ARCHIVES OF ENVIRONMENTAL PROTECTION

vol. 34 no.3 pp. 17 - 20 2008

PL ISSN 0324-8461

EFFECTS OF *PINUS MASSONIAN* PLANTATIONS ON SOIL MACROARTHROPODS IN DEGRADED ULTISOL, SUBTROPICAL CHINA

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Abstract: In the degraded red soil of subtropical China, restoration activities during the last century have mainly relied on extensive plantations of *Pinus massonian*. We analyze the changes in the soil macroarthropods in *P. massonian* plantations and the possible relationships between these changes and soil chemical parameters. The study revealed significant differences in the abundance of soil macroarthropods between the *P. massonian* plantations and the natural regenerated mesophilous herbosa (N1). The sharply differentiated pattern of soil macroarthropods seems closely linked to soil chemistry. Significant correlations of the abundance of soil macroarthropods with soil parameters suggest that their populations could have been affected by *P massonian*. The total abundance, the abundance of Hymenoptera and Termite were less in the *P. massonian* plantations when compared to the natural regenerated mesophilous herbosa (N1). This survey showed that *P.massonian* could adversely affect the decomposer community which could lower the nutrient cycling rate, thus *P.massonian* may not be an ideal plantation for restoration of eroded Ultisol, Subtropical China.

Keywords: Degraded Ultisol; *Pinus massonian*; Soil macroarthropods; Subtropical China

INTRODUCTION

The subtropical region of China is unique in its densely vegetated whereas in the other regions at the same latitude of the world are deserts or oceans [4]. Much of China's biodiversity resides in this region and it has also become China's primary area for food production.

Ultisols (commonly referred as red soils) derived from Quaternary red clay have covered over 0.114 million km^2, occupying about 10% of total area in Subtropical China [12]. Improper land and soil management, however, has caused severe soil and water erosion on the Ultisols in particular. The latest satellite image analysis showed that the area affected by soil-water erosion amounts to 25% of 3554 km^2 of land area in Yingtan, Jiangxi Province, where the Ultisols were dominant [5]. Land degradation has been a major ecological and economical problem in this area, resulting in massive environmental degradation and constituting a serious threat to sustainable agriculture and forestry [11], and calling for the restoration of vegetation on the eroded soils.

In the Subtropical China, restoration activities have been mainly based on the introduction of conifers, primarily Pinus *massonian*. Pinus *massonian* was preferentially chosen because of low-technical requirements for nursery production, high-resistance to adverse climatic and soil conditions, and because it was considered a pioneer species, favoring the establishment of late successionals. The effects of these plantations on soil physical and chemical property have been described detailed, however, the effect on soil fauna which exert vital functions to nutrient cycling is rare [2, 7].

The aims of this study were to analyze the changes in the soil macroarthropods in *P. massonian* plantations and the possible relationships between these changes and soil chemical parameters, and to provide data on conservation of soil biodiversity in this area

MATERIALS AND METHODS

The study site is located at the Ecological Experimental Station of Red Soil, Chinese Academy of Sciences in Yujiang County, Jiangxi Province, China (28°15' N, 116°55'E). It is a typical subtropical humid climate area with annual mean air temperature of 17.8°C and rainfall of 1700mm, and a frost free period of 262 days. About 50% of annual rainfall occurs during the period from March to July [11].

The soil prior to erosion was identified as a Typical Plinthudult according to USDA soil taxonomy [9], with pH 4-5. Five representative types were selected to study the effects of Pinus *massonian* in degraded ultisol [3] (Table 1).

Table 1. Characters of different types of restoration in Ultisols, Subtropical China.

Types	Characters
P1	A planted coniferous woodland (ca. 16 years), where *Pinus massonian* were planted on a degraded meadow established by *Miscanthus sinensis*, an initial colonizer.
P2	A *Pinus massoniana* sparse shrub and herbosa (ca. 20 years), dominating grass species included *Arundinella hirta* and *Schizanchyrium sanguineum*, where *Pinus massoniana* was sparsely planted on herbosa.
P3	A planted coniferous-broadleaf mixed woodland (ca. 16 years), where *Schima superba* and *Pinus massonina* were planted on a degraded meadow established by *Miscanthus sinensis*.
N1	A xere mesophilous herbosa (ca. 20 years), dominating grass species included *Miscanthus sinensis, Eriochloa, Ophiurolides, Eragrostis bulbillifera*, which had been naturally regenerated following a severe logging
N2	A natural evergreen broad-leaved forest (over 100 years, undisturbed is equal to control), dominating species included *Castanopsis sclerophylla, Schima superba.*

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Soil faunal sampling was carried out in October 2005. In each type, three replicate plots were sampled Soil macroarthropods were sampled using the standard Tropical Soil Biology and Fertility (TSBF) methodology [1]. Each plot was sampled by means of two transects separated by 10m, and each transect included six sampling points separated by 5m. Soil monoliths of 25cm×25cm×20cm were excavated and separated into litter (if present), 0-10cm and 10-20cm, from which macroarthropods were recovered by hand sorting and preserved in 70% ethyl alcohol. Specimens were identified at the order level [10].

Soil samples for chemical analysis were taken simultaneously. Samples were collected at 10 sampling points per plot using a drill corer (0–20 cm depth) and pooled, air-dried and finally sieved (2 mm mesh size). The analytical methods were the international standard methods as adopted and published by the Institute of Soil Science, Chinese Academy of Sciences [6]. Soil organic matter (SOM) was determined on the basis of oxidation with potassium dichromate in a heated oil bath. Total nitrogen (N_{total}) was measured according to the semi micro Kjeldahl method. pH was determined using a suspension of 1:5 soil: water ratios.

The significance of the difference in abundance of each taxonomic group was tested by the one factorial analysis of variance, data were log-transfored or square–root-transformed prior to analysis, if needed to fulfill the assumptions of the ANOVA. Tukey's HSD test (honestly significant difference test) was used as post hoc test, data shown in table are untransformed values. For soil chemical parameters, significant differences were tested by ANOVA followed by Tukey-tests. Correlations between abundances and chemical parameters were analyzed by means of the Spearman Rank Order Correlation Coefficient.

RESULTS

Total abundance of soil macroarthropods changed dramatically among these 5 types (Table 2). It was less in all *P.massoniana* plantations (P1, P2 and P3) than in either N1or N2. In N1 and N2, the most abundant taxon was Termite, which reached abundance of 928 ind m^{-2}, and 738.7 ind m^{-2}, respectively (Table 2). The effects of *P.massoniana* plantations on faunal communities may vary depending on the taxon considered, of the taxa in which differences were found, Hymenoptera and Termite were less in all *P.massoniana* plantations (P1, P2 and P3) than in either N1 or N2.

Changes in soil chemical parameters were indicative of restoration effects. SOM, pH and N_{total} were significantly lower in all *P.massoniana* plantations (P1, P2 and P3) as compared with either N1 or N2 (Table 3).

Statistically significant correlation coefficients ($P < 0.05$) for soil parameters and the abundance of soil macroarthropods were summarized in Table 4. Correlation analysis indicated that soil pH significantly positively correlated with total abundance of macroarthropods ($P = 0.005$), abundance of Hymenoptera ($P = 0.003$) and Termite ($P=0.04$), Soil organic matter (SOM) significantly positively correlated with abundance of Araneae ($P=0.002$) and Coleoptera larvae ($P=0.033$), N_{total} significantly positively correlated with Araneae ($P=0.01$) and Hymenoptera ($p=0.04$).

Table 2. Abundance (ind m^{-2}) of soil macroarthropods in different types of restoration in Ultisol, Subtropical China.

Taxa	P1	P2	P3	N1	N2
Araneae	32(11) b[a]	32(8.3) b[b]	36(11.2) b	35.2(21.1)b	141.3(49.1) a
Coleoptera adults	4.6(3) b	58.7(15.8) a	20(5.9) ba	41.6(23)a	40 (6.9)a
Coleoptera larvae	77.7(28.9) b	16(5.8) bc	168(25.5) a	51.2 (25)b	258.7 (33.4)a
Hymenoptera	43.4(9.7) b	69.3(45.7) b	64(37.0) b	188.8(74.6) a	274.7(91.5) a
Termite	0(-) d	162.7(111.7) c	0(-) d	928(762.9) a	738.7(583.3) b
Diptera larvae	43.4(27.7) a	0 (-)c	14(4.7) b	6.4(3.9) b	50.7(13.3) a
Diplura	2.3(2.3)	8(3.6)	0(-)	0(-)	8(3.6)
Hemiptera	2.3(2.3)	2.7(2.7)	18(10.2)	0(-)	2.7(2.7)
Orthoptera	2.3(2.3)	8(5.5)	20(20)	0(-)	0(-)
Lepidoptera	0(-)	2.7(2.7)	4(2.6)	0(-)	2.7(2.7)
Symphyla	0(-)	0(-)	0(-)	16(16)	0(-)
Blattoptera	16(4.9) bc	2.7(2.7) c	102(25.8) a	0(-) c	37.3(12.2) b
Chilopoda	11.4(4.8)	16(10.7)	18(6.6)	19.2(6.4)	8(8)
Diplopoda	2.3(2.3)	2.7(2.7)	16(9.6)	0(-)	0(-)
Total	237.7(47.2) b	386.7(117.1)b	482(82.7) b	1286.4(737.8)ba	1562.8(566.5) a

[a] Different letters denote significant differences among different stages ($P < 0.05$)
[b] Values in parentheses represent Standard error

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Table 3. Soil chemical parameters in different types of restoration in Ultisol, Subtropical China

Parameters	P1	P2	P3	N1	N2
SOM (mg g^{-1})	14..82 c[a]	14.98 c	15.22 bc	15.38 b	26.74 a
pH	4.61c	4.62c	4.64bc	4.68ab	4.73a
N_{total} (mg g^{-1})	0.8bc	0..83bc	0.85bc	0.89b	1.35a

[a] Different letters denote significant differences among different stages ($P < 0.05$)

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DISCUSSION

The results of the study show that characteristics of the soil macroarthropods community differentiated much between these *P.massoniana* plantations (P1, P2, P3) and natural regenerated mesophilous herbosa (N1). These differences were evident in the total abundance of soil macroarthropods and in the abundance of major taxonomic of soil macroarthropods, including Hymenoptera, Termite, which rarely reach the values shown by natural regenerated mesophilous herbosa even ca. 20 years after planting. These *P.massoniana* plantations had a significantly lower level of pH, SOM and N_{total} and show enhanced acidity when compared to N1, as well as limited improvement in chemical properties, which were related to soil macroarthropods [8]. Total abundance of soil macroarthropods and abundance of Termite were significantly correlated with pH, and the abundance of Hymenoptera was significantly correlated with either pH or N_{total}. These results suggest that the differences in abundance of soil macroarthropods in degraded red soil may be explained, in part, on the basis of soil parameters which are sensitive to *P.massoniana* plantations and the *P.massoniana* plantations may not be an ideal plantation for restoration of the eroded Ultisol, Subtropical China.

Acknowledges

We thank Prof. Xiaoyue Hong for his assistance, and we are also grateful to the staff of the soil ecology laboratory of Nanjing Agricultural University for their continuous help.

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Received: September, 2007; accepted: June, 2008.