layer, very much affected by precipitation; the second was the soil water attenuation layer, between h_p and h_q and largely affected by the vertical distribution of fine roots;.the third was the relatively stable soil water layer below h_q, below which soil water did not change much. The percentage of infiltration water supplied for the growth of fine roots reached a level of 88.32% on the shaded slopes and 85.21% on sunny slopes. This indicated infiltration of precipitation played a crucial role in the growth of *R. pseudoacacia* in the gully region of the Loess Plateau. The research of interaction between the distribution of fine roots and soil water in the profile will help to explain the reasons for the complete drying out of soils and provide a theoretical basis for continuing the policy of matching tree species with sites on the Loess Plateau.

Keywords *Robinia pseudoacacia*, fine roots, model, sites

1 Introduction

Fine roots of trees ($\leqslant 2$ mm in diameter) play a vital role in forest ecosystems. They are the primary pathways for soil water and nutrient uptake by trees. Their distribution within the soil is of great relevance to resource acquisition (Sun, 1994; Jackson, 1997; Schenk and Jackson, 2002). The architecture of fine roots shows considerable variation among plant species, but they are all very much affected by the growing conditions under which fine roots are distributed in deep soils. In general, water is a limiting factor to plant growth in semi-arid and arid regions and the distribution of fine roots responds to this condition. Quantifying the distribution of fine roots has taxed the ingenuity and stamina of many researchers. Although many studies have been conducted on fine root lengths, topology and turnover, it is difficult to describe precisely the distribution of fine roots in profiles. Gale et al. (1987) developed a model for the vertical distribution of roots based on the asymptotic equation $Y = \beta^d$, where Y is the cumulative fraction of roots mass $(0 < Y < 1)$ from the soil surface to a depth d (cm) and β is the fitted extinction coefficient. β is the only fitted parameter and provides a simple numerical index of rooting distribution. Large values of β imply a greater proportion of roots deep in the soil and low values indicate a greater proportion of roots in the top soil layer. Jackson et al. (1997) used the model to analyze the distribution of fine roots from 253 field studies all over the world and showed that tundra, boreal forests, and temperate grasslands had the shallowest rooting profiles ($\beta = 0.909$, 0.943, and 0.943, respectively), with 80%–90% of fine roots in the top 30 cm of soil; tropical deciduous forests and temperate coniferous forests showed the deepest profiles ($\beta = 0.982$ and 0.980, respectively), where the proportion of fine roots in the

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top layers was reduced to 45%. Schenk and Jackson (2002) also analyzed vertical root distribution from scanning the literature and found 475 profiles from 209 geographic locations, with a logistic dose-response curve (LDR). As well, many hydrological models have been used to estimate the dynamics of water and nutrients in the soil. In such studies, the ability of these models to estimate exactly water and nutrient uptake strongly depends on a practical description of root distribution in the soil (Bruckler et al., 1991; Nouvellon et al., 2000; Bouillet et al., 2002). However, the interaction between the distribution of fine roots and conditions (e.g. water and nutrients) in a given region was little taken into consideration in most root distribution models. The purpose of our study was: (1) to develop a model for the vertical distribution of fine roots in *R. pseudoacacia* plantations in the semi-arid regions of the Loess Plateau; and (2) to determine the interaction between the distribution of fine roots and water, which is a major limiting factor in semi-arid regions. We hypothesized that deep soil layers are not important in the supply of water for the growth of *R. pseudoacacia* in semi-arid regions of the Loess Plateau and that fine root distribution can reflect depletion of soil water.

2 Materials and methods

2.1 Experimental site

This study was conducted at Hamagou and Duntanshan at the Ansai Soil and Water Conservation Station which is located in the gully regions of the Loess Plateau (109°19′ E, 36°51′ N), Shaanxi Province, China. The elevation of the experimental site varies from 1,068 to 1,309 m. The climate is semi-arid and the average annual precipitation is approximately 505 mm, most of it falling from June to September. The mean temperature is 8.8°C. The ground layer is dominated by *Artemisia gmelinii*, *Artemisia giraldii*, and *Stipa bungeana*.

According to the Food and Agricultural Organization (FAO) soil classification system (FAO-UNESCO, 1988), the soil texture at the study site is silt loam in the 0–3 m profile with mean sand, silt, and clay contents of 19%, 72%, and 9%, respectively. The mean bulk density is 1.30 g/cm^3. The groundwater level is about 50–60 m below the soil surface, which precludes upward capillary flow into the root zone.

2.2 Sample processing

In this study, even-aged stands of *R. pseudoacacia* grown on both sunny and shaded slopes (general information of the stands is shown in Table 1) were selected as sampling plots for our investigation into the distribution of fine roots. In each stand, the average tree height and diameter at breast height were determined by measuring tree height and breast-height diameter of 30 randomly selected trees, from which four trees closest to the average height and breast-height diameter of the stand were selected as standard trees for investigation of fine roots. At each of the four standard trees, a 1/4 circle around the tree was marked as the sampling section given the position of each tree as indicated in Fig. 1 (Wang et al., 1994). From this configuration, the vertical distribution of fine roots of four trees in the same stand was investigated to represent the general distribution of fine roots. Relevant information of one complete tree in the stand was obtained or calculated. When sampling, three evenly distributed points on the 0.5 m radius and the 1.5 m radius were determined as sample points. At each sample point, a soil auger ($d = 6.8$ cm) was used for drilling each 10 cm layer from soil surface to 250 cm.

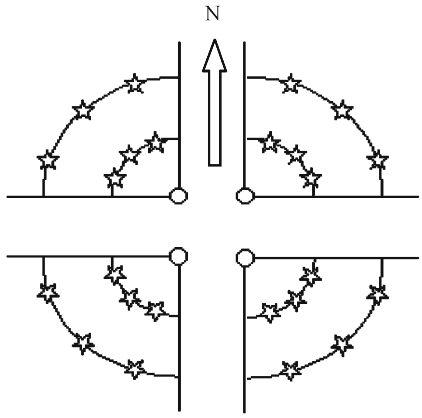

Fig. 1 Sketch of fine root investigation
☆: sample points at 0.5 m and 1.5 m distance from tree trunk; O: sample trees.

Fine roots selected from the soil of each layer were taken back to the laboratory in numbered plastic bags. The roots were washed and classified into two grades according to diameter ⩽ 2 mm and diameter > 2 mm. Fine root lengths,

Table 1 Survey of sample plots for fine root investigation of *R. pseudoacacia* at Ansai Station

No.	Site	Aspect of slope	Gradient /°	Position on slope	Stand age /year	Average height /m	Average DBH /cm	Stand density /(tree · hm^{-2})
1	Hamagou	Northeast	35	Middle	26	9.1	15.7	1,200
2	Hamagou	Northeast	30	Mid-under	26	7.7	18.3	1,200
3	Hamagou	South	32	Upper	30	7.4	19.1	1,250
4	Hamagou	Southwest	29	Middle	30	8.4	17.3	1,250
5	Duntanshan	Southeast	27	Middle	24	11.8	14.3	720^{a}
6	Duntanshan	Southwest	24	Middle	24	6.8	13.2	720^{a}

^{a} means that some trees were cut.

surface areas and volumes were measured with WinRHIZO (Canada Regent Instruments Inc.) which is an analytical image system specifically designed for measurement of roots of different forms.

2.3 Statistical analyses

The mean fine root density (*FRD*) from each soil layer was calculated by the following equation

$$FRD = \frac{\sum_{i=1}^{n}\sum_{j=1}^{k} m}{nk} \cdot \frac{1{,}000}{\pi r^2 h} \tag{1}$$

where *FRD* is the mean value of each layer (cm/dm^3, cm^2/dm^3 or cm^3/dm^3), r is the radius of the soil auger (cm), h is depth of the soil layer (cm), m is fine roots length (cm) or surface area (cm^2) or volume (cm^3), n is the total number of sample trees, and k is the number of sample points. Analyses were carried out using STATISTICA 5.5 (StatSoft Inc.) software.

3 Model description

In order to predict regular changes in *FRD* distributions of *R. pseudoacacia* as a function of depth, the following model, adjusted to *FRD* exigencies, was used

$$FRD = Ah^B(C + Dh + Eh^2 + Fh^3) \tag{2}$$

where A, B, C, D, E, and F are fitted coefficients ($A > 0, B > 0, F \neq 0$) and *FRD* is the fine root density at depth h (cm) from soil surface (cm^2/dm^3); the value of B reflects the maximum depth of *FRD*.

1) The general pattern of the distribution of fine roots of *R. pseudoacacia* at various depths at the Ansai Station of the Loess Plateau, simulated by the model, is shown in Fig. 2. h_p is the depth at which the *FRD* is at a maximum in the profile and obtained when the first derivative of *FRD* with respect to h was set to zero ($\mathrm{d}FRD/\mathrm{d}h = 0$). h_q is the maximum depth of infiltration of precipitation supplied to the growth of fine roots and can be interpreted as the boundary between infiltration water and deep soil water. It is obtained when the second derivative of *FRD* with respect to to h is set to zero ($\mathrm{d}^2FRD/\mathrm{d}h^2 = 0$). $h_{\max}$ is the maximum depth of the distribution of fine roots, when *FRD* is equal to zero, i.e.when $C + Dh + Eh^2 + Fh^3 = 0$. The model requires a real root and two conjugates complex roots to describe the distribution of fine roots. The only real root was $h_{\max}$.

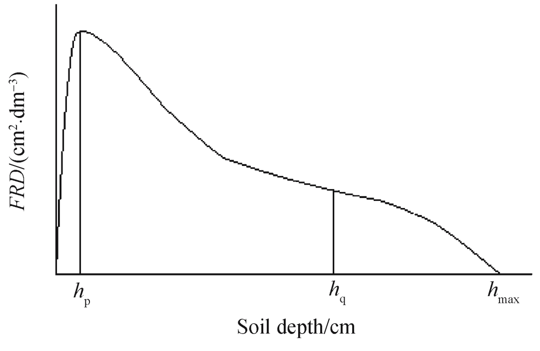

Fig. 2 General pattern of vertical distribution of fine roots of *R. pseudoacacia* simulated at Ansai Station

2) Interaction mechanism between fine root distribution and water

In eq.(2), the first derivative of *FRD* with respect to h was calculated and obtained. The incremental ratio of *FRD* was

$$\frac{\mathrm{d}FRD}{\mathrm{d}h} = FRD\left(\frac{B}{h} + \frac{D + 2Eh + 3Fh^2}{C + Dh + Eh^2 + Fh^3}\right) \tag{3}$$

The relatively incremental ratio of *FRD* was

$$\frac{1}{FRD} \cdot \frac{\mathrm{d}FRD}{\mathrm{d}h} = \frac{B}{h} + \frac{D + 2Eh + 3Fh^2}{C + Dh + Eh^2 + Fh^3} \tag{4}$$

We let

$$f_1(h) = Ah^B, f_2(h) = C + Dh + Eh^2 + Fh^3$$

then $FRD = f_1(h).f_2(h)$, and the relative increments of $f_1(h)$ and $f_2(h)$ were

$$\frac{1}{f_1} \cdot \frac{\mathrm{d}f_1}{\mathrm{d}h} = \frac{B}{h}, \frac{1}{f_2} \cdot \frac{\mathrm{d}f_2}{\mathrm{d}h} = \frac{D + 2Eh + 3Fh^2}{C + Dh + Eh^2 + Fh^3}$$

respectively. Therefore, the relative increment of *FRD* is the sum of $f_1(h)$ and $f_2(h)$,

$$\frac{1}{FRD} \cdot \frac{\mathrm{d}FRD}{\mathrm{d}h} = \frac{1}{f_1} \cdot \frac{\mathrm{d}f_1}{\mathrm{d}h} + \frac{1}{f_2} \cdot \frac{\mathrm{d}f_2}{\mathrm{d}h} \tag{5}$$

Equation (5) indicates the relative incremental ratio of *FRD* with soil depth and consists of two parts: (1) $f_1(h) = Ah^B$, the relative incremental ratio is $\frac{B}{h}$ decreasing with an increase in h, which implies the effect of infiltration of water to fine root growth; (2) $f_2(h) = C + Dh + Eh^2 + Fh^3$, the relative incremental ratio is

$$\frac{D + 2Eh + 3Fh^2}{C + Dh + Eh^2 + Fh^3}$$

which indicates that the *FRD* became very low at increasing depth and fine roots could only extract deep soil water. This determined the maximum depth of the distribution $h_{\max}$ of fine roots.

3) Contribution of infiltration water and deep soil water to growth of fine roots

The total amount of fine roots in the profile could be calculated by the integral from zero to $h_{\max}$ for *FRD* ($T = \int_0^{h_{\max}} FRD\mathrm{d}h$), the number of fine roots supplied by infiltration water was determined by $\int_0^{h_q} FRD\mathrm{d}h$, and the number of remaining fine roots depended on deep soil water was $\int_{h_q}^{h_{\max}} FRD\mathrm{d}h$. Then the percentage of infiltration water and deep soil water supplied to fine roots growth was $\eta_1 = \frac{1}{T} \cdot \int_0^{h_q} FRD\mathrm{d}h$ and $\eta_2 = \frac{1}{T} \cdot \int_{h_q}^{h_{\max}} FRD\mathrm{d}h$, respectively. Obviously, $\eta_1 + \eta_2 = 100\%$.

4) Relationship between distribution of fine roots and soil water in the profile

According to the model for the vertical distribution of fine roots of *R. pseudoacacia*, the soil water in the profile could be classified into three layers (Fig. 3): the first layer from soil surface to h_p is the active water exchange layer, and mainly affected by precipitation; the second was the soil water attenuation layer, between h_p and h_q and mainly affected by the distribution of fine roots, where the amount of soil water in the layer declined slowly from h_p to h_q; the third layer is the relatively stable soil water layer, below h_q where the amount of soil water changes relatively little.

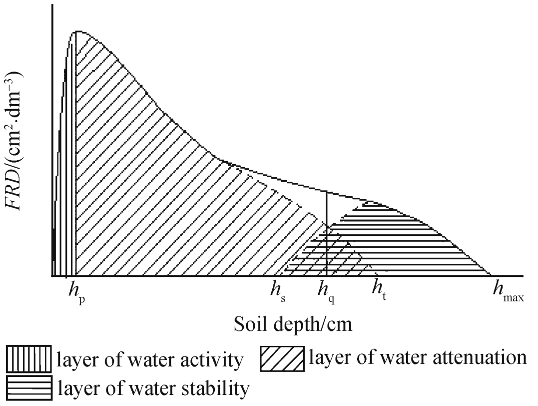

Fig. 3 Relationship between vertical distribution of fine roots and soil water in the profile.

Figure 3 indicates that soil water in the profile is composed of two parts: one part is the top soil layer that is supplied by precipitation from the soil surface to a depth of h_q, the other part is the deep soil water below h_q. Generally, if local precipitation supplies enough water to plants, the depth of the vertical distribution of fine roots would not exceed h_q. However, at Ansai precipitation could not provide enough water to the plants in the arid environment and plants sent deep fine roots to acquire deep soil water, which might lead to a severe negative effect on the ecosystem. Restoration of deep soil water would be difficult, if it were depleted in semi-arid and arid regions with deep groundwater. Under the latter condition, the depth of the distribution of fine roots could reach $h_{\max}$, infiltration water might reach h_t and the fine roots of plants could extract deep soil water from h_s. Therefore, there was a transition layer from h_s to h_t in the profile and the amount of soil water in this layer was higher than in the lower soil layers for overlapping infiltration water and deep soil water. Hence, fine roots of this transition layer were larger than those of the lower layer between h_t to $h_{\max}$.

4 Results and discussion

4.1 Vertical distribution of fine roots of *R. pseudoacacia* at different sites

The *FRDs* (surface area, length, and volume) distribution of *R. pseudoacacia* with depth on shaded and sunny slopes is presented in Figs. 4 and 5. It is clear that there are similar distributions of *FRD* with depth. High densities of fine roots are concentrated in the 0–20 cm surface soil layer and then decreased with increasing soil depth. Consistent results were observed in the vertical distribution of fine roots of *R. pseudoacacia* in Weibei at the Loess Plateau by Zhao et al. (2004).

Many studies on vertical distribution of fine roots show that it is common in forest stands for the majority of fine roots to be in the upper soil layers (Santantonio et al., 1977; Fabiao et al., 1991, 1995; Jama et al., 1998). John et al. (2001) reported that up to 77% of the total fine roots mass (pine 36% + herbaceous species 41%) was present in the top 20 cm soil layer. Bouillet et al. (2002) also showed about 16%–53% of the total fine roots in the 0–25 cm surface soil layer. In the present study, up to 22% of fine roots were in the top 20 cm soil profile of *R. pseudoacacia* stands. High densities of fine roots in the top soil layer could be related to the accumulation of organic matter and large amounts of available nutrients (Tiarks et al., 1998).

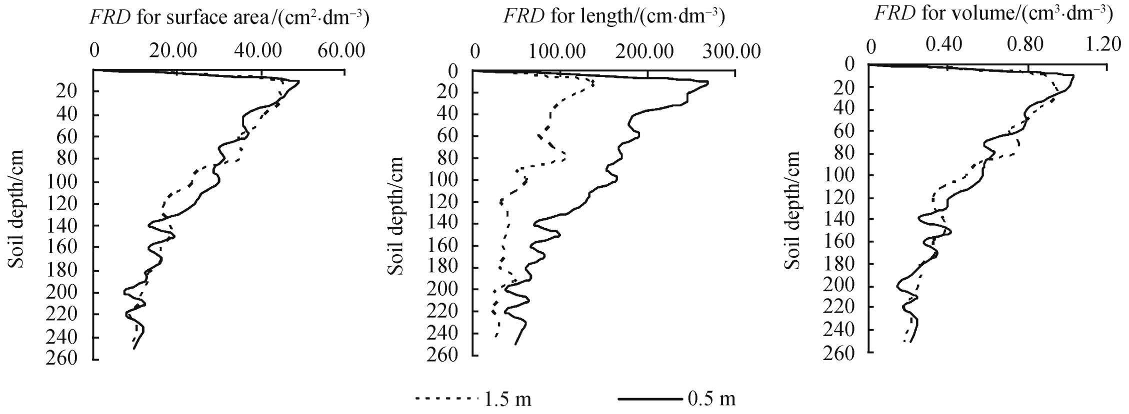

Fig. 4 Distribution of *FRD* for surface area, length and volume of *R. pseudoacacia* with increasing soil depth on shaded slopes

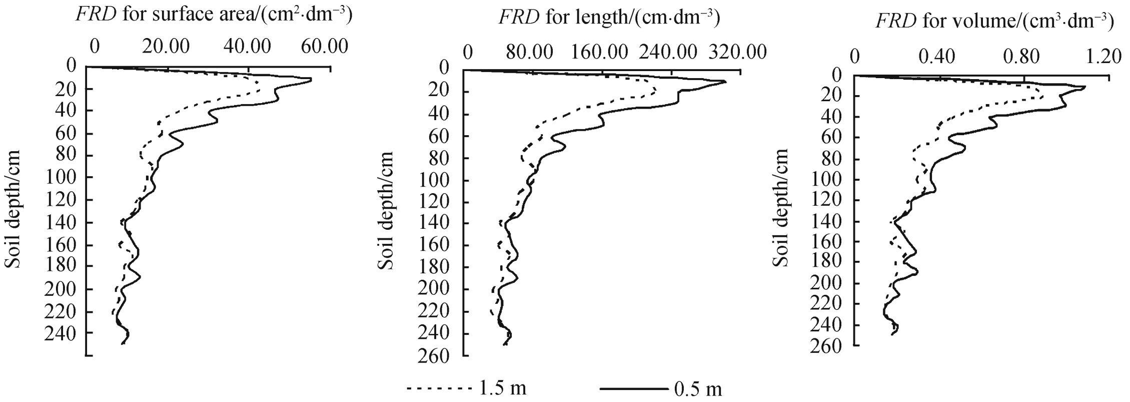

Fig. 5 Distribution of *FRD* for surface area, length and volume of *R. pseudoacacia* with increasing soil depth on sunny slopes

On shaded and sunny slopes (Figs. 4 and 5), *FRD* declined sharply from the soil surface to 1.5 m in the profile and then decreased slowly below 1.5 m. There were no significant differences ($p = 0.05$) of *FRD* for surface area and volume of *R. pseudoacacia* at distances of 0.5 m and 1.5 m from the base of the trunk on shaded slopes, the corresponding mean values of *FRD* were 22.54 cm^2/dm^3 and 21.88 cm^2/dm^3, 0.46 cm^2/dm^3, and 0.45 cm^2/dm^3, respectively. The fine root density (FRD) for length was significantly ($p = 0.05$) larger at the 0.5 m than at 1.5 m. The mean values of *FRD* were 118.96 cm^2/dm^3 and 54.06 cm^2/dm^3. This implied that there were relatively larger fine roots at 1.5 m distance from trunk than at 0.5 m. However, *FRD* for surface area, volume and length of *R. pseudoacacia* at a distance of 0.5 m showed significant differences ($p = 0.05$) with those values at a distance of 1.5 m on sunny slopes. In general, the *FRDs* at 0.5 m were larger than those at 1.5 m (the corresponding mean values of *FRD* were 18.18 cm^2/dm^3 and 14.38 cm^2/dm^3, 0.38 cm^2/dm^3 and 0.30 cm^2/dm^3, 92.32 cm^2/dm^3 and 72.27 cm^2/dm^3. It indicated that the number of fine roots was larger on shaded slopes than on sunny slopes. This was because soil water conditions on shaded slopes were better than on sunny slopes (Zhao et al., 2000). In addition, the values of *FRD* were, in general, high near the trunk (i.e. at 0.5 m distance). Fabiao et al. (1995), Pages et al. (2000) and Bouillet et al. (2002) have also shown that high *FRD* occurred under the stump. This could be related to stem flow carrying high concentrations of nutrients to supply the soil near the trunk (Laclau et al., 2000; Bouillet et al., 2002).

The fine root density (FRD) for surface area, length and volume varying with depth has similar distribution patterns both on the shaded and the sunny slopes (there are large differences in the lengths of fine roots on the shaded site). Many studies have found that the size of the surface area of fine roots was more pertinent to water and nutrient uptake than to other indices (e.g. length, biomass). Although biomass has become an important index to describe the distribution of fine roots, it may introduce bias when there is a small number of samples, a condition which often then cannot account for differences between treatments (Box, 1996). Wang et al. (1994) showed that the root surface area was a transfer interface for water and nutrient between roots and soil. Jackson (1997), He (2000) and Liu (2002) also reported that the surface area of roots was an important index to study the distribution of roots and water efficiency.

4.2 Relationship between distribution of fine roots and soil water

The models, adjusted to *FRD* (surface area) measurements for each site (0.5 m distance to the trunk), showed the change in vertical distribution of fine roots (Table 2 and Fig. 6). The values of the parameter *B*, vital in the determination of the maximum depth of the distribution of fine roots of *R. pseudoacacia*, were 0.15 and 0.16 for the shaded and sunny slopes, respectively. In general, the fitted *FRDs* with the model were acceptable, coefficients of determination for the regression of fitted *FRD* on observed values were high and root mean square errors (RMSE) were relatively low.

The depth of highest *FRD* h_p, the maximal depth of fine roots distribution h_{max} and the maximal depth of infiltration of precipitation in the soil h_q can be determined by the fitted equations (Table 3). In Table 3, the percentage of infiltration water supplied for fine root growth reached to 88.32% on shaded sloped and deep soil water only provided 11.68%; on sunny slope, the proportion were 85.21% and 14.79%, respectively. This indicated that infiltration of precipitation played a crucial role in the growth of *R. pseudoacacia* in the gully region of the Loess Plateau.

Table 2 Parameter estimates, coefficients of determination and RMSE of the model: $FRD = Ah^B(C+Dh+Eh^2+Fh^3)$ for two different sites

Site	R^2	RMSE	*A*	*B*	*C*	*D*	*E*	*F*
Shaded slope	0.951	3.59	0.000,022	0.15	1,718,341	−19,459.60	89.775,6	−0.147,736
Sunny slope	0.946	3.35	0.000,034	0.16	1,210,906	−17,350.80	90.029,0	−0.152,920

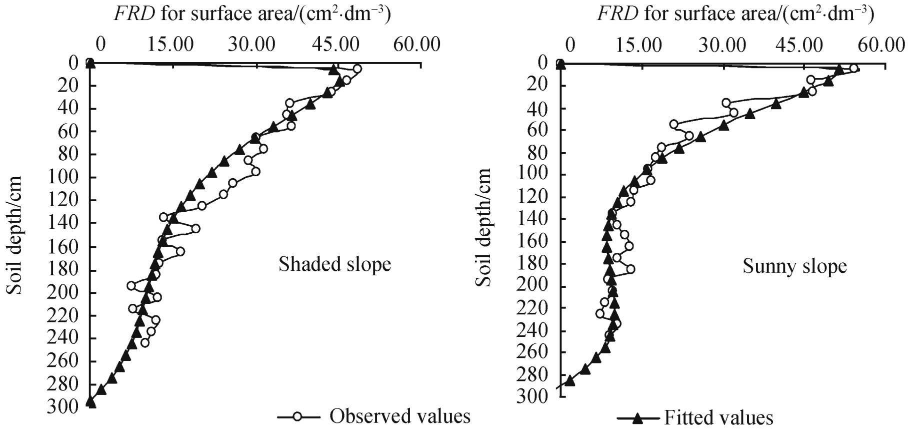

Fig. 6 Observed *FRD* of *R. pseudoacacia* and fitted values from the model: $FRD = Ah^B(C+Dh+Eh^2+Fh^3)$ for two different sites

Table 3 h_p, h_q, h_{max}, η_1 and η_2 calculated from the model: $FRD = Ah^B(C+Dh+Eh^2+Fh^3)$ for different sites

Site	h_p /cm	h_q /cm	h_{max} /cm	η_1 /(%)	η_2 /(%)
shaded slope	12.9	199.5	294.5	88.32	11.68
Sunny slope	10.7	196.3	295.3	85.21	14.79

A number of studies indicated that, in general, the depth of infiltration of precipitation did not extend over 2.0 m in depth in the soil profile without deep seepage on the Loess Plateau (Yang et al., 1988; Nie et al., 1989; Sun et al., 1999). Yang et al. (1994) showed that the first meter of the soil profile could, in a dry year, receive infiltration of precipitation, which could reach to 2.0 m in a wet year. The maximum infiltration depth of precipitation could reach a depth of 2.5 m in a specially wet year on the experimental site. Wang et al. (2002) reported that soil water in the profile of *R. pseudoacacia* woodland on the experimental site was classified into three layers: the first layer was the water exchange activity layer, from 0–0.2 m in depth; the second was the soil water bidirectional retrieve layer, located between 0.2–1.5 m in the profile; the third was the relatively stable soil water layer, below 1.5 m.

According to the vertical distribution of fine roots and earlier studies of soil water, the soil water in the profile on the shaded slope site could be newly classified into three layers: the top 0–12.9 cm of the soil layer as the soil water exchange activity layer, soil moisture changes frequently in this layer and is greatly affected by precipitation; the second is the soil water attenuation layer from 12.9–199.5 cm in depth, up to 75% of total fine roots are concentrated between 20–200 cm in the profile but decreases sharply with depth, the soil moisture declines correspondingly; the third layer, below 199.5 cm is the relatively stable soil water layer, where *FRD* is low and evenly distributed in the profile of the layer. The soil moisture level was also relatively stable. The sunny slope showed similar conditions. It may be profitable to study the efficiency of water by *FRD* distribution of *R. pseudoacacia* on the Loess Plateau.

In this study, the maximum depth of the distribution of fine roots of *R. pseudoacacia* was almost 3.0 m, with most of the fine roots in the 0–2.5 m soil layer. The mean *FRD* values were below 2.0 m. The scarce fine roots played a crucial role in water uptake during the dry season, when the soil moisture of the upper layers was close to the wilting point of plants (Laclau et al., 2001). When the deep soil moisture is depleted, the soil can dry out completely, for ground water generally occurs at a depth of 50–60 m on the Loess Plateau and cannot be extracted by plants. Wang et al. (2000, 2001), Yang et al. (2001), and Mu et al. (2003) reported that deep (below 3.0 m) soil moisture was depleted by *R. pseudoacacia* plantations. According to the present study, deep soil moisture cannot be extracted by fine roots and a low moisture content can result during loess sedimentation. Liu et al. (1985) reported that “the environment becomes more and more drought stricken during the evolution of loess”. The reason is that the soil moisture content of loess declines and promotes environmental aridity besides the effect of geological conditions and water erosion. Under these conditions, moisture content further declines during the development of loess, so that the low moisture content of deep soil (below 3.0 m) cannot even be depleted by plants.

5 Conclusions

The investigation into the deep distribution of fine roots of *R. pseudoacacia* found that high densities of fine roots were confined to the top 0–20 cm of soil. High values of *FRD* were generally observed near the trunk. Mean values of *FRD* were larger on shaded slopes than on sunny slopes. One of our findings, not consistent with earlier studies, is that low moisture content of deep soils (below 3.0 m) is depleted by plants, a condition that may develop during the evolution of loess.

A statistical model was developed for the vertical distribution of fine roots of *R. pseudoacacia* on the Loess Plateau, $FRD = Ah^B(C+Dh+Eh^2+Fh^3)$, which explains the role of infiltration and deep soil water in the growth of fine roots. The depth of the highest *FRD* h_p, the maximum depth of *FRD* h_{max} and the depth h_q supplied by infiltration were determined by the model. h_q was taken as the boundary between infiltration and deep soil water. The parameter *B* was vital in the determination of the highest *FRD*. The soil water in the profile could be classified into three layers by the model: the soil water exchange activity layer from the soil surface to a depth of 12.9 cm, the soil water attenuation layer between 12.9 cm and 199.5 cm and the relatively stable soil water layer, below 199.5 cm on shaded slopes. Similarly, the layers from 0–10.7 cm, 10.7–196.3 cm and below 196.3 cm in the profile represented the three layers on the sunny slope. This study has indicated that the vertical distribution of fine roots was very relevant in relation to the soil water in the profile on our experimental site. Infiltration played a crucial role in the growth of *R. pseudoacacia* in the gully region of the Loess Plateau.

Further research is needed to confirm and extend these results. In particular, modeling of the interaction between the dynamics of fine roots of different trees and soil water is an important direction in this field.

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