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Diversity analysis of soil dematiaceous hyphomycetes from the Yellow River source area: I*

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Abstract: Twenty-four soil samples of eight ecosystem-types around the Yellow River source area were investigated for the number and specific composition of soil dematiaceous hyphomycetes by dilution plate technique. And then the co-relationship between genus species of soil dematiaceous hyphomycetes and ecosystem-types was analyzed. The results show that the amount and species distribution of soil dematiaceous hyphomycetes had an obvious variability in different ecosystem-types, and that the dominant genus species varied in the eight ecosystem-types studied, with *Cladosporium* being the dominant genus in seven of the eight ecosystem-types except wetland. The index of species diversity varied in different ecosystem-types. The niche breadth analysis showed that *Cladosporium* had the highest niche breadth and distributed in all ecosystem-types, while the genera with a narrow niche breadth distributed only in a few ecosystem-types. The results of niche overlap index analysis indicated that *Stachybotrys* and *Torula*, *Doratomyces* and *Scolecobasidium*, *Cladosporium* and *Chrysosporium* had a higher niche overlap, whereas *Arthrinium* and *Gliomastix*, *Phialophora* and *Doratomyces*, *Oidiodendron* and *Ulocladium* had no niche overlap.

Key words: Yellow River source area, Ecosystems, Fungal species diversity, Soil dematiaceous hyphomycetes, Niche breadth, Niche overlap
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INTRODUCTION

Microorganisms take part in the soil material transformation process, and play an important role in soil formation, fertility evolution, plant nutrient in effect, soil structure formation and improvement, and degradation and purification of the toxic substances (Zhong and Cai, 2004; Donnison *et al*., 2000; Buée *et al*., 2007; Heilmann-Clausen and Christensen, 2003). Nutrient cycles caused by soil microorganisms play an important part in stability and improvement of the service functions of the soil ecosystem (Rogers and Tate, 2001). Therefore, the study of the number of soil microorganisms can reveal the important link of energy floating and material recycling in the ecosystem.

As an important component of soil microorganisms, fungi take a very important position in structure and function of the ecosystem. They can decompose organic matter, form humus, release nutrients, assimilate soil carbon, and fix inorganic nutrition (Ogram, 2000; Kirkegaard *et al*., 2000). We investigated the species, components, ecological distribution, diversity and niche breadth of the soil dematiaceous hyphomycetes at genus level in the Yellow River source area. A diversity comparison and analysis of the soil dematiaceous hyphomycetes at genus level were also carried out to reveal the basic characteristics, distribution and species diversity of the soil dematiaceous hyphomycetes in different ecosystem-types in this area.

MATERIALS AND METHODS

Study sites

The Yellow River originates in the north of Bayan Har in Qinghai Province, China. The regions

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over Longyan gorge are known as the Yellow River source area, including 18 counties, i.e., Qumalai, Maduo, Dari, Gande, Chengduo, Maqin, Jiuzhi, Xinghai, Henan, Zeku, Gonghe, Tongde, Jianzha, Tongren, Guide, Xunhua, Hualong, and Guinan. The Yellow River source area lies in the hinterland of the Qinghai-Tibetan Plateau and the average altitude of most the area is over 4000 m. It is mostly covered with grasslands, forests, glaciers and gobi in which farming areas are mainly distributed in the downstream of the Yellow River source area. The climate is typical plateau-inland climate: cold, drought, windy, strong radiation and less rainfall. Soil types are the alpine meadow soil, mountain grassland soil and cold desert soil. The ecological environment in this area is very fragile.

Sample collection

Soil samples tested in the present investigation were collected from eight counties, viz. Gonghe, Guide, Guinan, Zeku, Tongde, Henan, Tongren and Jianzha. Each sample was collected 2~10 cm deep from the surface soil at several points in one ecosystem-type, according to various vegetation, elevation, and other environmental factors. Each sample contained about 100 g soil and was placed in a plastic bag. All samples were kept in 4 °C freezer after being taken back and isolations were carried out within two months.

Isolation methods

Soil plate method and soil-dilution plate method were used. Each sample was repeated 4 times. Soils were cultured for 3 weeks at 20 °C, and the amount of soil dematiaceous hyphomycetes colonies was calculated and identified for species.

Data analysis

The following indicators were used to analyze the diversity of soil dematiaceous hyphomycetes:

Richness (*S*): the total number of species in the community;

Berger-Parker dominance index: $d_i=N_i/N$, in which N_i represents the number of species *i*, and *N* represents the total number of the species in the community;

Shannon-Wiener diversity index (Lloyd *et al*., 1968): $H' = -\sum_{i=1}^{n} P_i \ln P_i$, in which P_i represents the proportion of the individual *i* number to the total number in the community;

Pielou evenness index (Pielou, 1966): $J=H'/\ln S$, in which H' represents the Shannon-Wiener diversity index, and *S* represents the total number of species in the community;

Levins niche width index: $B = 1/\sum P_i^2$, in which P_i represents the proportion of individual *i* in the resource;

Pianka niche overlap index: $O_{ij} = \left(\sum P_{ik} P_{jk}\right) / \sqrt{\sum_{k=1}^{r} P_{ik}^2 \cdot \sum_{k=1}^{r} P_{jk}^2}$, in which O_{ij} represents the niche overlap between the species *i* and *j*; P_{ik} and P_{jk} represent the proportions of species *i* and *j* in resource *k*, respectively; *r* represents the total number of resource.

DPS 3.01 and EXCEL 2003 were used in data analysis.

RESULTS

Species composition and dominance index analysis

Forty-three isolates of soil dematiaceous hyphomycetes from 24 soil samples were obtained, of which 33 species in 18 genera were identified. These genera included *Alternaria*, *Arthrinium*, *Chrysosporium*, *Cladosporium*, *Doratomyces*, *Gliomastix*, *Humicola*, *Monodictys*, *Myrothecium*, *Oidiodendron*, *Phialophora*, *Scolecobasidium*, *Scytalidium*, *Stachybotrys*, *Torula*, *Ulocladium*, *Veronaea* and *Wardomyces*.

The genus is classified as a dominant, general, or rare genus, according to the dominance index of >0.1, 0.01~0.1, and <0.01, respectively (Gao and Long, 1996). Thus, *Cladosporium* was identified as a dominant genus in seven of the eight ecosystem-types except wetland (Table 1). In desert, *Cladosporium* and *Myrothecium* were dominant genera while others did not distribute. *Chrysosporium* and *Gliomastix* were dominant genera in grassland while *Humicola*, *Monodictys*, *Myrothecium*, *Oidiodendron*, *Scytalidium* and *Veronaea* were general genera. *Alternaria*, *Phialophora*, *Scytalidium*, *Stachybotrys* and *Ulocladium* were general genera in gobi. *Stachybotrys* and *Torula* were dominant genera in forest soil

Table 1 Total numbers (*n*) and dominance index of soil dematiaceous hyphomycetes at genus level in different ecosystem-types in the Yellow River source area

	Dominance index																		*n*
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	
E1	0	0	0	0.77	0	0	0	0	0.23	0	0	0	0	0	0	0	0	0	39
E2	0	0	0.27	0.5	0	0.51	0.017	0.03	0.017	0.017	0	0	0.02	0	0	0	0.077	0	117
E3	0.1	0	0	0.73	0	0	0	0	0	0	0.025	0	0.025	0.025	0	0.1	0	0	40
E4	0	0	0	0.56	0	0	0.016	0	0.03	0	0	0.02	0.03	0.13	0.13	0	0	0.08	61
E5	0.02	0	0	0.73	0	0.07	0	0.07	0.02	0	0.024	0	0	0.02	0	0.02	0	0	41
E6	0	0	0	0.41	0.13	0	0.0128	0	0.05	0	0	0.13	0.05	0.10	0	0	0	0	39
E7	0.28	0.17	0	0.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
E8	0	0	0	0.05	0	0.054	0	0	0	0	0.76	0	0.027	0.11	0	0	0	0	37

Ecosystem-types: E1: desert; E2: grassland; E3: gobi; E4: forest; E5: alpine meadow; E6: farmland; E7: wasteland; E8: wetland. Genera: G1: *Alternaria*; G2: *Arthrinium*; G3: *Chrysosporium*; G4: *Cladosporium*; G5: *Doratomyces*; G6: *Gliomastix*; G7: *Humicola*; G8: *Monodictys*; G9: *Myrothecium*; G10: *Oidiodendron*; G11: *Phialophora*; G12: *Scolecobasidium*; G13: *Scytalidium*; G14: *Stachybotrys*; G15: *Torula*; G16: *Ulocladium*; G17: *Veronaea*; G18: *Wardomyces*

while *Myrothecium*, *Scolecobasidium*, *Scytalidium* and *Wardomyces* were general genera. All the genera distributed in alpine meadow were found to be general genera except the genus *Cladosporium*. In farmland soil, *Doratomyces* and *Scolecobasidium* were dominant genera while the others were general genera. In wetland, the dominant genera were *Phialophora* and *Stachybotrys*. *Chrysosporium*, *Doratomyces*, *Oidiodendron*, *Torula*, *Veronaea* and *Wardomyces* distributed only in one or two ecosystem-types. The results show that the distribution of the dominant and general genera of soil dematiaceous hyphomycetes varied in the eight ecosystem-types, and *Cladosporium* was the only genus distributed in all the eight ecosystem-types and was dominant in seven of them.

Diversity analysis of soil dematiaceous hyphomycetes

As shown in Table 2, the diversity indices of grassland, forest and farmland were much higher than those of other ecosystem-types. The farmland soil had the highest diversity index in all eight ecosystem-types while the diversity index of desert was the lowest. In the eight ecosystem-types, the wasteland was the highest in evenness, while the alpine meadow was the lowest. Nine genera were isolated from grassland soil while only two genera were isolated from desert. The numbers between three genera isolated from wasteland soil varied notably, so that the Shannon-Wiener diversity index of this ecosystem was small. Because there was less difference between the numbers of each genus, the Shannon-Wiener diversity index of farmland soil was the highest in all ecosystems.

Table 2 Community characteristics of soil dematiaceous hyphomycetes in the Yellow River source area

Ecosystem-type	Richness index (*S*)	Diversity index (*H*′)	Evenness index (*J*)
Desert	2	0.77935	0.77935
Grassland	9	2.08573	0.65798
Gobi	6	1.39989	0.54155
Forest	8	2.05232	0.68411
Alpine meadow	7	1.53520	0.51173
Farmland	8	2.44364	0.87044
Wasteland	3	1.41527	0.89294
Wetland	5	1.24713	0.53711

Niche breadth analysis of soil dematiaceous hyphomycetes

According to niche breadth theory, niche breadth can reflect the scope and intensity of the organism activities. As shown in Fig.1, *Cladosporium* had the widest niche breadth, while *Scytalidium* was the next. The niche breadths of *Torula*, *Arthrinium*, *Doratomyces*, *Veronaea*, *Chrysosporium*, *Oidiodendron* and *Wardomyces* were the lowest in 18 genera isolated. *Cladosporium* distributed in all the 8 of ecosystem-types, indicating that it had a strong ability to adapt to the environment. In contrast, the genera with lower niche breadth distributed only in individual ecosystem-types, reflecting their weak environment adapting ability.

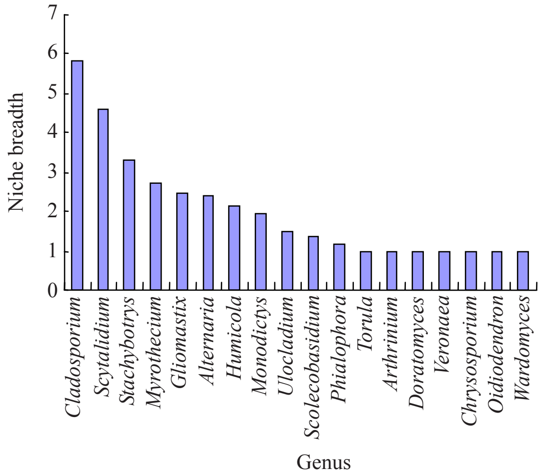

Fig.1 Niche breadth of soil dematiaceous hyphomycetes in the Yellow River source area

Niche overlap analysis of soil dematiaceous hyphomycetes

As shown in Table 3, *Stachybotrys* had a higher niche overlap with *Torula* and a lower niche overlap with *Alternaria*; *Doratomyces* had a higher niche overlap with *Scolecobasidium*; *Cladosporium* had a higher niche overlap with *Monodictys*, *Veronaea*, *Chrysosporium*, *Gliomastix*, *Oidiodendron* and *Scytalidium*, but a lower niche overlap with the other genera; *Gliomastix* had a higher niche overlap with *Monodictys*, *Veronaea* and *Chrysosporium*, but a lower niche overlap with *Alternaria*; and *Phialophora* had a lower niche overlap or no overlap with all the other genera. Several genera had no niche overlap with one another; for example, *Arthrinium* had no niche overlap with other genera except for *Cladosporium* and *Alternaria*. This illustrated that some genera of soil dematiaceous hyphomycetes have no or very weak competing power for natural resources. Contrarily, the genera with higher niche overlap between or among others generally have strong competing power. The distribution of soil dematiaceous hyphomycetes in eight ecosystem-types agreed with their niche breadth and niche overlap.

Table 3 Niche overlap of soil dematiaceous hyphomycetes in the Yellow River source area

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	0.61	0.41	0.35	0.39	0.47	0.26	0.12	0.18	0.05	0.74	0.67	0.67	0.73	0.48	0.67	0.39	0.76
2		1	0.03	0.02	0.21	0.26	0.24	0	0.21	0.003	0.23	0.21	0.21	0.22	0.30	0.20	0.21	0.33
3			1	0.64	0	0.12	0	0	0	0.04	0.15	0	0	0.10	0	0	0	0.26
4				1	0	0.08	0	0.77	0	0.03	0.09	0	0	0.07	0	0	0	0.17
5					1	0.81	0.20	0	0	0	0	0	0	0	0.18	0	1	0.53
6						1	0.55	0	0.40	0.41	0.06	0	0	0.16	0.52	0	0.81	0.78
7							1	0	0.98	0	0	0	0	0	0.93	0	0.20	0.63
8								1	0	0	0	0	0	0	0	0	0	0
9									1	0	0	0	0	0	0.91	0	0	0.53
10										1	0.02	0	0	0.30	0	0	0	0.28
11											1	0.8	0.8	0.94	0.29	0.80	0	0.43
12												1	1	0.86	0.37	1	0	0.53
13													1	0.86	0.37	1	0	0.53
14														1	0.31	0.86	0	0.53
15															1	0.37	0.18	0.78
16																1	0	0.53
17																	1	0.53
18																		1

Note: 1: *Cladosporium*; 2: *Myrothecium*; 3: *Ulocladium*; 4: *Alternaria*; 5: *Torula*; 6: *Stachybotrys*; 7: *Scolecobasidium*; 8: *Arthrinium*; 9: *Doratomyces*; 10: *Phialophora*; 11: *Monodictys*; 12: *Veronaea*; 13: *Chrysosporium*; 14: *Gliomastix*; 15: *Humicola*; 16: *Oidiodendron*; 17: *Wardomyces*; 18: *Scytalidium*

DISCUSSION AND CONCLUSION

Diversity of soil fungi and vascular plant species are positively related, and farming, burning, logging, grazing, irrigation and fertilization could change the fungal diversity (Christensen, 1981; Claridge *et al*., 2000). Some researches also showed that the soil pH, organic matter content and water were the main factors affecting the fungus numbers and diversity (Yu *et al*., 2007; Dong *et al*., 2004; Song *et al*., 2004; Zhang *et al*., 2001; Ju *et al*., 2008). We studied the soil dematiaceous hyphomycetes in eight ecosystem-types around the Yellow River source area. The results showed that the amounts and distribution of soil dematiaceous hyphomycetes at genus level had a close relation with ecosystem-types, and the dominant genera of soil dematiaceous hyphomycetes were different in the eight ecosystem-types studied. *Cladosporium* was the dominant genus in seven ecosystems and *Phialophora* was the dominant genus in wetland. The species diversities of soil dematiaceous hyphomycetes in farmland, grassland and forestland were much higher than those in the other ecosystem-types. Among the eight ecosystem-types in the Yellow River source area, farmland soil contains rich organic matters, and is located at the regions of relatively low altitudes where temperature and humidity are relatively high than in other ecosystem-types. Forestland and grassland are covered with better vegetation and the soil environment is relatively steady. Therefore, the diversity index of soil dematiaceous hyphomycetes in these ecosystem-types was much higher. Due to the fragileness and the lack of organic matter in the soil of desert-type of ecosystem, the number of species and the diversity index of soil dematiaceous hyphomycetes were lower than those of any other ecosystem-types studied.

Among the various genera and species of soil dematiaceous hyphomycetes in the Yellow River source area, *Cladosporium* was the only genus that distributed in all the eight ecosystem-types and had a widest niche breadth, indicating that it adapts to different environment well. The genera with a narrow niche breadth distributed only in a few types of ecosystems. The relationship between distribution of soil dematiaceous hyphomycetes and their special requirements for temperature and nutrition needs to be further investigated in the future.

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