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Study of Soil Microbiological Character at Different Altitudes in the Region of Dry and Hot River Valley

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ABSTRACT

In this paper, soils at various altitudes in the lower reaches of the Jinshajiang River, Ningnan County, Sichuan Province, China, were selected to study the variation in characteristics of soil enzymes and soil microbial biomass and their activities at different altitudes. By laboratory testing, statistical analysis and correlation analysis, results indicated that in the dry-hot river valley region, the altitude has a significant impact on the soil microbial characteristics, including soil enzyme activities, microbial biomass, soil basal respiration intensity and substrate-induced respiration intensity (SIR). The major indicators of soil enzymes and microbial biomass exhibit an evident linear increasing trend with the rise in altitude. Soil enzymes and microbial biomass and their activities increase gradually with the reduction in dry-hot wind impact at altitudes ranging from 705-1005 m; thereafter, these indicators tend to be stable as a whole, as the altitude continues to rise and the impact of the dry-hot wind lessens. Under wet-dry cycling conditions, the main soil microbial characteristics, including soil enzyme activities, microbial biomass, soil basal respiration intensity and SIR, display an evident dry-wet seasonal change following a similar law of change; that is, the soil enzymes and microbial biomass and their activities in the dry season are significantly lower than are those in the wet season. The metabolic quotient (qCO_2) in the dry season initially falls, then rises and, finally tends to be stable with the rise in altitude, whereas, in the wet season, there is no significant change in qCO_2 with altitude. Further analysis shows that soil enzyme indicators, enzyme activities, soil microbial biomass and its activities in both dry and wet seasons have relatively strong correlations with soil physical and chemical properties, and, thus, can act as the indicators for soil fertility assessment. Therefore, the dry-hot wind is one of the major factors that impact soil enzymes and microbial biomass and their activities in the dry-hot river valley region along the Jinshajiang River. Technical measures should be taken, so far as is possible, during the ecological restoration to reduce the stress effects of the dry-hot wind on soil and vegetation and, thus, to promote sustainable development of regional ecological construction.

INTRODUCTION

Soil is one of the important components of terrestrial ecosystem. It is the core area of material circulating, energy exchanging and information transferring. Soil can affect the environmental change by interacting with water, air and vegetation. Soil can also reflect the change of biogeochemical circulation caused by human activities. Soil microbes and soil enzymes in soil ecological system are involved in most of ecological processes, such as nutrient circulation and organic decomposition etc. They are the motivation of material transferring and nutrient circulation in soil. The majority of soil microbial biomass comes from soil microbes' activities, vegetation root secretions and decomposition of animal bodies (Guan 1986). It is an important parameter of material and energy flowing in soil ecological system. Soil enzymes are the key force of soil ecological system's metabolism. Both, soil microbial biomass and soil enzymes can actively reflect the process of environmental factors, land management and ecological functions. They are usually used to assess soil quality (Powlson et al. 1987, Anderson et al. 1993, Rogers et al. 2001) to reflect the change of microflora's status and function. They are sensitive indicators of the soil ecological system's change as well (Zhou et al. 1987, Institute of Soil Science 1985). Different altitudes have different environments. It affects the redistribution of light, energy, humidity and air. Altitude acts directly on the character of environmental climate ecology. It changes the physical, chemical and biological character of soil by changing the climate, as well as vegetation community's structure and types' evolvement (Huang et al. 2001, Begon et al. 2000), leading to the change of ecological function (Huang et al. 2001). In recent years, scholars have intensively studied the vegetation and soil property at different altitudes (Zhuang et al. 2008, Zhou et al. 2009, He et al. 2004). But those studies had been investigated in various areas, so that the results differ from each other greatly. And there are very few studies that focus on the investigation of soil microbial biomass and soil enzymes in the area of dry and hot river valley.

The dry and hot river valley in Jinsha Jiang River is a unique geology and climate formed in the section of the Hengduan Mountain region's deep valley in southwest China. It is a sub type of arid valley. In this region, the weather is dry. The hydrothermal condition does not have balance. Furthermore, human activities like discovering mineral resources, agricultural over-cultivating etc., result in apparent decline of ecological functions in this region (Yang et al. 2001, Cui et al. 1999, Bai et al. 2006). Therefore, this study mainly investigates the grass lain at different altitudes in dry and hot river valley at Jinsha Jiang River, and discusses the altitude influence on soil microbial biomass and soil enzyme activity under the alternation of dry and wet. With the result obtained from this study, the biological mechanism at different altitudes in dry and hot river valley at Jinsha Jiang River can be understood better. And more, the results can also offer scientific and reasonable advice to manage and strengthen the ecological system in this region.

STUDY SITES AND METHODS

Natural conditions: The study is in the river valley of east Jinsha River downstream in Ningnan County. It is located at east longitude 102°54'-103°02' and north latitude 26°54'-27°09'. The average annual temperature is 20-27°C ≥10°C. The annual sunshine hours are 2179-2736 and regarded as rich sunshine district. The annual precipitation is 600-800 mm. The annual evaporation is 3-6 times of annual precipitation. The dry season and wet season are distinct. In dry season the evaporation is more than 20 times of precipitation. Soil contains relatively low moisture and effective water. The soil is dry and red one that has lower anti-evaporation capacity, including brown red soil, red soil and purple soil and so on. The main vegetations are dry and hot valley shrubs and savanna shrubs. The typical herbs are *Heteropogon contortus* P. Beauv, *Cymbogon distens* and *Eulaliopsis binata* Hubbard etc. The typical shrubs are *Dodonaeoan gustifolia*, *Phyllanthus emblica* L., *Opuntia monacantha* Haw and *Psidium guajava* Linn. etc. The typical trees are *Bombax ceiba* L., *Leucaena leucocephala* (Lam.) de Wit *cv. Salvador*, *Camptotheca acuminata* and *Robinia pseudo-acacia* L. etc.

Sample collection and analysis: In April (dry season) and October (rainy season), 2008, after investigating wild vegetation, a typical slope in this investigated region had been chosen. Seven grass fields from altitude 705-1500 m and one Yunnan pine forest at an altitude 1585 m had been selected as samples, although the field above an altitude 1500 m is normally considered to be affected hardly by dry and hot wind. The details of samples and sites are given in Table 1. In order to reduce the effects caused by terrain and human activities, the samples are collected on the windward slopes with similar position and gradient. At each altitude three sites had been selected. In every site seven samples as S-type at the depth of 0-20 cm below the earth had been collected and mixed homogenously. The mixed and quartered samples were used in the experiment. Since, the distance among samples is bigger than the spatial dependence of the soil physicochemical property and the majority microbial character (Mariotte et al. 1997), the samples mentioned above are regarded as true duplication.

Visible animal bodies, vegetation and rocks in soils were removed when the samples had been handled in the lab. Each sample was first mixed, and then separated into two parts. One part was dried naturally by air. Another part was kept fresh. Air-dried soil sample was again divided into two parts, which were sieved by 0.25 mm and 1 mm sieves respectively. The first partial soil (0.25 mm sieve, from dry season) was used to determine the physicochemical parameters. The second partial soil (1 mm sieve, from dry season and rainy season) was used to decide the soil enzyme activ-

Table 1: Description of the sampling plots.

Sites	Land form	Slope aspect	Slope degree/°	Altitude/ m	Soil type	Vegetation Coverage (%)	Vegetation
Grass	WS	ES17°	35°	705	dry red soil	70	*Setaria viridis*, *Roegneria kamoji*
Grass	WS	NE6.5°	28°	805	dry red soil	20	*Artemisia giraldii*, *Calystegia hederacea*
Grass	WS	ES11°	26°	920	dry red soil	20	*Calystegia hederacea*, *Roegneria kamoji*
Grass	WS	ES	26°	1005	dry red soil	20	*Ixeris sonchifolia*, *Sonchus oleraceus*
Grass	WS	ES16°	30°	1235	dry red soil	20	*Heteropogon contortus*
Grass	WS	WN33°	30	1400	dry red soil	30	*Rumex hastatus, Artemisia giraldii*
Grass	WS	ES16°	26°	1500	dry red soil	20	*Rumex hastatus*, *Bothriochloa ischaemun*
Pine	WS	ES14°	40°	1585	dry red soil	80	*Pinus yunnanensisf, Cyclobalanopsis glauca*

WS: windward slopes

ity. The fresh sample had been taken back to lab with portable refrigerator. The fresh sample was sieved by 2 mm sieve and used to determine the microbial biomass and respiration intensity.

The core method was used to determine the soil bulk density.

The methods that decided relevant parameters are as follows:

- Total organic carbon (TOC): Oxidation of potassium dichromate by heating.
- Total nitrogen (TN): Kjeldahl method.
- Soil (H_2O:soil= 2.5:1) pH value: pH meter.
- Soil total phosphorus (TP): Sodium carbonate fusion-molybdenum (Mo)-antimony (Sb) colorimetric method (2401 UV-spectrophotometer, Shimadazu, Japan).
- Soil available phosphorus: Olsen method.
- Soil available potassium: Ammonium acetate extraction-flame photometry (Lu 1999).
- Saccharase (SAC): 3,5-dinitrosalicylic acid colorimetric method, expressed by milligram glucose in 1 g soil within 24 h.
- Urease (URE) : Indophenol colorimetry, the activity is expressed by milligram NH_3-N in 1 g soil within 24 h.
- Alkaline phosphatase (ALP): Disodium phenyl phosphate colorimetry, expressed milligram phenol in 1 g soil within 24 h.
- Cellulase (CEL): Nitrosalicylic acid colorimetry, expressed milligram glucose in 10 g soil within 72 h.
- Catalase (CAT): Titration with 0.1 N standard $KMnO_4$, the activity is expressed by millilitre 0.1N $KMnO_4$ consumed in 1 g soil within 20 min.
- Polyphenol oxidase (PPO): Iodometric titration, the activity is equivalent to millilitre 0.01 N I_2 in 1 g soil liquid (Guan 1986).

Chloroform fumigation and potassium sulphate extraction were utilized before the measurements of microbial biomass carbon by automatic organic carbon analyser and microbial biomass nitrogen by automatic organic nitrogen analyser (Horwath et al. 1994, He et al. 1994). Soil respiration was absorbed by the alkali. Soil induced respiration (SIR) was decided by using the matrix induction method. Metabolic quotient (qCO_2) is the ratio of basal respiration intensity and microbial biomass carbon (Xu et al. 1986).

Data analysis: In order to completely study the dynamic character of soil enzyme activity under different usage condition, this investigation weighted and calculated soil enzyme index on the basis of all enzymes (Wang et al. 2009). Because the soil property normally differs from the active factors' status and importance, so the common coefficient represents the important degree of each individual factor. This study analysed the main factors through converted membership matrix, and calculated every main factor's contribution rate and accumulative contribution rate. The load amount was analysed by using the main factors. The size of each factor was calculated and weighted (by calculating the percentage of the every common factor's variance and the sum of common factor's variances, and changing the value to 0-1). The equation is as follows:

$$W_i = C_i / C \quad \text{...(1)}$$

Where, W_i: index weight of each enzyme, C_i: common factor's variance, C: sum of common factor's variances.

Based on each normalized and weighted index, soil enzyme index is calculated by weighted sum method. The mathematical equation is shown below.

$$SEI = \sum_{i=1}^{n} w_i \times SEI(x_i) \quad \text{...(2)}$$

Where, $SEI(x_i)$: soil enyzme's membership value, W_i: the weight of soil enzyme (i).

Every data is the mean of triplicate. The significant difference and correlation were analysed by using single factor analysis of variance (ANOVA) at SAS 6.12.

RESULTS

The Influence of Different Altitudes on Soil Enzyme Activity

The activity of ALP: As shown in Fig. 1, the activity of soil ALP clearly shows the linear relationship with increased altitude. In dry season, the activity of ALP does not have significant difference at an altitude of 705-920 m before it rises. At altitude 1005 m, the activity value maximizes. ALP activity keeps stable at an altitude of 1400-1585 m. The general phenomenon of ALP change in wet season is as similar as the change in dry season. However, the maximum activity of ALP in dry season appears at altitude 1005 m. In addition, it must be pointed out that the ALP amount in wet season is higher than in dry season.

The activity of URE: The activity of soil URE appears in linear relationship. The similar changes in dry season and wet season have been found and shown in Fig. 2. In dry season, from altitude 705 m to 920 m, the URE activity slightly grows. But the increased activity does not reach the maximum value until at an altitude of 1005 m. With increased altitude, the activity decreases. In wet season, the maximum activity of URE is at an altitude 1235 m. Neither pine forest at 1585 m altitude nor grass at 1500 m altitude,

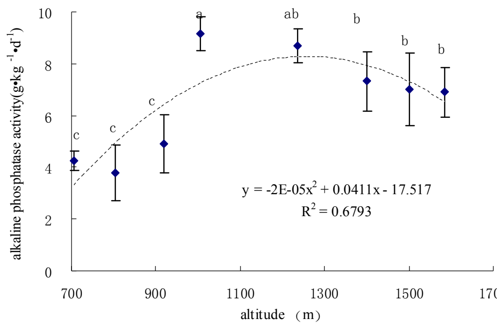

Fig. 1A: Change in ALP at different elevation in dry season.

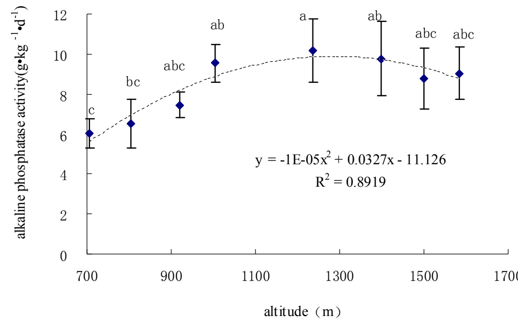

Fig. 1B: Change in ALP at different elevation in wet season.

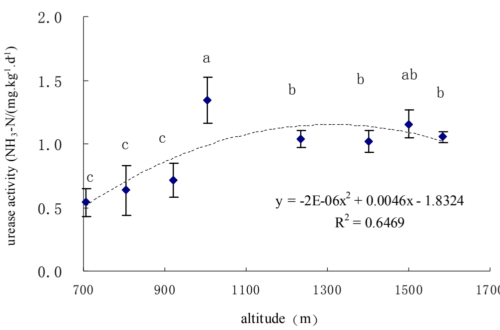

Fig. 2A: Change in URE at different elevation in dry season.

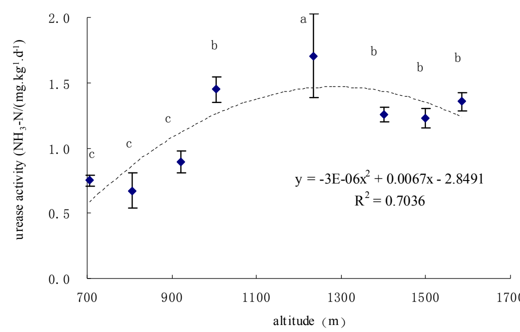

Fig. 2B: Change in URE at different elevation in wet season.

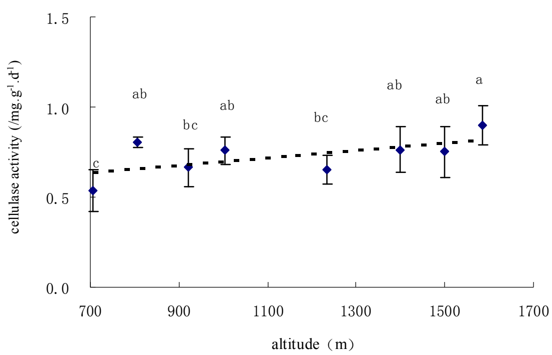

Fig. 3A: Change in CEL at different elevation in dry season.

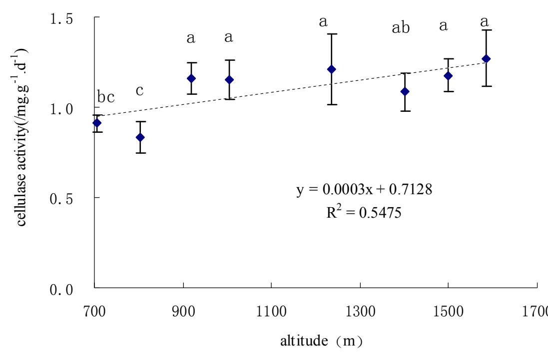

Fig. 3B: Change in CEL at different elevation in wet season.

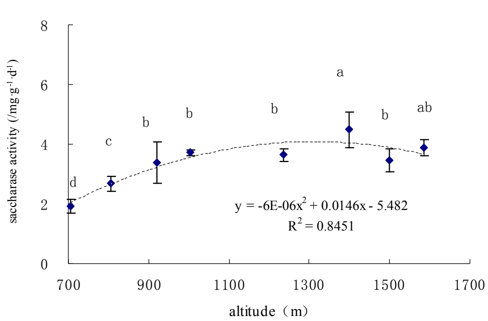

Fig. 4A: Change in SAC at different elevation in dry season.

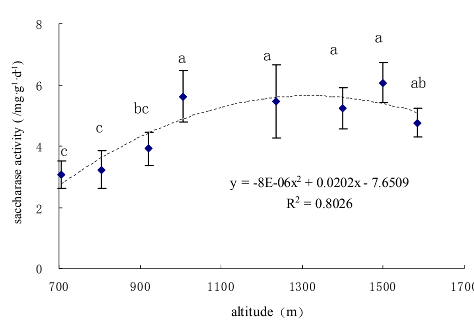

Fig. 4B: Change in SAC at different elevation in wet season.

in both dry season and wet season, differ from each other. At the same altitude URE activity in wet season is higher a bit than in dry season.

The activity of CEL: In Fig. 3, it is shown that in dry season, CEL activity increases and keeps stable after one minimum value at 705 m altitude. In wet season, CEL activity at 705 m altitude does not differ from that at 805 m altitude. Regression analysis indicates that only in wet season CEL activity has linear relationship with risen altitude. Similarly, CEL activity in wet season is higher than in wet season.

The activity of SAC: Obviously, SAC activity rises with growing altitude (Fig. 4). In dry season, the activity has linear relationship with increasing altitude. At an altitude of 705-1005 m, SAC activity gradually grows, and then remains relatively stable. Neither pine forest at 1585 m altitude nor grass at 1500 m has any big difference. In both, dry and wet seasons, the trend of enzyme activity is similar. But in wet season there is no increased phenomenon at 705-1005 m altitude. As same as the change of SAC activity in dry season there is no big difference in both, the pine forest at altitude 1585 m and grass at altitude 1500 m. SAC activity at any altitude in wet season is higher distinctly than in dry season.

The activity of PPO: As shown in Fig. 5, PPO activity rises with growing altitude. At 705-805 m altitude no significant change in dry season has been found, which followed a stable status with the activity rapidly rising. Regression analysis shows a significant change of quadratic function. There is no big difference between pine forest at 1585 m altitude and grass at 1500 m altitude. In wet season, PPO activity at 805 m altitude is higher than at 705 m altitude. At 1235 m altitude, PPO activity reaches maximum. After altitude 1235 m till 1585 m, activity value of PPO declines slightly. But the difference is not too big. Regression analysis is still in linear relationship. In general, in wet season, PPO activity is higher than in dry season.

The comprehensive index of soil enzymes: According to the analysis above, altitude has big influence on the type of enzyme. In order to eliminate the incomplete investigation of the soil enzyme's different properties at various altitudes, soil enzyme index (SEI) has been taken to express the comprehensive effect on enzyme factors, so that the character of soil enzyme activity can be objectively and comprehensively researched. The results show that SEI changes regularly with increased altitude in both dry season and wet seasons (Fig. 6). In two seasons at 705-920 m altitude, SEI did not raise. But once altitude is higher, soil enzyme activity increases rapidly. At 1005 m altitude the activity reaches maximum value, before the activity declines and keeps stable in the dry season. On the contrary, in wet season, it is always stable. Regression analysis indicates the linear relationship between enzymes activity and growing altitude.

The Influence of Different Altitudes on Soil Microbial Biomass

With increased altitude, soil microbial biomass carbon (SMBC) shows different increase phenomenon. The increasing phenomenon is individual in both, dry season and wet seasons (Fig. 7). Generally, linear relationship between increased altitude and SMBC has been found at altitude from 705 m to 920 m (Fig. 7). Above that altitude, SMBC remains almost stable at an altitude of 1005-1500 m, which does not differ from it in pine forest at 1580 m altitude. SMBC in pine forest has linear regression towards rising altitude. Soil microbial biomass nitrogen (SMBN) changes regularly with rising altitude (Fig. 8). In dry season, SMBN increases gradually and slowly. At an altitude of 1005 m SMBN is much higher than at an altitude of 705 m. Above altitude 1005 m, SMBN is relatively steady. Similarly, altitude and SMBN has linear regression relationship. In wet season, the increased value of SMBN reaches significant level at 805 m altitude compared with at 705 m altitude. Between 805 m and 1235 m altitude, it is relatively stable. Afterwards it is increased remarkably till 1400 m altitude. Above 1400 m till 1585 m altitude, it does not increase greatly and yet reached the significant level. Regression analysis explains that SMBN has linear relationship with increased altitude. At the same altitude both, SMBC and SMBN, in wet season are higher than in dry season. Grass at 1500 m altitude and pine forest at 1585 m altitude both in dry season and in wet seasons do not reach significant level.

The Influence of Different Altitudes on Soil Respiration Intensity

As shown in Fig. 9, basal respiration intensity is logarithmic growth with increased altitude. In dry season, although basal respiration intensity increases at altitude 705 m to 1005 m, it does not reach the significant level. Basal respiration intensity that is distinctly higher than at altitude 705 m grows greatly at an altitude 1005-1400 m, and shows fluctuant growth. Respiration intensity of pine forest at 1585m altitude appears maximum value. And the phenomenon has been found in grass at an altitude of 1500 m as well. In wet season, its growth reaches significant level at 805 m altitude. Afterwards it shows fluctuant increase. But the growth does not reach the significant level. The respiration intensity of pine forest at 1585 m altitude is stronger than the grass at 1500 altitude. However, the analysis of variance does not get significant level. At same altitude in wet season, basal respiration intensity is more intensive than

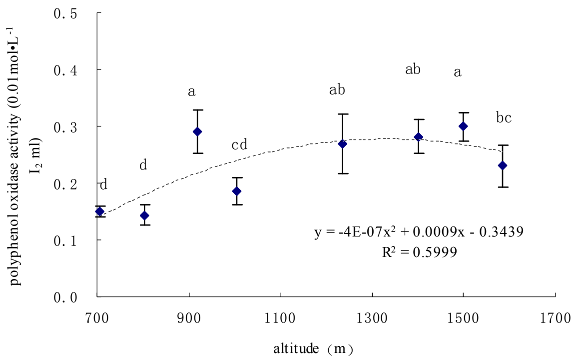

Fig. 5A: Change in PPO at different elevation in dry season.

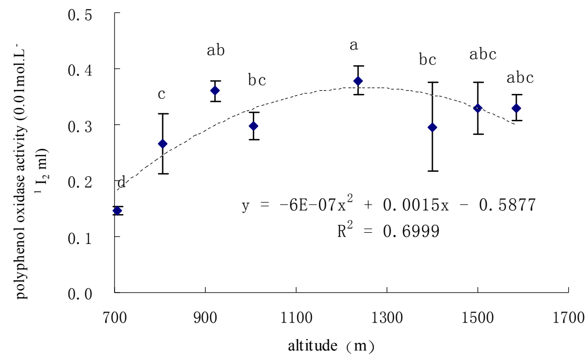

Fig. 5B: Change in PPO at different elevation in wet season.

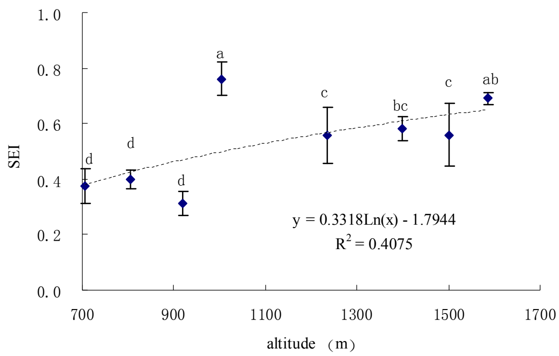

Fig. 6A: Change in SEI at different elevation in dry season.

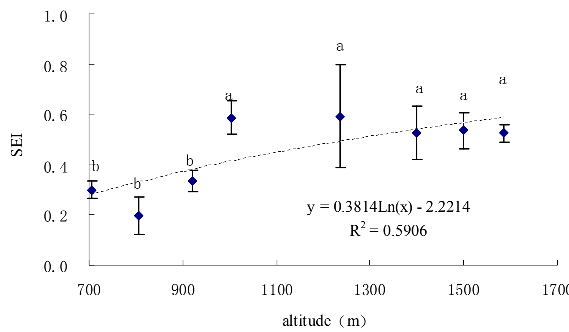

Fig. 6B: Change in SEI at different elevation in wet season.

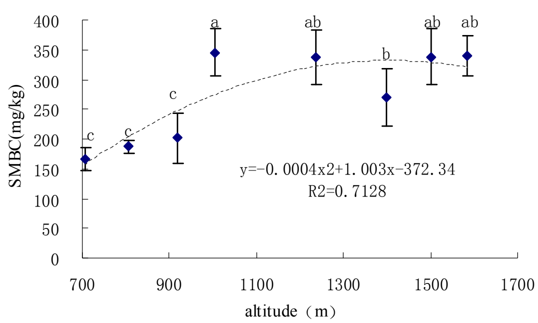

Fig. 7A: Change in SMBC at different elevation in dry season.

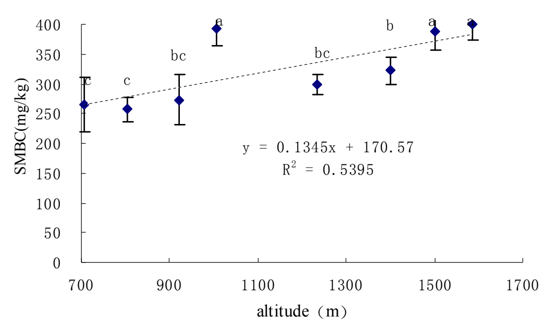

Fig. 7B: Change in SMBC at different elevation in wet season.

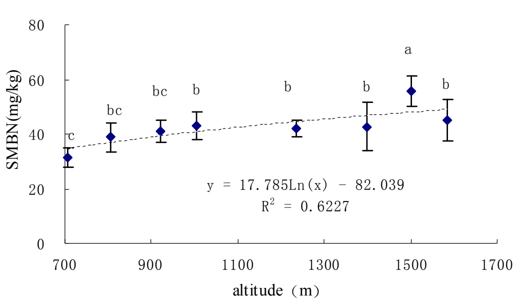

Fig. 8A: Change in SMBN at different elevation in dry season.

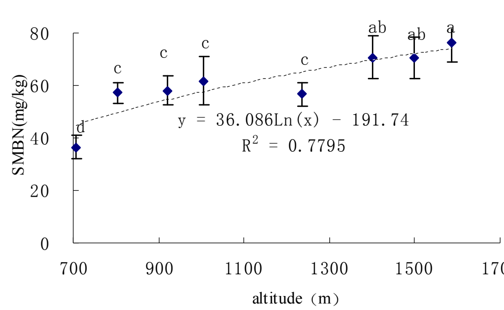

Fig. 8B: Change in SMBN at different elevation in wet season.

in dry season. Soil induced respiration (SIR) indicates certain regular change with rising altitude (Fig. 10). In dry season, with growing altitude, SIR slightly decreases and then increases. At an altitude 705-1400 m, the change does not go to significant level and reach the maximum value until altitude 1400 m. But at altitude 1580 m the respiration intensity of pine forest is maximizing. The maximum does not differ from the one of grass at altitude 1500 m. In wet season, SIR increases with growing altitude. Its growth increases slowly between altitude 705 m and 1005 m. However, the growth does not reach the significant level. In comparison with the intensity at an altitude of 705 m, the intensity at 1235 m altitude is much higher. Although the intensity becomes stronger, it does not reach significant level. At altitude between 1500 m and 1580 m, the intensity is the strongest. Regression analysis explains that SIR has linear relationship with increased altitude. In wet season SIR is more intensive than in dry season at same altitude.

The Influence of Different Altitudes on Soil Metabolic Quotient

Compared with other indexes, qCO_2 does not increase with increased altitude remarkably (Fig. 5). In general, qCO_2 in dry season decreases slowly. At an altitude 1005 m, qCO_2 goes to the minimum, and then it increases slowly. Totally, in wet season there is no significant difference. Within certain fluctuant range, at same altitude, qCO_2 in dry season does not differ from in wet season (Fig. 11).

DISCUSSION

Soil enzyme and soil microbes are important motivation and components of soil ecological metabolism. They are sensitive indicators to assess soil quality and reflect microbial community changes (Zhou et al. 1987, Institute of Soil Science 1985). Altitude is the comprehensive reflection of average temperature, active accumulated temperature and precipitation. Vertical changes of terrain can change the structure of vegetation community and evolution type (Huang et al. 1994, Begon et al. 2000). Furthermore, it changes soil physical, chemical and biological properties by interacting with soil, light, energy, water and air (Huang et al. 2001). In the end, the changes in ecological functions are caused. Currently, the difference of individual study about the effect of altitude on soil microbes and soil enzyme activity is quite big (Xu et al. 1997, Tang et al. 2008, Chen et al. 2010). The main reason is relevant to climate, soil type and vegetation community studied. Especially, the studies focused on the soil microbes at different altitude in dry hot river valley are few.

The results in this study show that soil ALP, URE, CEL, SAC, PPO and enzyme comprehensive indexes generally show linear relationship with increased altitude. At altitude of 705-920m they do not increase greatly. But above altitude 920 m they increase significantly. Most of these indexes reach the maximum at an altitude between 920 m and 1235 m. And then they increase or keep stable. It can be explained that it is related to dry and hot wind. Altitude 705-920 m locates 100-200 m above the river. The weather and litter are affected sincerely by dry and hot wind, so that vegetation growth is poor. Litter goes back to soil hardly. Additionally, since the altitude soil is greatly short of water, soil metabolism capacity weakens. Hence, soil enzyme activity becomes low. At higher altitude with less effect of hot and dry wind, vegetation growth and the amount of litter returned to soil increases remarkably. Soil microbial biomass is greater and metabolism is faster, so that soil enzyme activity becomes stronger. There is less and less impact of dry and hot wind at altitude above 1005 m. In general, the condition of sunlight and water is similar at altitude higher than 1005 m. There is no big difference among the vegetations. The material circulating metabolism in soil ecological system is relatively high and maintains equilibrium. So soil enzyme activity does not differ much.

The research of soil microbial biomass shows that the content is very low at altitude 705 m, but increases with rising altitude. At altitude 705-920 m, apart from the SMBN amount that increases greatly, SMBN does not reach significant level, because of the impact of dry and hot wind. Within this altitude, 100-200 m above river, the impact of dry and hot wind is heavy, vegetation growth is poor, and litter returns soil badly due to the influence of dry and hot wind. In addition, at this altitude soil is short of water and soil metabolism is weak, so that microbial biomass is relatively low. At altitude 920-1005 m, the growth of SMBC is quick. In dry season, SMBN at this altitude is obviously higher than at 705 m altitude. At this level, the influence of dry and hot wind reduces, so that vegetation and litter amount increases greatly. The material needed by microbes increases distinctly, and microbial biomass increase as well. Above altitude 1005 m there is less impact of dry and hot wind, so that the condition of sunlight and water is totally similar. Vegetation and other conditions do not change so much. So, soil microbes lie nearly in the same environment, and microbial biomass maintains stability.

Soil respiration represents soil biological character and metabolism intensity. The results in this study show that in both dry and wet season, basal respiration intensity and SIR increase with rising altitude. On sunny slope soil respiration has intensive growth at an altitude above 1400 m in comparison with at altitude 705 m. In wet season, at an altitude of 920 m and 1235 m, the increase reaches significant level. It indirectly means that the dry and hot wind in dry

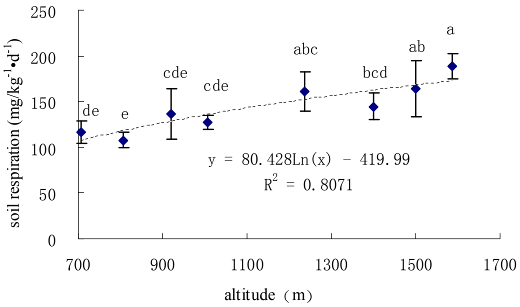

Fig. 9A: Change in respiration at different elevation in dry season.

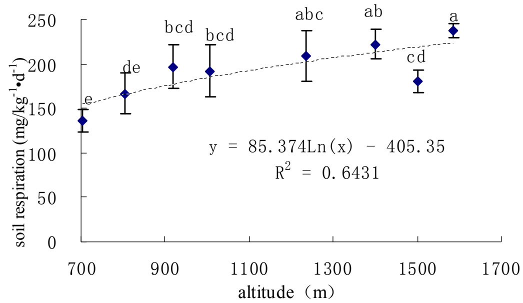

Fig. 9B: Change in respiration at different elevation in wet season.

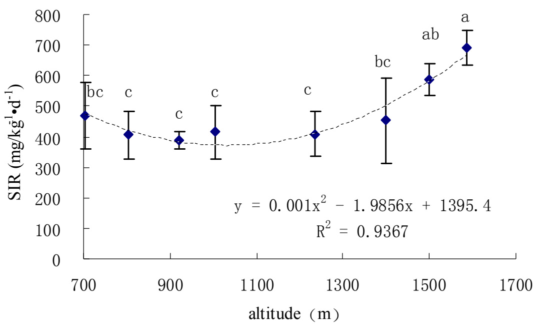

Fig. 10A: Change in SIR at different elevation in dry season.

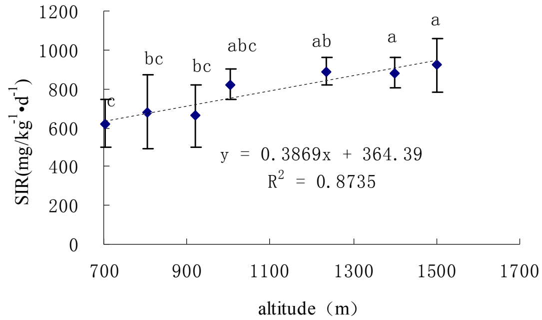

Fig. 10B: Change in SIR at different elevation in wet season.

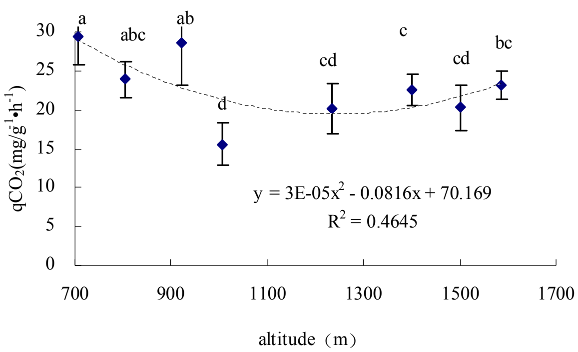

Fig. 11A: Change in qCO_2 at different elevation in dry season.

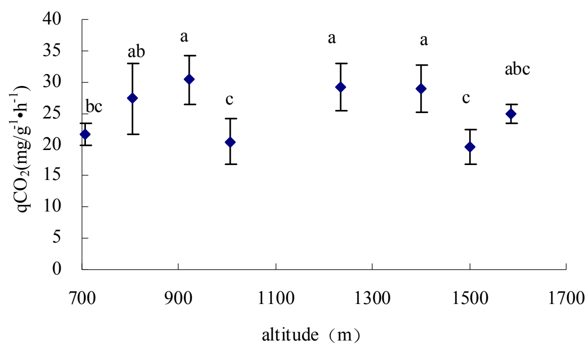

Fig. 11B: Change in qCO_2 at different elevation in wet season.

season has stronger influence than in wet season. More the stress from environment, stronger the influence of dry and hot wind. Therefore, the impact of soil biological character and metabolism is heavier. The qCO_2 indicates maintenance capacity of microbial community and matrix utilization efficiency. It is a sensitive indicator to reflect the impact of environmental factors and practical management changes etc. (Brookes et al. 1985, Brookes 1995). This study finds that in dry season qCO_2 decreases at altitude 705-1005 m. It means, with increased altitude, dry and hot wind has less influence, so that soil and vegetation stresses reduce, as well as qCO_2 efficiency increases. Soil excellent property and sustainable potential strengthens. At altitude above 1005 m, qCO_2 is stationary. At this level, environmental factors affect the soil stability. Microbes metabolize with certain efficiency. In wet season, qCO_2 is stable and its change is not found. This case explained that the altitude does not affect microbes' metabolism efficiency. The reason perhaps is that in wet season there is rich blossomed vegetation. Stress of soil microbes from environment is less, and metabolism efficiency keeps stable. According to the analysis mentioned above, altitude and dry and hot wind are the main factors to impact soil microbial biomass.

The alternation of dry and wet seasons has big influence on soil microbes and enzyme activity (Mondini et al. 2002, Wu et al. 2005, Zhang et al. 2004, Li et al. 2007). Wet and dry seasons are different completely in the region of dry and hot river valley. More than 90% of rainfall concentrates in wet season. Annual evaporation is several times higher than annual rainfall. In March and April, humidity index is less than 0.02. Under the condition of dry climate and disequilibrium of water and energy, the alternation of dry and wet conditions can impact the soil microbial biomass and enzyme activity. The investigation of enzyme activity and microbial biomass show that at same altitude, soil enzyme activity and microbial biomass change with the seasons distinctly and regularly. The reasons may be as follows:

1. Compared with dry season, wet season has rich water, so that soil respiration and physical structure can be improved. Therefore, soil microbes grow greatly and soil enzyme is secreted rich.
2. The alternation of dry and wet conditions has an important influence on soil microbial biomass and community structure (Mondini et al. 2002, Wu et al. 2005, Zhang et al. 2004, Li et al. 2007). Dry condition leads to death of most of the soil microbes, resulting in the decline of the microbial biomass and enzyme activity (Hamer et al. 2007, Iovieno et al. 2008). Again, in wet season, soil contains rich water. The cells of dead microbes can be degraded by the survived microbes in soil, so that microbes can grow further. Therefore, microbial biomass rise and metabolism capacity strengthen, leading to active enzyme activity. Additionally, in dry season because of the impact of water shortage, vegetation grows poorly and some species are still in the state of dormancy. The growth of root stops. However, in dry season the situation is completely on the contrary. Due to rich water in wet season, vegetation grows greatly and root is in the fast growing period. There is a lot of secretion. Soil metabolize quickly. Enzyme activity in wet season is improved significantly than in dry season.

This study shows that SMBN and SMBC in wet season are lower than in dry season, except for at an altitude of 705 m. The ratio of bacterial nitrogen and carbon is lower than fungi (Iovieno et al. 2008). Fungi in dry season are assumed to be higher than in wet season. The result is as similar as the report of Gordon (2008), which considers that fungi have stronger endurance on dry situation than bacteria. In arid period the richness of fungi increases correspondingly.

CONCLUSION

1. In the region of dry and hot river valley, altitude significantly affects on soil enzyme activity and microbial biomass. Soil enzyme activity and microbial biomass appear distinctly in linear relationship with increased altitude. At altitude between 705 m and 1005 m, soil enzyme activity and microbial biomass do not change or increase greatly. At an altitude above, the impact of dry and hot wind reduces. Soil microbial biomass and enzyme activity totally keep stable. Altitude between 1005 m and 1400 m can be regarded as the transition zone of the impact of dry and hot wind.
2. Soil enzyme activity and microbial property change clearly in dry and wet season. And the change in both the seasons is similar. In dry season soil enzyme activity and microbial biomass are lower than in wet season because of the impact factors like water, vegetation and so on. In dry season qCO_2 decreases firstly, and then increases before it reaches the stable level. However, in wet season, qCO_2 has no significant change.
3. In both dry and wet season, soil enzyme activity and soil microbial biomass have strong correlation with nutrient property, which is regarded as the indicator to assess soil fertility. From the aspect of ecological resiliency, we should relieve the stress of soil and vegetation from dry and hot wind, as well as water, so that the ecological sustainable development in this region could be promoted.

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