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Changes in soil physico-chemical properties, enzyme activities and soil microbial communities under *Mimosa pudica* invasion

RUILONG WANG[1,2†], TINGTING DAI[1,2†], GUOMING QUAN[1,2,3†] and JIAEN ZHANG[1,2*]

Department of Ecology, College of Natural Resources and Environment,
South China Agricultural University, Guangzhou 510642, China
E. Mail: jeanzh@scau.edu.cn, rlw2009@gmail.com

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ABSTRACT

We studied the activity of soil enzymes, soil physico-chemical properties and soil microbial communities in 4-areas divided according to the invasive intensity of *Mimosa pudica*. Soil organic matter, pH, total N, P, and K, available N contents were higher in the heavily invaded area than those in the newly invaded area, non-invaded area or native vegetation area. Compared to the native vegetation area, *M. pudica* invasion significantly increased the soil urease, invertase, protease, catalase and cellulase in the heavily invaded area. Soil microbial community functional diversity was studied and compared using BIOLOG-ECO plates. The BIOLOG results indicated that Shannon index, McIntosh index, Simpson index and Richness index of microbial communities in the heavily invaded area and newly invaded area were higher than those in the non-invaded area. But the Pielou's evenness index in the heavily invaded area and newly invaded area were lower than that in the non-invaded area. Our results indicate that *M. pudica* changes the soil physico-chemical properties and soil microbial communities, thus creating favorable soil environment to benefit its further invasion.

Key words: Invasion, *Mimosa pudica*, soil enzyme activity, soil microbial community, soil physical-chemical property

INTRODUCTION

Rapid expansion of invasive plants in natural and agricultural ecosystems is threatening biodiversity and ecosystem health world wide (20,22,29,34). Exotic plant invasion may alter the soil characteristics as well as soil microbial communities (3,11,24,27,37). *Falcataria moluccana* invasion alters the composition and function of soil communities in addition to the forest structure and biogeochemistry (1). Similarly soil biota alteration after invasion by *Ageratina adenophora* is reported to *be* an important part of its invasion process to benefit itself as well as to inhibit the native plants (26). The invasion of *Mikania micrantha* into the evergreen broadleaved forests in South China has changed most of the soil characteristics (19). Alien invasive plants can therefore strongly alters the soil microbial community composition (14,17,33,39).

*Corresponding author, [1]Key Laboratory of Agro-Environment in the Tropics, Ministry of Agriculture, South China Agricultural University, Guangzhou 510642, China. [2]Key Lab. of Agroecology and Rural Environment of Guangdong Regular Higher Education Institutions, South China Agricultural University, Guangzhou 510642, China.[3]Department of Urban Construction Engineering, Guangzhou City Polytechnic, Guangzhou 510405, China.† These authors contributed equally to this work.

Mimosa pudica L. (Mimosaceae) is a creeping perennial herb. It is a native of Middle America and is now widely distributed in all tropical areas (24). It is now more prevalent in Hainan province, China. Its invasion has caused severe damage to the native ecosystem and great economic losses (41). Currently, information is lacking on the responses of soil properties to *M. pudica* invasion. This study aimed to understand the response in soil properties and soil microbes to invasion by this weed under different invasion intensities.

METHODS AND MATERIALS

The study area was located in the Yifengpo (Wenchang city, Guangdong province, south China) (N 19º61', E 110º72'), where *M. pudica* has been dominant for > 10 years. The mean annual temperature and rainfall in the area are 23.9□ and 1529.8 mm, respectively, and the area is characterized by tropical monsoon climate. Four sites were selected in the study area and classified by *M. pudica* coverage (Table 1). (i) Heavily invaded area dominated by *M. pudica.* (ii) Newly invaded area dominated by a mixture of *M. pudica* and native plants. (iii) Non-invaded area with some native plants and (iv) Barren area with no plants or the weed. *M. pudica* cover was more than 97.2% in the heavily invaded site and between 35% and 45% in the newly invaded site. Four plots (20 m × 20 m each) were randomly set at each site and the distances between plots were about 200-300 m.. The soils were sieved through a 2 mm mesh sieve and stored in sealed plastic bags at -18□ until further analysis. All experiments were replicated thrice.

Table 1.. The weeds status in the sampling sites

Site type	Coverage (%)		Density (plants/m^2)	Plant height (cm)
	Native plants	Native plants		
Heavily invaded area	2.3	97.2	26.2	58
Newly invaded area	30.7	40.3	15.4	41
Native vegetation area	58.9	0	36.4*	27*
Non-invaded area	0	0	0	0

* These two data represented the density and height of native plants.
All data represent means. Values followed by different letters in the same row indicate significant differences (P < 0.05) according to Duncan's multiple range test.

Soil characteristics: Soil moisture was measured gravimetrically after oven-drying at 105°C for 24 h (15). Soil organic matter, pH, total N, available N, total P, available P, total K and available K were determined in all soil samples. Soil pH was measured using a glass electrode, of a suspension of soil in water (1:2.5 w/v,30 min). The soil organic matter content was determined by the potassium dichromate method (15). Total N was analyzed by the Kjeldahl method (4) and available N by alkali-diffusion Method. Total K by NaOH melt flamer method (21). Available K by using th NH_4OAc method, available P was measured by hydrochloric acid-sulfuric acid extraction method. Total soil P was determined by the Mo-Sb colorimetric method (21). Three independent soil samples were used for each treatment. All these parameters were determined on soil dry weight basis and all measurements were in triplicate.

Soil enzyme activities: Soil catalase activity was determined using potassium permanganate titration method (23), urease activity by phenol-sodium hypochlorite colorimetric method (23,38). Invertase and cellulase by the 3,5-dinitrosalicylic acid colorimetric method (38) and protease by the ninhydrin colorimetric method (23). The soil enzyme activities per unit of soil were determined on dry weight basis. Each test was done in triplicate.

Soil microbial community: Functional diversity of soil microbial communities was determined using BIOLOG-ECO method (28). Overall colour development in BIOLOG plates was analyzed as Average Well Color Development (AWCD). The Shannon-Wiener index, Simpson index, Pielou's evenness index and McIntosh index and Richness index of the different areas were measured (13,36). Soil microbial biomass C, soil microbial biomass N and soil microbial biomass P were estimated by chloroform fumigation extraction method (5). All experiments were conducted with three independent replicates.

Statistical analysis: All statistical analyses ($P < 0.05$) were done by one-way ANOVA followed by a Duncan's multiple range test using the SPSS 13.0 software package (SPSS, Chicago, IL, USA).

RESULTS AND DISCUSSION

Soil chemical and physical properties

All soil physical and chemical characteristics varied significantly in the soils at four levels of invasion (Figure. 1). Soil pH increased from 4.4 to 5.5 in the heavily invaded area. The total N and available K in the heavily invaded area increased by 37.9% and 37.3% respectively, than those in the newly invaded area but total K and available P was not significantly altered in different areas. There are reports about the changes in soil characteristics after invasion by different weeds. Long term invasion by *Wedelia trilobata* is reported to alter soil physical-chemical properties and increases the available plant nutrients content, increase soil organic matter, total N, available K and P (16). *Falcataria moluccana* invasion is also reported to increase soil total P content at the 50 year-old site, (1). It is presumed that *Falcataria* invasion increased soil P, by mining additional P from unweathered rock (1). The soil organic carbon was also changed significantly by the invasion of exotic grass *Spartina alterniflora* (35). *Amaranthus viridis* invasion is also reported to significantly increase the soil total P and soluble P in Senegal (30). *Agropyron cristatum* invasion decreased soil total N at the northern edge of the Great Plains, USA. (6). Similarly, total N content was significantly lower, whereas the contents of NO_3^--N and total P were significantly higher in *E. adenophorum* invaded area (19). In our study, the contents of soil organic matter, total N, P, available N, K and P in the heavily invaded area and newly invaded area were all significantly higher than those in the non-invaded area and native vegetation area, suggesting that *M. pudica* modifies the soil physico-chemical properties by invasion. Many studies have indicated that plant invasions were associated with elevated or fluctuating nutrient resource levels (8,9). *M. pudica* being a legume, can fix nitrogen and hence, is helpful in improving the soil nitrogen level. The roots of *M. pudica* may produce exudates containing some allelochemicals (24) which may

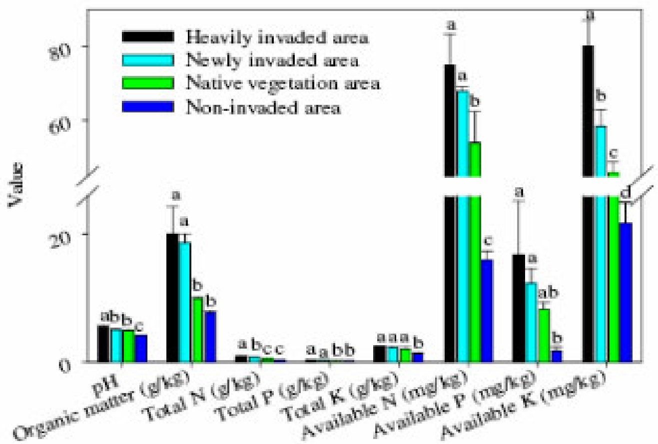

Figure 1. The effects of *M. pudica* invasion on soil physico-chemical properties. All data represent means + SD. Values followed by different letters in the same row indicate significant differences ($P < 0.05$) according to Duncan's multiple range test.

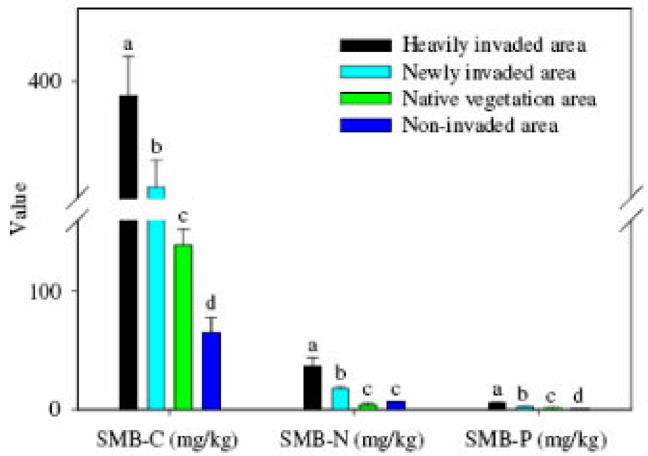

Figure 2. The effects of *M. pudica* invasion on soil microbial biomass C, N and P of soil. *SMB: Soil microbial biomass. All data represent means + SD. Values followed by different letters in the same row indicate significant differences ($P < 0.05$) according to Duncan's multiple range test.

Table 2. The effects of *M. pudica* invasion on soil enzyme activities

Soil enzyme activity	Heavily invaded area	Newly invaded area	Native vegetation area	Non-invaded area
Urease (μg NH_3-N g^{-1} $24h^{-1}$)	163.31±9.88 a	128.17±6.97 b	85.02±4.06 c	40.70±3.48 d
Protease (μg NH_3-N g^{-1} $24h^{-1}$)	1.47±0.03 a	1.41±0.01 b	1.36±0.01 c	1.07±0.01 d
Invertase (mg glucose g^{-1} $24h^{-1}$)	7.96±0.29 a	5.07±0.19 b	4.39±0.11 c	2.20±0.10 d
Cellulose (mg glucose g^{-1} $72h^{-1}$)	4.06±0.08 a	3.12±0.05 b	2.50±0.06 c	1.97±0.05 d
Catalase (0.1 N $KMnO_4$ g^{-1} $20min^{-1}$)	0.26±0.02 a	0.16±0.01 b	0.12±0.01 c	0.08±0.01 d

All data represent means ± SD. Values followed by different letters in the same row indicate significant differences ($P < 0.05$) according to Duncan's multiple range test.

enhance the solubility of insoluble soil phosphorus, thereby increasing the phosphorus content in soil. However, this possible mechanism in the soil-plant system needs further research.

Soil enzyme activity: *M. pudica* invasion increased the activities of urease, protease, invertase, cellulase and catalase in the heavily invaded area and newly invaded area (Table 2). Its invasion increased the urease level by 301.25% in the heavily invaded area than that in the non-invaded area. The level of protease significantly increased by 8.08% and 3.68% in the heavily invaded area and newly invaded area, respectively.

Invasive plants are reported to influence the soil habitat and change the plant nutrients status in the native soil by increasing soil enzyme activities (18). It is reported that *F. moluccana* invasion increased the acid phosphatase activities to 490 µmol g^{-1} soil h^{-1} compared to 30-60 µmol g^{-1} soil h^{-1} in native dominated stands (1). The growth of *W. trilobata* significantly decreased the urease activity, but there was no effect on catalase (16). The invasion by the exotic plant, *Eupatorium adenophorum* significantly increases the levels of soil acid phosphatase, urease, peroxidase and polyphenol oxidase (32) and these changes are reported to play an important role in *E. adenophorum* invasion (32). The levels of rhizosphere urease, invertase and acid phosphatase at fruiting stage of the invasive plant *Bidens pilosa* increased significantly, but the nitrate reductase level was reduced (12). Soil enzyme activities were also significantly changed by the invasion of the exotic plant *Mikania micrantha* (19) and the invasion by *Ipomoea cairica* significantly increased the levels of invertase, urease, phosphatase and nitrate reductase (40). Our studies showed that *M. pudica* invasion increased the levels of soil urease, protease, invertase, cellulase and catalase, and this perhaps helps the weed in competition.

Soil microbial biomass: *M. pudica* invasion significantly changed the soil microbial biomass (Figure 2). The soil microbial biomass C in the heavily invaded area, newly invaded area native vegetation area and non-invaded area varied significantly from 390.03, 327.48, 139.39 to 65.20 mg/kg, respectively. The soil microbial biomass P showed a similar trend. The contents of soil microbial biomass N in heavily invaded area and newly invaded area were higher than in the non-invaded area. However, the soil microbial biomass N was not significantly different between the non-invaded and native vegetation areas. The total soil microbial biomass was significantly higher in *M. pudica* invaded sites than in the uninvaded site. The invasive plants are reported to alter the soil microbial biomass. For example, the invasive plant *Eupatorium adenophorum* is reported to release some chemical compounds which decreases the soil microbial biomass and changes the microbial composition (2). Similarly, *F. moluccana* invasion significantly decreased the total microbial biomass C (1).

Functional diversity of soil microbial community

The activity of soil microbial communities was analyzed by the Average Well Color Development (AWCD) (Figure 3). The results indicated that AWCD changed with the progress in incubation time of different treatments in following order: heavily (newly) invaded area > native vegetation area > non-invaded area. Substrates in BIOLOG-ECO plates were divided into 6 groups: carbohydrates, carboxylic acids, polymers, amino acids,

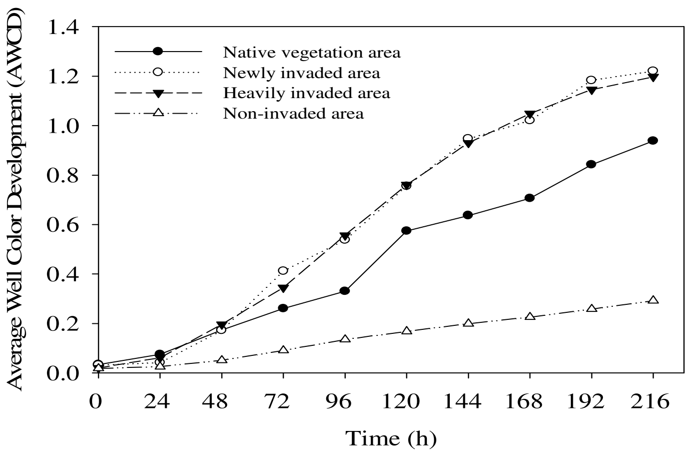

Figure 3. The Average Well Color Development (AWCD) on BIOLOG-ECO plates of soil microbes under *M. pudica*

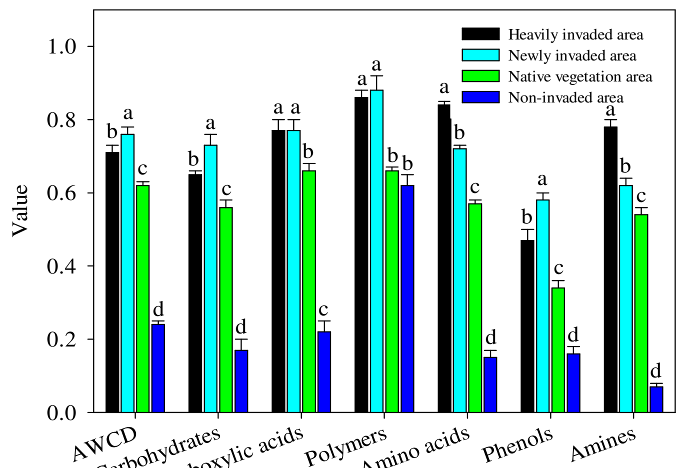

Figure 4. The Average Well Color Development (AWCD) and different carbon sources use efficiency of soil microbial community in the different soil samples. All data represent means + SD. Values followed by different letters in the same row indicate significant differences (P < 0.05) according to Duncan's multiple range test.

phenols and amines (Figure 4). The use of carbohydrates and phenols in the newly invaded area were higher than those in the heavily invaded area, native vegetation area and non-invaded area. There were no significant changes in the carboxylic acids and polymers, between the heavily invaded area and newly invaded area. But the amino acids and amines increased by 47.37% and 44.44% in the heavily invaded area than that in the native vegetation, respectively. *M. pudica* invasion significantly increased the microbial Shannon-Wiener index, McIntosh index, Richness index and Simpson index in the invaded area than those in non-invaded area and native vegetation (Figure 5). Compared to the heavily invaded area, the McIntosh index was significantly decreased by 153.81% and 53.6% in the non-invaded area and native vegetation area, respectively. We found the Pielou's evenness index was lower in the heavily invaded area, newly invaded area and native vegetation area than in non-invaded area. These results indicated that *M. pudica* could significantly change the soil microbial community especially in the in the heavily invaded area.

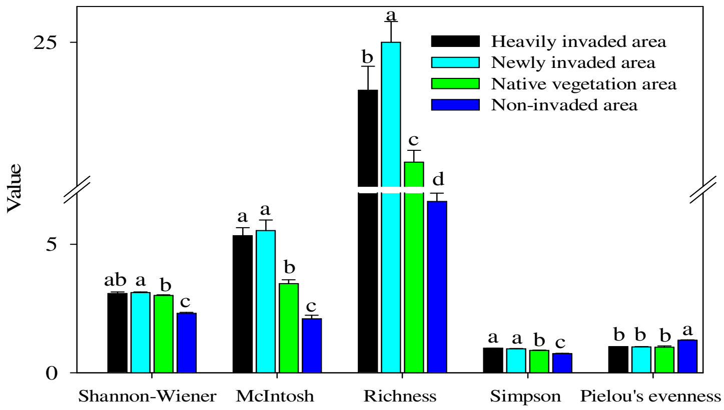

Figure 5. Diversity indices of soil microbial community in different soil samples. All data represent means + SD. Values followed by different letters in the same row indicate significant differences ($P < 0.05$) according to Duncan's multiple range test.

Plant invasions can alter the microbial community structure and nutrients cycling (7,10,25). Invasion by *Eupatorium adenophorum* has been reported to affect the soil microbial community (32). The responses of soil enzyme activities and soil microbes indicate that the biogeochemical effects of *F. moluccana* invasion are pervasive (1). *E adenophorum* invasion changes the soil structure and reduces the biological diversity but its invasion significantly improves the soil nutrients and microbial biomass (31). Our results indicated that the soil microbial community in the *M. pudica* heavily invaded areas and newly invaded areas had changed and differed from native vegetation areas.

CONCLUSIONS

M. pudica invasion influenced the soil properties such as total N, total P, available N, P, K, soil microbial biomass C, N and P. The soil enzyme activities and soil microbial community were also significantly different in the invaded sites compared with the native vegetation areas. These changes in soil properties may have a role in the invasive process of *M. pudica*.

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