

The effect of monoculture peanut and cassava/peanut intercropping on physical and chemical properties in peanut rhizosphere soil under the biochar application and straw mulching

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Abstract. Cassava/peanut intercropping is a popular cultivation method in the south China, with the advantage of apparent yield increase. In order to analyze the effect of cassava/peanut intercropping on physical and chemical properties in peanut rhizosphere soil, the physical and chemical properties were investigated under the biochar application and straw mulching. The result showed that the Ph, organic materials content, available phosphorus content, available potassium content in peanut rhizosphere under the biochar application increased by 7.06%, 94.52%, 17.53%, 25.08% (monoculture peanut) and 8.47%, 89.94%, 17.93%, 22.87% (cassava/peanut intercropping) compared with Ck in the same planting patterns. In addition, the available nitrogen content, organic materials content, available phosphorus content, and available potassium content in peanut rhizosphere under the straw mulching increased by 89.80%, 60.92%, 5.95%, 9.98% (monoculture peanut) and 67.09%, 52.34%, 6.96%, 11.94% (cassava/peanut intercropping) compared with Ck in the same planting patterns. In the same treatment conditions, bulk density in peanut rhizosphere soil decreased and porosity and saturated permeability coefficient increased slightly. But there was no significant difference between the two. At the same time, cassava/peanut intercropping could increase soil nutrients. Therefore, it is beneficial to apply biochar and straw mulching, and the suitable intercropping row spacing is more beneficial to increase soil nutrient contents.

1. Introduction

The sustainable utilization of farming land is the base of actualizing sustainable development of agricultural production, and the basis of the agricultural development relies on plowing. Plenty of scientific researches^[1-2] indicated that a variety of conservation tillage could improve organic matter content in the soil and soil structure, which was represented by biochar and straw mulching.

Peanut/cassava intercropping is a special planting pattern in Southern China. It can improve multiple crop indexes and the utilization ratio of arable land and it can also increase planting benefit. Currently, some studies indicated that peanut/cassava intercropping could raise the output. However, the influence of soil micro-ecological environment is still unknown. Therefore, the effect of monoculture peanut and cassava/peanut intercropping on physical and chemical properties in peanut rhizosphere



soil under the biochar application and straw mulching were studied in this paper to offer the theory support and practice guidance for improvement of soil structure in Guangzhou.

2. Materials and methods

2.1 Test materials

The experiment was carried out at the end of March 2016 to the end of July in Zengcheng research base of South China Agricultural University (113°29'4"~113°59'44"E, 23°4'42"~23°37'20"N) and climate was typical marine monsoon climate. The Yuyou 7 (Peanut) and Huanan 205 (Cassava) was tested in the field experiment. Biochar was from Sanli corporation, and straw was from the experimental base of South China Agricultural University. At the beginning of experiment, the average value of pH in soil was 5.5, the content of organic matter was 12.13mg/kg, the content of total nitrogen was 317.60mg/kg, the content of total phosphorus was 292.68mg/kg, the content of total potassium was 2236.61kg/kg, the content of alkali hydrolyzable nitrogen was 27.13mg/kg, the content of available phosphor was 1.14mg/kg and the content of available potassium was 64.14mg/kg.

2.2 Test design

The trial began on July 8, 2016, and ended on March 8, 2016, four months, in Zengcheng research base of South China Agricultural University. Three treatments were established, including blank control (Ck), straw mulching (4500kg/ hm²) and biochar application (1000kg/ hm²). Plot area was 4m² with the random arrangement and three replications. P, K and 70%N were applied as base fertilizers. The application of biochar and straw were directly covered on the soil surface. Four rows peanuts were planted in the peanut monoculture treatment, where the distance from the edge was 10cm, the distance of the edge row was 23cm while that of the internal row was 40cm. A peanut seed per hole was planted at a distance of 20cm. Peanut intercropping included one-row cassava and two-rows peanuts, cassava row was in the middle of the plot, peanut row was on the edge of the plot with a distance of 10cm to edge, and the distance between peanut and cassava was 40cm. A cassava seedling was planted at a distance of 1m, and a peanut seed per hole was planted at a distance of 20cm. At the end of the trial period, collecting the rhizosphere of peanut. The soil was air-dried and sifted.

2.3 Analysis and the method of determination

2.3.1 Determination of soil physical properties. Soil bulk density was determined by cutting-ring method^[4]. Porosity was calculated by the bulk density and specific gravity of the soil^[4]. Soil saturated permeability coefficient was calculated according to Darcy's theorem^[4].

2.3.2 Determination of soil chemical properties. Soil pH was measured by the electric potential method and the water-soil ratio was 2.5:1^[3]. Available nitrogen content adopted alkaline hydrolysis diffusion^[4]. Organic matter content adopted potassium dichromate-volumetric method^[4]. Available phosphorus content adopted extraction-molybdenum antimony colorimetric method^[4]. Available potassium content was determined by flame atomic absorption spectrophotometry^[4].

2.4 Data analysis

Using Excel 2007 to analyze the data and draw the chart and the data in all graphs was the average of the three repetitions. All the data were treated with SPSS 17.0 statistical package, The descriptive statistic analysis was used according to the type of the data, significance test used t-test and variance analysis.

3. Result analysis

3.1 The effect of monoculture peanut and cassava/peanut intercropping on physical properties in peanut rhizosphere soil under the biochar application and straw mulching

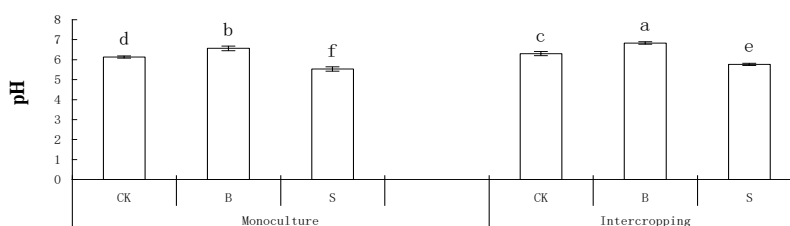
Table 1 showed that in the same planting patterns, biochar application and straw mulching could reduce bulk density in peanut rhizosphere soil and increase porosity in peanut rhizosphere soil. Furthermore, to a certain extent, both could improve the permeability in peanut rhizosphere soil. The results showed that bulk density and porosity and saturated permeability coefficient didn't reach a significant level between monoculture peanut and cassava/peanut intercropping ($P > 0.05$).

Table1. The effect of monoculture peanut and cassava/peanut intercropping on physical properties in rhizosphere soil under the biochar application and straw mulching

Planting pattern	Treatments	Bulk density (g/cm^3)	Porosity (%)	Saturated permeability coefficient ($10^{-3}\text{cm}/\text{s}$)
Monoculture peanut	Ck	1.239 \pm 0.061a	61.627 \pm 0.939b	2.650 \pm 0.327c
	Biochar application	0.884 \pm 0.054b	67.987 \pm 0.704a	8.117 \pm 0.622a
	Straw mulching	0.952 \pm 0.024b	66.500 \pm 0.576a	4.783 \pm 0.510b
Cassava/peanut intercropping	Ck	1.203 \pm 0.117a	62.533 \pm 0.887b	2.673 \pm 0.100c
	Biochar application	0.840 \pm 0.089b	68.420 \pm 0.997a	8.307 \pm 0.169a
	Straw mulching	0.857 \pm 0.095b	67.660 \pm 0.885a	4.953 \pm 0.074b

3.2 The effect of monoculture peanut and cassava/peanut intercropping on chemical properties in peanut rhizosphere soil under the biochar application and straw mulching

3.2.1 The effect of monoculture peanut and cassava/peanut intercropping on pH in peanut rhizosphere soil under the biochar application and straw mulching. Figure 1 showed that in the same planting patterns, pH of the plots of biochar application in peanut rhizosphere soil increased by 7.06%(monoculture peanut) and 8.47%(cassava/peanut intercropping) respectively compared with Ck ($P < 0.05$). PH of the plots of straw mulching in peanut rhizosphere soil reduced by 9.78% (monoculture peanut) and 8.46%(cassava/peanut intercropping) respectively compared with Ck ($P < 0.05$). Furthermore, under the same treatment conditions, pH in peanut rhizosphere under intercropping was lower than that under monoculture.



Note: the capital letters indicate different treatment conditions, Ck represents blank treatment, B represents biochar application, S represents straw mulching. The data with different little letters show a significant difference ($P < 0.05$). The same below.

Fig.1 The effect of monoculture peanut and cassava/peanut intercropping on pH in rhizosphere soil under the biochar application and straw mulching

3.2.2 The effect of monoculture peanut and cassava/peanut intercropping on carbon and nitrogen in peanut rhizosphere soil under the biochar application and straw mulching

3.2.2.1 The effect of monoculture peanut and cassava/peanut intercropping on available nitrogen in

peanut rhizosphere soil under the biochar application and straw mulching. Figure 2 showed that under the same planting patterns, available nitrogen content of the plots of biochar application in peanut rhizosphere soil reduced by 54.69%(monoculture peanut) and 59.49%(cassava/peanut intercropping) respectively compared with Ck($P<0.05$). Available nitrogen content of the plots of straw mulching in peanut rhizosphere soil increased by 89.80%(monoculture peanut) and 67.09%(cassava/peanut intercropping) respectively compared with Ck($P<0.05$). Furthermore, under the same treatment conditions, available nitrogen content in peanut rhizosphere soil under intercropping was higher than that under monoculture($P<0.05$).

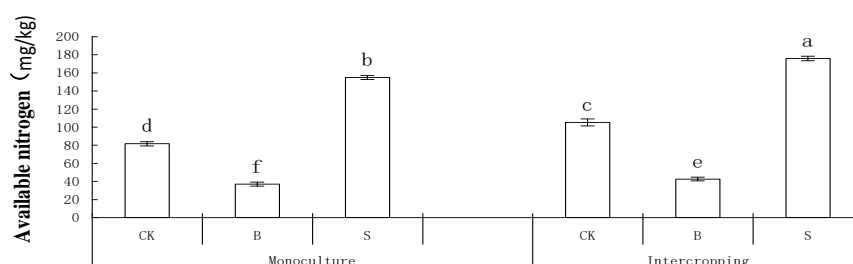


Fig.2 The effect of monoculture peanut and cassava/peanut intercropping on available nitrogen in rhizosphere soil under the biochar application and straw mulching

3.2.2.2 The effect of monoculture peanut and cassava/peanut intercropping on organic matter in peanut rhizosphere soil under the biochar application and straw mulching. Figure 3 showed that in the same planting patterns, organic matter content of the plots of biochar application in peanut rhizosphere soil increased by 94.52%(monoculture peanut) and 89.94%(cassava/peanut intercropping) respectively compared with Ck($P<0.05$). Organic matter content of the plots of straw mulching in peanut rhizosphere soil increased by 60.92%(monoculture peanut) and 52.34%(cassava/peanut intercropping) respectively compared with Ck($P<0.05$). Furthermore, under the same treatment conditions, organic matter content in peanut rhizosphere soil under intercropping was higher than that under monoculture($P<0.05$).

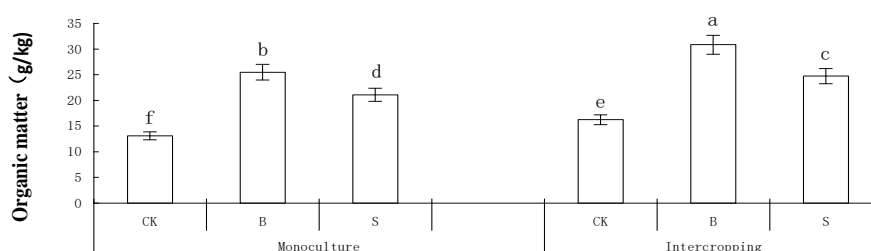


Fig.3 The effect of monoculture peanut and cassava/peanut intercropping on organic matter in rhizosphere soil under the biochar application and straw mulching

3.2.3 The effect of monoculture peanut and cassava/peanut intercropping on available phosphorus in peanut rhizosphere soil under the biochar application and straw mulching. Figure 4 showed that in the same planting patterns, biochar application and straw mulching can prominently improve available phosphorus content in peanut rhizosphere soil. The results showed that available phosphorus content of the plots of biochar application in peanut rhizosphere soil increased by 17.53%(monoculture peanut) and 17.93%(cassava/peanut intercropping) respectively compared with Ck($P<0.05$). Available phosphorus content of the plots of straw mulching in peanut rhizosphere soil increased by 5.95%(monoculture peanut) and 6.96%(cassava/peanut intercropping) respectively compared with

Ck($P < 0.05$). Furthermore, In the same treatment conditions, Available phosphorus content in peanut rhizosphere soil under intercropping was higher than that under monoculture($P < 0.05$).

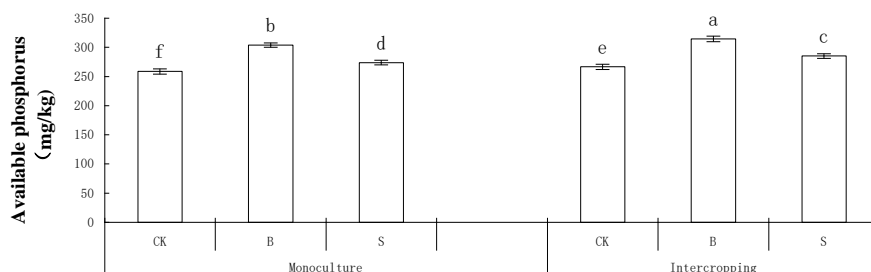


Fig.4 The effect of monoculture peanut and cassava/peanut intercropping on available phosphorus in rhizosphere soil under the biochar application and straw mulching

3.2.4 The effect of monoculture peanut and cassava/peanut intercropping on available potassium in peanut rhizosphere soil under the biochar application and straw mulching. Figure 5 showed that in the same planting patterns, biochar application and straw mulching can prominently improve available potassium content in peanut rhizosphere soil. The results showed that available potassium content of the plots of biochar application in peanut rhizosphere soil increased by 25.08%(monoculture peanut) and 22.87%(cassava/peanut intercropping) respectively compared with Ck($P < 0.05$). Available potassium content of the plots of straw mulching in peanut rhizosphere soil increased by 9.98%(monoculture peanut) and 11.94%(cassava/peanut intercropping) respectively compared with Ck($P < 0.05$). Furthermore, in the same treatment conditions, Available potassium content in peanut rhizosphere soil under intercropping was higher than that under monoculture($P < 0.05$).

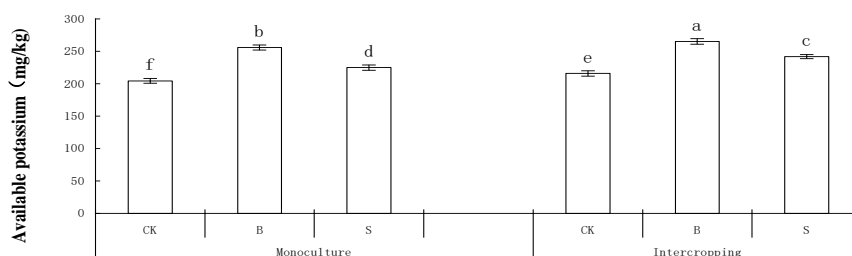


Fig.5 The effect of monoculture peanut and cassava/peanut intercropping on available potassium in rhizosphere soil under the biochar application and straw mulching

4. Discussion

4.1 The effect of monoculture peanut and cassava/peanut intercropping on physical properties in peanut rhizosphere soil under the biochar application and straw mulching

Biochar possesses loose texture, so it can directly improve firmness and reduce bulk density in peanut rhizosphere soil. Eastman's study^[5] showed that bulk density decreased by 7.8% and total porosity increased by 6.4% in the soil after using biochar 25t/hm⁻². This is consistent with results of this study. Straw mulching can reduce bulk density in peanut rhizosphere soil and increase the total porosity and permeability, because the humus is porous, its viscosity is far less than the viscous soil clay, so it can make soil loose and reduce tillage resistance^[6].

4.2 The effect of monoculture peanut and cassava/peanut intercropping on chemical properties in peanut rhizosphere soil under the biochar application and straw mulching

4.2.1 The effect of monoculture peanut and cassava/peanut intercropping on pH in peanut rhizosphere

soil under the biochar application and straw mulching. PH in peanut rhizosphere soil under cassava/peanut intercropping is significantly lower than that under monoculture, because after intercropping of cassava and peanut, the interaction between root systems will induce the secretion of H^+ and OH^- in the root system^[7]. Applying biochar to increase peanut rhizosphere soil pH may be due to the different concentrations of alkaline substances in the ash of the biomass, such as K, Ca, Na, magnesium oxides, hydroxides, carbonates, etc. After the biochar application in the soil, it can improve soil base saturation and reduce the level of exchangeable aluminum^[8]. Straw mulching can reduce pH in peanut rhizosphere soil. Because acid gas produced by microorganisms can reduce pH in peanut rhizosphere soil in the metabolism of straw^[9-10].

4.2.2 The effect of monoculture peanut and cassava/peanut intercropping on carbon and nitrogen in peanut rhizosphere soil under the biochar application and straw mulching

4.2.2.1 The effect of monoculture peanut and cassava/peanut intercropping on available nitrogen in peanut rhizosphere soil under the biochar application and straw mulching. Biochar application leads to the ratio of C/N increased, that will cause biological fixation of soil alkaline hydrolysis nitrogen^[11]. Straw mulching can increase available nitrogen content in peanut rhizosphere soil. Because straw mulching can increase soil microbial activity and continuously increase the content of soil microbial biomass nitrogen^[12]. Cassava/peanut intercropping can increase available nitrogen content in peanut rhizosphere soil. Because effects of cassava root zone on transfer and utilization of nitrogen in peanut root zone can stimulate and promote nitrogen fixation in the root zone of peanut^[13].

4.2.2.2 The effect of monoculture peanut and cassava/peanut intercropping on organic matter in peanut rhizosphere soil under the biochar application and straw mulching. Biochar application can increase organic matter content in peanut rhizosphere soil. Because the formation of soil organo-mineral aggregates improves aggregate stability and reduces the leaching of organic matter^[14]. Straw mulching can increase organic matter content in peanut rhizosphere soil. Because there are a large number of microbes around the straw, these microorganisms can accelerate the decomposition and release of organic nutrients in straw^[15]. Due to the weakening of microbial activity in organo-mineral aggregates, cassava/peanut intercropping can increase organic matter content in peanut rhizosphere soil^[16].

4.2.3 The effect of monoculture peanut and cassava/peanut intercropping on available phosphorus in peanut rhizosphere soil under the biochar application and straw mulching. Biochar and straw contain more available phosphorus, not only that, due to generating positive charge, so biochar and straw can absorb phosphorus nutrients which are not absorbed by the organic matter^[17]. Cassava/peanut intercropping can increase available phosphorus content in peanut rhizosphere soil. Because root exudates are more abundant under intercropping and these secretions can activate the soil nutrients^[18].

4.2.4 The effect of monoculture peanut and cassava/peanut intercropping on available potassium in peanut rhizosphere soil under the biochar application and straw mulching. Biochar contains more available potassium and reduces the dissolution and migration of potassium nutrients^[19]. Straw mulching can increase available potassium content in peanut rhizosphere soil. Because straw mulching can reduce adsorption of potassium in soil and increase its desorption rate^[20]. Cassava/peanut intercropping can increase available potassium content in peanut rhizosphere soil. Because intercropping can increase microbial quantity and diversity, so that can promote the transformation of soil organic nutrients into inorganic nutrients^[20].

5. Conclusion

(1) Under the conditions of this study, biochar application could increase the total soil porosity, permeability, pH, organic matter content, available phosphorus content and available potassium content in peanut rhizosphere soil and reduce bulk density and available nitrogen content in peanut

rhizosphere soil. Straw mulching could increase the total soil porosity, permeability, available nitrogen content, organic matter content, available phosphorus content and available potassium content in peanut rhizosphere soil and reduce bulk density and pH in peanut rhizosphere soil. In short, biochar application and straw mulching can increase the nutrient content in peanut rhizosphere soil and improve soil fertility.

(2) In the same treatment conditions, there was no difference in physical properties between cassava/peanut intercropping and monoculture peanut. In chemical properties, available nitrogen content, organic matter content, available phosphorus content and available potassium content in peanut rhizosphere soil under intercropping were higher than that under monoculture, but pH in peanut rhizosphere soil under intercropping was slightly lower than that under monoculture. In a word, cassava/peanut intercropping can increase nutrient content to improve the micro-ecological environment in peanut rhizosphere soil, and the suitable intercropping spacing is more conducive to increase nutrient content in peanut rhizosphere soil.

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