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Effect of Litter Decomposition on Soil Polarization in Three Typical Planted Pure Coniferous Forests in Loess Plateau, China

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Abstract

Soil polarization is a new concept which describes the deviation of soil properties of planted pure forest from its original equilibrium status toward an extreme condition due to long-term growth or continuous planting of single tree species. It is thought to be one fundamental obstacle of the development of forest. In order to investigate the effect of litter decomposition on soil polarization of planted forests in the hilly area of Loess Plateau, China, humus soil and litter (leaf litter and fine roots) were sampled in three typical coniferous forests, and 4 treatments as "soil +leaf litter", "soil + roots", "soil+ leaf litter + roots", and CK were set for laboratory incubation experiment in this research. The results showed that polarizations of different properties were variable, in both direction and degree, after the incubation with litters. Based on analyzing the polarization ratios by PCA (principal component analysis) method, the results of comprehensive soil properties is showed as follows: both of leaf litter and roots resulted in negative polarization in the *Platycladus orientalis* and *Larix principis-rupprechtii* forest soil, conversely, as for the *Pinus tabulaeformis* forest soil, both of leaf litter and roots resulted in positive polarization. When leaf litter and roots mixed-together with the soil, the interaction sequence is *P. tabulaeformis* (2.329)＞*P. orientalis*(-0.916)＞*L. principis-rupprechtii* (-1.413). In general, *P. tabulaeformis* litter is more beneficial for soil properties than the other two plants after incubation.

Keywords: Litter decomposition; Soil polarization; Planted pure coniferous forests

Introduction

The Loess Plateau, China has long been suffering from serious soil erosion. In order to withstand further deterioration of ecosystem, the Chinese government has established various re-vegetation projects aiming to restore the vegetation and reduce soil erosion (Du *et al*., 2007; McVicar *et al*., 2007). Under the umbrella of these projects, a lot of planted pure coniferous forests were planted in the hilly region of the Loess Plateau. In addition, there are some studies have suggested that the planted forest has been a key content of water and soil conservation for ecological environment managements in the local place (Zheng, 2006; Jiao *et al*., 2007). However, recently some studies have shown that, there were some problems occurred in the planted pure forests along with trees continuously planting for long term, such as soil fertility declines, tree growth slows, and natural regeneration ceases (Liu *et al*., 1998; Zhang *et al*., 2006; Li *et al*., 2008). If the problems become more seriously, the ability of planted pure forests for water and soil conservation will be decreased, and the ecosystem will be destroyed again. In order to deeply analyze the reason of soil degradation of the planted pure forest, a new concept of soil polarization (Liu *et al*., 2007b) was presented. Each tree species has unique biological and ecological characteristics, and the presence of single tree species in planted pure forest will result in selective nutrient absorption and special environmental effects (Liu *et al*., 1998; Liu and Qiang, 2002), which will cause the soil to deviate from its original equilibrium status and gradually develop toward an unbalanced or extreme status. For example, some nutrients content may increase in the soil while others may decrease; some soils become more acidic while others become more alkaline; some biological properties are improved, while others may be worsened. These changes explain the effect called "soil polarization". This is thought to be the fundamental obstacle to continuous growing of planted pure forest. Based on this principle, models were established to evaluate the soil properties of planted pure forests in the hilly area of the Loess Plateau and the results showed that there were tendency of polarization in the local forests soil (Liu *et al*., 2009).

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However, the exactly reason of soil polarization is unknown by now. We just generally understand that soil polarization is a complicated ecological process which may be simultaneously affected by many variables, such as litter decomposition, roots selective nutrient absorption, excretion and so on. In the forest ecosystem plant litter decomposition plays a critical role in the processes of nutrient cycling and organic matter turnover within ecosystem (Sundarapandian and Swamy, 1999; Li *et al*., 2009), and these processes are important determinants of soil properties. Therefore a better understanding of the relationship between litter decomposition and soil properties is helpful to analyze the principle of the soil polarization.

The objectives of this study were (1) to investigate the effect of litter decomposition on soil polarization of three typical planted pure coniferous forests in hilly region of Loess Plateau by lab incubation experiments; (2) to get the sequence of soil polarization of three forests soil after litter decomposition, valuable scientific information was provided to prevent soil degradation and continuous plantation obstacle.

Materials and Methods

Study Area

The study sites are located in Huangling County in Shaanxi Province, China. This area belongs to a typical hilly region of Loess Plateau. It has warm temperate and semi-humid climate with an average annual temperature 9.4℃. The average annual precipitation is 630.9 mm, average frost-free period is approximately 150 days, and the relative humidity is 64%. The soil belongs to a typical grey cinnamon soil. Three typical planted pure coniferous forests as *Platycladus orientalis*, *Larix principis-rupprechtii* and *Pinus tabulaeformis* were selected for this study.

Sampling

In the typical sites of the three forests, set up standard plots (Table 1) of 20 m×20 m and measured the site factors and tree growth indexes. In the standard plots randomly selected 5 quadrats of 1 m×1 m, collected the humus layer soil at 0-10 cm depth in each quadrat after cleared the litters above the ground, then bulked to one composite sample per stand and took to laboratory. Leaves, roots, and gravel were removed from soil samples by using 5 mm mesh sieves. Then samples were stored in sealed bags at room temperature until incubation.

Newly shed leaf litter was collected from the forest floor and dead fine roots (φ＜0.5 cm) were dug up from the upper 50 cm of soil in the aforementioned forest sites. Thereafter, all litter samples were taken back to the laboratory, gently washed and oven-dried at 65℃ for 24 h to achieve constant weight. Then the dry litters samples were ground by using laboratory mill (φ=1 mm) for incubation.

Laboratory Incubation

Four treatments including soil + leaf litter (S+L), soil + roots (S+R), soil+ leaf litter + roots (S+L+R, leaf litter and roots with ratio 1：1) and control soil (CK) were set for laboratory incubation experiment. Litter and soil were thoroughly mixed with the ratio 2：100 to final weight 2.5 kg. Placed mixed samples in the glass jar (Φ=18 cm, H=16 cm) and each jar was equipped with a lid with 4 holes (1 cm diameter) to permit free gas exchange. During the incubation, soil moisture content was monitored and maintained at 50％of their water holding capacity by adding distilled water weekly. All the external conditions were kept consistent among the samples. The mixed soil samples were incubated at room temperature（20～25℃）for 120 days until the litter decomposed completely. All samples have been done on triple.

Soil Properties Measurements

Fresh soil was picked up to test microbe quantities. The left soil samples were air-dried, then grounded in a laboratory mill (Φ=1 mm) for biological and chemical properties measurements.

Among soil biological properties, microbe quantities were measured by dilution-plate method (Nanjing Institute of Soil Science, 1985) (bacteria-beef extract peptone agar culture medium, fungi-potato dextrose agar culture medium, actinomyces-GAO 1^{th} synthetic culture medium). Enzymes were measured by the methods as followed (Guan, 1986). Sucrase activity was measured by $Na_2S_2O_3$ titration method, protease activity was measured by ninhydrin colorimetry method, polyphenoloxidase activity was measured by iodine titrimetry method, phosphatase activity was measured by disodium phenyl phosphate colorimetric method (in pH 8.5 borate buffer), urease activity was measured by sodium phenate-sodium hypochlorite colorimetric method, catalase activity was measured by $KMnO_4$ titrimetry method, and dehydrogenase activity was measured by triphenyl tetrazolium chloride colorimetric method.

Soil chemical properties were measured by followed methods (Lu, 1999). Soil pH was measured by glass electrode method (the ratio of soil to water was 1:2.5), organic matter was measured by oil bath-K_2CrO_7 titration method, CEC was measured with NaOAc-NH4OAc and blaze photometer method, available nitrogen was measured by micro-diffusion technique after alkaline hydrolysis, available phosphorus was measured by bicarbonate extraction method, and available potassium was measured by NH_4OAc and blaze photometer method.

Data Analysis

All data reported were mean values of three replications. Statistical procedures were carried out using the software packages SPSS version 17.0 for windows. One-way

ANOVA and least significant difference (LSD) test were used for determining whether differed significantly (P<0.05) among the treatments.

We fixed the properties of control soil as the equilibrium status. The effect of litter decomposition on soil polarization was analyzed by comparing the variation of soil properties between soils mixed with litter and control soil after incubation. However, the variations were various after incubated with litter, so it is difficult to explain the comprehensive effect of the litter decomposition on soil polarization by analyzing one single soil property index. Hence, principal component analysis (PCA) was used in this study (Lin and Zhang, 2005). Based on principal component model, the sum principal components were calculated. Then we analyzed the comprehensive effect of the litter decomposition on soil polarization by them.

Among the selected soil properties, most of them are more beneficial to the tree growth when the values are higher except pH value. Therefore, the increase ratios (%) of soil properties except pH are chosen for extracting principal components, which characteristic values are above 1. The sum principal component is determined with the equation as follows:

$$F=\lambda_1/(\lambda_1+\lambda_2+\ldots+\lambda_n)\times F_1+\lambda_2/(\lambda_1+\lambda_2+\ldots+\lambda_n)\times F_2+\ldots+\lambda_n/(\lambda_1+\lambda_2+\ldots+\lambda_n)\times F_n$$

Where F_i is principal component which characteristic value are above 1, λ_i is the characteristic value. If F>0, indicates that litter decomposition results in positive polarization on soil properties, if F<0 results negative polarization.

The interaction between leaf litter and roots is estimated by the principle as followed. Presumed there is no interaction between leaf litter and roots on soil properties during incubation, and soil properties values can be expressed as the formula:

$$T_{LR}= a\,P_L + b\,P_R$$

Where T_{LR} is the theoretical values of soil properties after the leaf litter and roots mixed incubation; P_L and P_R represent practical values after leaf litter and roots separated incubation; a, b express the percents of leaf litter and roots in the mixed sample (the values of a, b are 50%). If theoretical value (T_{LR}) and the practical value (P_{LR}) are not equal, this indicates that there is interaction between leaf litter and roots. If $P_{LR}>T_{LR}$, this indicates interaction is positive and if $P_{LR}<T_{LR}$ indicates interaction is negative.

Results

Effect of Leaf Litter and Roots Separated-decomposition on Soil Polarization

The properties of soil samples (S+L, S+R, CK), which have incubated for 120 days were shown in Table 2. In the *P. orientalis* forest soil, with exceptions of catalase activity, pH and available K in mixed-leaf litter treatment and available N in mixed-roots treatment, other properties were significantly affected by litter addition in contrast to control soil. In the mixed-leaf litter treatment, the polarizations of soil properties were as follows. The activities of 4 enzymes (protease, phosphatase, urease, dehydrogenase) were higher than those in the CK at 7.18%～93.47%. Fungi quantity was more than 5 times compared it in the CK. Actinomycetes quantity was 68.70% higher than CK. Organic matter, available N and CEC were significantly, but no more than 20%, higher than CK. However, activities of sucrase were significantly, but slightly, lower than CK, and showed negative polarization. Polyphenoloxidase, available P and bacteria quantity also decreased significantly by leaf litter addition. As for the mixed-roots treatment, soil properties as protease, polyphenoloxidase were higher than CK at no more than 10%. The activities of 3 enzymes (phosphatase, urease, dehydrogenase) were higher than those in the CK at 28.57%～72.10%. Fungi quantity was almost 2 times as it in CK. Soil showed slightly acidic after the incubation with roots. And organic matter, available P, available K, CEC were significantly greater than that in control soil at some extent. Conversely, sucrase and catalase activities were lower than those in CK at 8.35% and 29.66% respectively. Bacteria and actinomycetes quantity were also lower at 60.63% and 22.14% in contrast to control.

In the *L. principis-rupprechtii* forest soil, with exceptions of sucrase and urease activities in mixed-leaf litter soil and available N in mixed-roots soil, other properties were significantly affected by litter addition in contrast to control soil. Soil showed slightly alkaline after the incubation with litters. The activities of 4 enzymes (protease, phosphatase, catalase, dehydrogenase) were higher than those in the CK by litter addition. Fungi and actinomycetes quantity were much higher in both mixed-leaf litter and mixed-roots treatment than those in CK. Organic matter, available N, available P and CEC were higher than those in the CK at 4.88%～31.90% by leaf litter addition. However, polyphenoloxidase activity, bacteria quantity and available K were significantly lower at 13.23%, 25.44% and 27.36%, respectively in mixed-leaf litter treatment than CK. As for the mixed-roots treatment, soil properties as polyphenoloxidase, urease, CEC, and available K were significantly higher than that in control soil; however organic matter, available P, bacteria quantity were lower at 4.09%, 27.04%, and 10.53% respectively in contrast to control treatment.

In the *P. tabulaeformis* forest soil, with exception of available K in mixed-leaf litter treatment, other properties were significantly affected by litter addition in contrast to control soil. Soil showed slightly alkaline after the incubation with litters. The activities of 5 enzymes as sucrase, protease, phosphatase, urease, dehydrogenase and pH, organic matter, available N,

Table 1: Standard plots of planted pure coniferous forests

Forest type	Age (a)	Elevation (m)	Aspect	Slope (º)	BHD (cm)	Height (m)	Density (individul·hm^{-2})
P. orientali	32	1020	SE45°	32°	12.31	7.4	1500
L. principis-rupprechtii	29	1100	NE50°	25°	21.92	17.2	1590
P. tabulaeformis	29	1100	NE80°	30°	16.93	12.2	1350

Table 2: The variation of soil properties after separated-decomposition with litter and roots

Soil properties	*P. orientalis*			*L. principis-rupprechtii*			*P. tabulaeformis*		
	S+L	S+R	CK	S+L	S+R	CK	S+L	S+R	CK
Biological properties									
Sucrase（ml • g^{-1} • d^{-1}）	1.288a	1.207b	1.317c	1.312a	1.330b	1.320a	1.300a	1.169b	1.069c
Protease（ug • g^{-1} • d^{-1}）	1.419a	1.364b	1.324c	1.276a	1.284a	1.117b	1.398a	1.209b	0.946c
Polyphenoloxidase（mL • g^{-1}）	0.363a	0.470b	0.438c	0.282a	0.345b	0.325c	0.162a	0.357b	0.226c
Phosphatase（mg • kg^{-1}）	2.224a	2.487b	1.666c	1.021a	0.847b	0.539c	1.373a	0.628b	0.518c
Urease（mg • g^{-1} • d^{-1}）	0.026a	0.018b	0.014c	0.021a	0.035b	0.020a	0.045a	0.047b	0.030c
Catalase（ml • g^{-1}）	2.085 a	1.435b	2.040a	1.175a	1.900b	0.925c	1.195a	1.905b	1.795c
Dehydrogenase（ml • g^{-1} • d^{-1}）	1.186a	1.055b	0.613c	0.675a	0.656a	0.436b	0.679a	0.573b	0.274c
Bacteria (10^{5} • g^{-1})	5.40a	3.15b	8.00c	4.25a	5.10b	5.70c	29.00a	21.50b	14.50c
Fungi (10^{2} • g^{-1})	28.00a	13.00b	4.50c	1.20a	1.25b	0.30c	1.00a	0.25b	0.15c
Actinomycetes (• 10^{5} • g^{-1})	11.05a	5.10b	6.55c	7.50a	7.00b	0.35c	0.82a	0.51b	0.14c
Chemical properties									
pH	7.82a	7.72b	7.89a	7.89a	8.03b	7.73c	8.46a	8.38b	8.27c
Org-M（g • kg^{-1}）	98.48a	95.56b	85.17c	40.75a	36.84b	38.41c	41.31a	40.61b	30.80c
CEC (cmol • kg^{-1})	19.12a	18.89a	17.81b	11.09a	11.65b	10.14c	11.27a	11.27a	9.90b
Available N (mg • kg^{-1})	136.50a	124.95b	122.50b	75.25a	71.40b	71.75b	74.55a	67.20b	64.75c
Available P (mg • kg^{-1})	8.12a	9.15b	8.48c	14.68a	8.12b	11.13c	6.05a	4.69b	3.91c
Available K (mg • kg^{-1})	213.2a	277.2b	209.8a	178.7a	277.2b	246.0c	172.6a	178.7b	171.1a
Sum of principal components	-0.776	-1.411		-0.487	-0.106		2.086	0.694	

Values sharing the same letters differ non-significantly (P＞0.05)

Table 3: Comparisons between practical (P_{LR}) and theoretical (T_{LR}) values of soil properties after mix-incubated forest soil with leaf litter and roots

Soil properties	*P. orientalis*			*L. principis-rupprechtii*			*P. tabulaeformis*		
	P_{LR}	T_{LR}	Δ %	P_{LR}	T_{LR}	Δ %	P_{LR}	T_{LR}	Δ %
Biological									
Sucrase（ml • g^{-1} • d^{-1}）	1.322	1.248	5.97	1.322	1.321	0.08	1.332	1.235	7.90
Protease（ug • g^{-1} • d^{-1}）	1.401	1.392	0.63	1.232	1.280	-3.77	1.268	1.304	-2.73
Polyphenoloxidase（mL • g^{-1}）	0.450	0.416	7.99	0.363	0.313	15.67	0.305	0.259	17.41
Phosphatase（mg • kg^{-1}）	2.434	2.355	3.35	0.920	0.934	-1.47	0.902	1.000	-9.83
Urease（mg • g^{-1} • d^{-1}）	0.023	0.022	4.91	0.017	0.028	-38.17	0.032	0.046	-30.05
Catalase（ml • g^{-1}）	1.475	1.760	-16.19	1.135	1.538	-26.18	1.860	1.550	20.00
Dehydrogenase（ml • g^{-1} • d^{-1}）	1.107	1.120	-1.15	0.649	0.665	-2.44	0.604	0.626	-3.45
Microbe quantity									
Bacteria (10^{5} • g^{-1})	3.55	4.275	-16.95	3.25	4.675	-30.48	39.5	25.25	56.43
Fungi (10^{2} • g^{-1})	11.00	20.50	-46.34	0.90	1.23	-26.53	1.25	0.63	100.00
Actinomycetes (10^{6} • g^{-1})	8.10	8.07	0.31	4.20	7.25	-42.06	0.84	0.66	27.27
Chemistry									
pH	7.91	7.77	1.80	7.95	7.96	-0.13	8.42	8.42	0.00
Org-M（g • kg^{-1}）	95.01	97.02	-2.07	43.16	38.79	11.28	43.94	40.96	7.28
CEC (cmol • kg^{-1})	19.11	19.00	0.58	10.87	11.36	-4.34	10.56	11.27	-6.25
Available N (mg • kg^{-1})	129.85	130.72	-0.67	69.30	73.32	-5.49	74.55	70.87	5.19
Available P (mg • kg^{-1})	9.35	8.63	8.30	9.61	13.65	-29.59	3.51	5.37	-34.53
Available K (mg • kg^{-1})	235.8	245.2	-3.81	178.1	196.8	-9.48	173.7	175.7	-1.08
Sum of principal components			-0.916			-1.413			2.329

available P, CEC, bacteria, fungi, actinomycetes significantly higher after mixed decomposition with leaf litter than in CK; however activities of polyphenoloxidase and catalase significantly lower at 28.32%, 33.43% by leaf litter addition. Moreover, all soil properties significantly higher than those in CK after mixed decomposition with roots.

We used principle component analysis to estimate the comprehensive effect of litter decomposition on soil polarizations. We thereby derived the principle component function:

$$F=0.431F_1+0.239F_2+0.196F_3+0.134F_4 \quad (1)$$

Where F_1、F_2、F_3、F_4 indicated the first, second, third, and forth principal component which characteristic value was above 1.

Based on the sum of principal component values (F) which reflect the total effect of litter decomposition on soil properties polarization, the species can be ordered as follows: *P. tabulaeformis* leaf litter（2.086）＞*P. tabulaeformis* roots（0.694）＞*L. principis-rupprechtii* roots（-0.106）＞*L. principis-rupprechtii* leaf litter（-0.487）＞*P. orientalis* leaf litter（-0.776）＞*P. orientalis* roots（-1.411）. This result showed that according to the comprehensive soil properties, in the *P. orientalis* forest soil, both of leaf litter and roots resulted in negative polarization, and roots showed greater effect than leaf litter; in the *L. principis-rupprechtii* forest soil both of leaf litter and roots resulted in negative polarization, and leaf litter showed greater effect than roots. In the *P. tabulaeformis* forest soil both of leaf litter and roots resulted in positive polarization, and leaf litter showed greater effect than roots.

Interaction between Leaf Litter and Roots in Affecting on Soil Properties

Leaf litter and roots cannot exist separately in the forest ecosystem, when they mixed with soil, does the effect equal to the separate effects, which add together, or new promoted or inhibitory effect will appear? The comparisons between practical (P_{LR}) and theoretical (T_{LR}) values of soil properties after mix-incubated forest soil with leaf litter and roots are shown in Table 3. In the *P. orientalis* forest soil, the mixed decomposition of leaf litter and roots showed promoting effect on soil sucrase, protease, polyphenoloxidase, urease, phosphatase, actinomycetes, CEC and available P, however showed inhibitory effect on soil catalase, dehydrogenase, bacteria, fungi, organic matter, available N and available K. In *L. principis-rupprechtii* forest soil, mixed decomposition of leaf litter and roots showed promoting effect on soil sucrase, polyphenoloxidase and organic matter, however showed inhibitory effect on soil protease, phosphatase, urease, catalase, dehydrogenase, bacteria, fungi, actinomycetes, CEC, available N, available P and K. In the *P. tabulaeformis* forest soil, mixed decomposition of leaf litter and roots showed promoting effect on soil sucrase, polyphenoloxidase, catalase, fungi, bacteria, actinomycetes, organic matter and available N, however showed inhibitory effect on soil protease, urease, phosphatase, dehydrogenase, CEC, available P and available K.

In order to explain the comprehensive interaction between leaf litter and roots in affecting on soil properties, the increment ratios (Δ%) of practical (P_{LR}) values in contrast to theoretical (T_{LR}) values were used for principal component analysis. The principal component model was expressed as follows:

$$F=0.592F_1+0.407F_2 \quad (2)$$

F_1、F_2 indicated the first and second principal components, which the characteristic value was above 1.
Based on the sum of principal component values (F), the species can be ordered as follows: *P. tabulaeformis* (2.329) ＞*P. orientalis* (-0.916)＞*L. principis-rupprechtii* (-1.413). The result indicated that leaf litter and roots when mix-incubated with forest soil showed promoting effect on soil properties in the *P. tabulaeformis* forest soil, and showed inhibitory effect on soil properties in *P. orientalis* and *L. principis-rupprechtii* forest soil.

Discussion

To maximize commercial value, man-made coniferous forests were established on a large scale in the hilly area of the Loess Plateau, as pure stands consisting of a single dominating species. This silvicultural practice may result in soil degradation with concomitant decline in tree growth, particularly after two or more rotations under continuous cropping. Therefore, soil degradation in pure plantations under continuous cropping has become cause of increasing concern in recent years in China. Despite our current understanding of some phenomena relating to soil degradation, little is known about the mechanism by which soil degradation occurs and tree growth is reduced under continuous cropping. In order to deeply analyze the reason of soil degradation of the planted pure forest, we proposed a new concept called "soil polarization" which means non-equilibrium or polarizing tendency of soil development in pure forests due to its single tree species. The negative polarization of soil is thought to be one fundamental obstacle to the forest development. And in this research we investigated the relationship between litter decomposition and soil properties polarization.

Our research results clearly indicated that most of the soil properties deviated from its original status of equilibrium (CK) due to the effect of litter decomposition. The result showed that soil microbial community were marked shifted in *P. orientalis* and *L. principis-rupprechtii* forest soil after incubation with litter. Bacteria quantities were lower than CK, but fungi quantities were higher. Some researchers reported that the structure of the soil microbial community involved in the decomposition of organic matter in forest ecosystems and is influenced by the quality of litter species composition (Bååth *et al*., 1995; Pennanen, 2001; Reith *et al*., 2002). The changes in structure and composition of the decomposer community will inevitably affect the balance of soil properties during decomposition (Schulze, 2000). And some researchers have demonstrated that the change in structure and composition of the microbial community was one of the primary causes of the soil quality decline in the continuous cropping farmland (Gao and Zhang, 1998; Xing *et al*., 2011). These researches were consistent with our results, which the negative polarization of *P. orientalis* and *L. principis-rupprechtii* forest soil comprehensive properties was accompanied by unbalanced shifts in the composition of the soil microbial community. All the microbes in the *P. tabulaeformis* forest tended to positive polarization by litter decomposition. This maybe the litter of *P. tabulaeformi* provided the necessary nutrients and more adapted microenvironment for all microbes in the process of decomposition, and they made the microbial quantity, activity improved.

Soil enzymes can directly express the state of soil community metabolism and available nutrients, so soil enzymes are identified as the most important parameters in evaluating soil quality. Some enzymes activities tended to positive polarization after incubation with litters. Maybe litters had released various enzymes or metabolite into the soil to enhance the enzymes activity (Guan, 1986). At the same time different litter type released different metabolite, which maybe had inhibited effect on some enzymes activities.

Different polarizations of soil chemical properties may be caused by two reasons. First, some litter released sufficient chemical directly into soil to increase the nutrient， but some not released enough, what's more, it depleted some nutrient during the decomposition process; second, the microbes and enzymes activities the chemical properties indirectly (Arunachalam *et al*., 1998; Alhamd *et al*., 2004; Lemma *et al*., 2007).

The community structure in the planted pure forest is very simple. And this results in that the litter is also not various. As a long term consequence the single litter decomposition may release the special chemical material to the soil, which may alter the original balance of the soil properties. This problem will be exacerbated in the second rotation under continuous planting. Some soil properties will develop to the positive direction and others negative direction. The negative polarization will cause the continuous planting obstacle, resulted in soil degradation and decline in tree growth (Liu *et al*., 2007b). Nèble *et al.* (2007) reported that soil microbes and enzymes activity showed decline trend as the effect of litter decomposition in the planted pure forest. The study of Liu Shirong showed that decrease in soil nutrients and decline in tree growth occurred in pure larch plantation after the continuous planting (Liu *et al*., 1998).

The conditions of lab incubation experiment are very difficult to consistent with the outdoor forest environment. However, this research controlled all soil samples in the same incubation condition and accelerated the litter decomposition rate. Even if the results can not reflect the true outdoor condition, but still have valuable scientific basis for prevention of soil degradation and continuous plantation obstacle. The result indicated that, from the view of sustainable development of the local forests, *P. tabulaeformis* was suitable for successive planting in this area during a certain time, and *P. orientalis* and *L. principis-rupprechtii* were not suitable. A low-cost and effective way to prevent soil polarization in pure forest is to develop mixed stand in future afforestation. Plant rotation with different tree species should be adopted instead of continuous pure *P. orientalis* and *L. principis-rupprechtii* planting in order to maintain long term stability of soil fertility and forest productivity of plantations.

As the previous studies showed, not only the chemical components of leaf litter and roots are different (Lemma *et al*., 2007), but also the way to release chemical material to soil is not the same (Zhang *et al*., 2009). Leaf litter and roots play different roles in the forest ecosystem, some research showed leaf litter and roots decomposition had significant interaction in soil respiration, organic carbon, and microbial activity (Li *et al*., 2004; Liu *et al*., 2007a). This research showed that leaf litter and roots have interaction when mixed with soil. It proved that although leaf litter and roots are homologous litter of the tree, when they mixed with soil, the effects does not equal to the separate effects, which add together. Incongruities in litter scale between above ground and below ground have impeded our understanding. It is very difficult to calculate the ratio of the upper and underground litter, so this research just studied the interaction when they have the same quantities. After measured the exactly ratio of leaf litter and roots, to research the interaction between them on soil properties is the key point of the future research.

In conclusion, the polarizations of soil chemical and biological properties were variable, in both direction and degree, after incubation with litters. The results showed that litter decomposition was inevitable reason which caused soil polarization. And some negative polarizations will caused soil quality declaim if continuous cropping more rotations. As for the comprehensive soil properties, both of leaf litter and roots resulted in negative polarization in the *P. orientalis* and *L. principis-rupprechtii* forest soil. In addition, leaf litter and roots appeared inhibitory effect on soil properties after mixed decomposition. However, in the *P. tabulaeformis* woodland soil, both of leaf litter and roots resulted in positive polarization; moreover, the mixed decomposition of leaf litter and roots appeared promoting effect on soil properties. In general, *P. tabulaeformis* litter decomposition is more beneficial for soil properties than the other two plants after incubation.

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