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RESEARCH ARTICLE

Effects of intercropping with persimmon on the rhizosphere environment of tea

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Abstract The rhizosphere environment of tea (*Camelllia sinensis* Kuntze) intercropped with persimmon (*Diospyros kaki*) differs from monocultures of tea. A trial was conducted to determine the effects of intercropping with persimmon on root exudates and soil nutrient condition of tea. Amino acid exuded in intercropping was three times higher than that in monoculture. Phenol, phenol/amino acid ration, dissolved sugar, and total organic acid were also lower in intercropping. The value of pH in soil was higher, and soil nutrient condition of rhizosphere, especially available nutrient, was not as well in intercropping as that in tea grown alone. While soil nutrient of non-rhizosphere was better than that in monoculture, tea quality and soil nutrient condition were better in intercropping ecosystem.

Keywords intercropping, tea, persimmon, rhizosphere environment

1 Introduction

Tea (*Camelllia sinensis* Kuntze) is a popular beverage in most countries and its consumption is increasing due to its positive effects on human health. Tea is cultivated in many parts of the humid and sub-humid tropical regions of the world, mainly in acidic soils. The topographty of South Hubei Province, China is typically low in elevation, high temperature, and relatively dry. Bad climate and soil erosion have increasingly led to poor productivity and prevented any further expansion of tea as a sole crop in this region. China, as a center of origin, has a large number of persimmon (*Diospyros kaki*) cultivars. Persimmon forms a closed canopy when mature. Tea is a perennial evergreen shrub that is generally regarded as relatively shade tolerant, and recent trials have demonstrated that tea and persimmon crops are compatible in terms of resource capture.

Intercropping is an honored practice in China and it has been mentioned earlier that intercropping systems could be beneficial. In the past, many studies were carried out on intercrop micro-climate, radiation, physiology, and biochemistry (Ni et al., 1990; Fu et al., 1995; Shen et al., 1995; Zhou et al., 1995; Liu 1997; Liu 1998; Fan and Huang 1999; Huang et al., 1999; Zhou 2001; Liang et al., et al. 2002). However, only few on crop rhizosphere environment (Marschner, 1995; Jing, 1999; Hao et al., 2003), most important for intercropping, have been reported. To achieve this, this study was conducted with the following specific objectives:

(i) identify the contents of main root exudates of different tea systems;
(ii) identify the soil pH value of different tea systems;
(iii) identify the soil nutrient content of the different systems.

2 Materials and methods

2.1 Field experiments

The field experiments were conducted at Hesheng Bridge tea garden of Hubei Province, China. The soil of the field experiment site is brown–red soil. The crops, tea and persimmon, used in the experiments were rebuilt in 1997 and engrafted in March, 1999. The same measurement was applied for both sole cropping and intercropping.

2.2 Collection of root exudates

Three tea samples were respectively selected from the mono

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cropping and intercropping system. The plant roots were then washed with tap water and then with sterilized, deionized water to collect root exudates (Hu et al., 1995). The root exudates solution was immediately filtered, vacuum concentrated to 30 mL and then a little alcohol and deionized water were added to make it 50 mL for amino acid, phenol (Xu and Zheng, 1986), dissolved sugar (Nanjing Agricultural University, 1981), and total organic acid analysis (Zhang, 1981).

2.3 Collection of soil

Six soil samples were collected from the same tea plants, and the bulk soil samples were randomly collected at 0–30 cm depth. The rhizosphere soil was collected by carefully removing the soil adhering to the plant roots (Zhang et al., 2001). Both rhizosphere and bulk soils were air-dried, passed through sieve for the soil nutrient (Nanjing Agricultural University, 1981) and pH analysis (Agro-chemistry Specialty Committee of China Soil Academy, 1983).

3 Results

3.1 Composition of root exudates

Concentration of root exudates, expressed in root dry weight, in the intercropping system was significantly different from that of the sole cropping system (Table 1). In the intercropping system, amino acid in the root exudates was approximately three times higher than that in the sole cropping system. While the values of phenol, dissolved sugar, and total organic acid in intercropping system were lower than those inthe sole cropping system, decreasing by 45.45%, 30.77%, 38.91%, respectively. Phenol/amino acid ratio in the root exudates for sole cropping was five times higher than that in the intercropping system.

Table 1 Main root exudates (mg/g dried root weight) of different tea ecosystem

Cropping model	Amino acid	phenol	Phenol/amino acid ration	Dissolved sugar	Total organic acid[a]
Intercropping tea garden	0.941	0.018	0.02	1.98	1.68
Sole cropping tea garden	0.313	0.033	0.11	2.86	2.75

[a] The estimation of total organic acid was made on malic acid.

3.2 Value of pH in soil

Same variations were found on the value of soil pH in the rhizosphere and bulk soil between the intercropping and sole cropping systems (Table 2). Compared to the sole cropping system, a slight increase was observed in the soil pH for the intercropping system, from 4.5 to 4.7 of rhizosphere and from 4.7 to 4.9 of bulk soil, respectively.

Table 2 Values of soil pH in different tea ecosystems

Cropping model	Intercropping tea garden		Sole cropping tea garden	
	Rhizosphere	Bulk	Rhizosphere	Bulk
pH	4.70	4.87	4.51	4.69

The different changes also occurred in the same system. The value of soil pH in the rhizosphere was 0.2 higher than that in the bulk soil for the intercropping system and 0.2 lower than that in the bulk soil in the sole cropping system.

3.3 Changes in soil nutrient status under different cropping systems

Different crop management practices led to several changes in the soil nutrient status (Table 3). In terms of the bulk soil for intercropping, available nitrogen, phosphorus, and potassium were higher than those in sole cropping, and the reverse for rhizosphere.

In the sole cropping system, soil organic matters, soil nitrogen, and phosphorus were higher in the rhizosphere than those in the bulk soil, and also the same in the intercropping system.

Table 3 Soil nutrient status of different tea ecosystem

Cropping model	Nutrient indexes	Rhizosphere	Bulk
Intercropping tea garden	Organic matter / ($g \cdot kg^{-1}$)	20.53	18.74
	Total nitrogen / ($g \cdot kg^{-1}$)	0.54	0.52
	Total phosphorus / ($g \cdot kg^{-1}$)	0.30	0.30
	Available nitrogen / ($mg \cdot kg^{-1}$)	87.95	82.18
	Available phosphorus / ($mg \cdot kg^{-1}$)	3.79	2.96
	Available potassium / ($mg \cdot kg^{-1}$)	162.09	161.60
Sole cropping tea garden	Organic matter / ($g \cdot kg^{-1}$)	20.15	18.50
	Total nitrogen / ($g \cdot kg^{-1}$)	0.52	0.50
	Total phosphorus / ($g \cdot kg^{-1}$)	0.31	0.28
	Available nitrogen / ($mg \cdot kg^{-1}$)	102.23	77.98
	Available phosphorus / ($mg \cdot kg^{-1}$)	5.57	2.67
	Available potassium / ($mg \cdot kg^{-1}$)	186.80	156.68

4 Discussion

Tea is a kind of shade-tolerant species, when exposed to the strong light, its photosynthetic efficiency will decrease and its quality will be negatively affected. In the intercropping system, the leaves of persimmon are large enough to shade the tea, which is favorable to the increase in nitrogen metabolism and the decline of carbon metabolism (Chen, 1989). Therefore, the nitrogen and amino acid accumulation in tea obviously increase, but the amount of carbonaceous compounds and phenol decreases. Because of the advantage of the habitat, tea can grow better. The good habitat enhances its root vigor and its absorbing, assimilating, and metabolizing ability, which makes it easier to synthesize more amino acid. As a result, amino acid in roots exudates increases (Tang et al., 1997). The quality of tea improves because the decrease in the phenol/amino acid ratio and dissolved sugar lessen the bitter taste of green tea (Tian et al., 2002). And in the intercropping system, root exudates lessen the amount of organic acid, consequently, less aluminium is accumulated in the soil. Soil acidification and degeneration can possibly be prohibited at a certain extent.

Tea grows in the regions of acidic soils with pH value as 5.0–6.0 (Wang, 1995). At these regions with low pH values, nutrient components are highly soluble and can be absorbed well by tea. However, seven percent of all the tea garden soil in China has a pH value lower than 5.0. Soil acidification becomes a restricting factor for the high yield and good quality of tea (Liu et al., 1994). In the intercropping system, root exudates can lessen organic acid, therefore, this system can effectively abate soil acidification and provide a better condition for tea growth.

The physical, chemical, and biological characteristics of rhizosphere soil are different from those of bulk soil, because the rhizosphere environment is affected by the assimilation and exudation of plants, cell desquamation of root, and activities of microorganism around the root (Philippe, 2001; Chen et al., 2002). And these factors have direct influence on the available nutrients in the soil and their assimilation by plants. Plants can exudate organic compounds such as carbon and nitrogen during their growth, which, on the one hand, provides energy for microorganism around the root and improves their biological activities and nutrition transition. On the other hand, organic compounds exudated by plants can promote those undissolved elements to be soluble ones. The rate of nutrient assimilation of tea is slower than that of nutrition transition, therefore, a distribution pattern of soil, with higher available nutrients near the root and far lower from the root, is observed. Under the conditions of shade, tea grows better with higher root activities and demands more nutrition. Thus, relative low nutrition in rhizosphere soil appears although there is high nutrition in the bulk soil.

Compared to the sole cropping system, the intercropping system has higher nutrient content in the bulk soil. Persimmon intercropped in the tea garden lessens the impact rainfall to the soil, improves the physical feature of the soil and also increases the litter, and decreases surface runoff making rainfall penetrate into deep into the soil, which not only prevents nutrient lose because of surface runoff but also increases the nutrient input from rainfall into the soil. The humus acid formed by litter can enhance the nutrient availability by dissolving the undissolved elements, while the release of nutrients becomes slow and durative because of the decline of light radiation in the intercrop, which avoids nutrients to be released too fast and to be wasted t too much.

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