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Original Research

Study on Soil Physical Properties in Uncaria Rhynchophylla-Producing Areas under Different Land Use Patterns

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Abstract

In order to explore the physical properties of the soil in different land use patterns. In this paper, the rhizosphere and non-rhizosphere soil under different land use patterns (Uncaria rhynchophylla base, forest land and wasteland) in Uncaria rhynchophylla-producing areas of Jianhe County, Guizhou Province were studied, and the distribution characteristics of soil physical indexes under different land use patterns and their correlations were studied. The results showed that there were significant differences in soil physical properties between rhizosphere and non-rhizosphere under different land use patterns. Compared with forest land and wasteland, Uncaria rhynchophylla base can significantly increase the soil water content, soil capillary porosity, and significantly reduce the soil bulk density. The rhizosphere soil water content was as follows: Uncaria rhynchophylla base (21.09 g/cm^3) < forest land (20.19 g/cm^3) < wasteland (19.19 g/cm^3); The variation of soil capillary porosity was as follows: Uncaria rhynchophylla base (45.04 g/cm^3) > forest land (31.37 g/cm^3) > wasteland (22.51 g/cm^3). Most of the physical indexes of rhizosphere and non-rhizosphere soil in forest land and wasteland showed weak significant correlation. The correlation of soil physical indexes in wasteland is weak, and the correlation between soil water content in rhizosphere and soil capillary porosity is strong. Different land use patterns have a great impact on soil physical indexes, so the role of land use pattern should be considered in the process of Uncaria rhynchophylla planting.

Keywords: Uncaria rhynchophylla, soil physical index, land use, Jianhe County

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Introduction

Jianhe County, Guizhou Province is known as the "hometown of medicinal materials", among which the most popular Chinese herbal medicine is Uncaria rhynchophylla. As a perennial vine, Uncaria rhynchophylla is an acid loving negative tree species with developed root system. It can significantly reduce the excitability of cerebral cortex, reduce blood pressure, calm and sleep [1], and effectively inhibit the release of inflammatory cytokines. These compounds have the effects of lowering blood pressure, anti arrhythmia and anti thrombosis. The rich Uncaria rhynchophylla plants have provided high-value medicinal effects for human beings. At present, the planting area of Uncaria rhynchophylla is gradually expanding. Guizhou Province, as the main production area of "Jianhe Uncaria rhynchophylla", faces many obstacles. Due to the unreasonable cultivation and fertilization methods of human beings, the soil fertility deteriorates and the soil hardens seriously, which makes the original function of soil lose [2], resulting in poor growth, low yield and poor quality of " Uncaria rhynchophylla Jianhe", which can't meet the market supply. In order to solve the current situation, it is necessary to fully understand the physical and environmental properties of soil. Secondly, scientific cultivation and chemical fertilizer application can be carried out on this basis to improve crop yield and quality.

Soil is the base bed for the growth and development of Chinese herbal medicines and the formation of yield and quality. It is also the key factor in the ecological environment system of Chinese herbal medicines, providing necessary water, fertilizer, gas and heat conditions for the growth and development of Chinese herbal medicines [3]. Changes in soil physical environment will affect soil quality, such as soil bulk density, capillary porosity, soil water content and other soil functions to provide services for crops. Up to now, the relevant research on Uncaria rhynchophylla in Guizhou has mainly focused on soil heavy metals [4, 5], the relationship between soil trace elements and effective components [6], soil enzyme activity [7, 8], etc., while the research on soil physical properties of Uncaria rhynchophylla-producing areas in Guizhou is rarely reported. The physical properties of soil were greatly affected by the long-term plowing and compaction of soil, which affected the yield and quality of Uncaria rhynchophylla. In order to fully understand the physical properties of the rhizosphere and non-rhizosphere soil of Uncaria rhynchophylla under different land use patterns, this paper mainly carried out the research on five physical indexes, such as soil bulk density, soil porosity and soil water content, in order to provide scientific basis for the efficient planting of Uncaria rhynchophylla in Jianhe County, Guizhou Province.

Materials and Methods

General Situation of Research Area

The research area is Jiuyang Township, Jianhe County, Guizhou Province, which is located in the southeast of Guizhou Province and the east of Qiandongnan Prefecture, which is located at 108°17'08″~109°04'12″E and 26°20'42″~26°55'42″N, as shown in Fig. 1. The study area belongs to subtropical monsoon climate, with no cold in winter, no heat in summer, and mild and humid [9]. The average annual rainfall is 1220 ml, and the rainfall is concentrated from April to October, accounting for 84% of the total annual rainfall. The average annual sunshine is 1236.3 h, and the sunshine is sufficient [10].

Habitat of Uncaria Rhynchophylla

Uncaria rhynchophylla, which has grown for more than 30 years since the 1980s, is a shade tolerant,

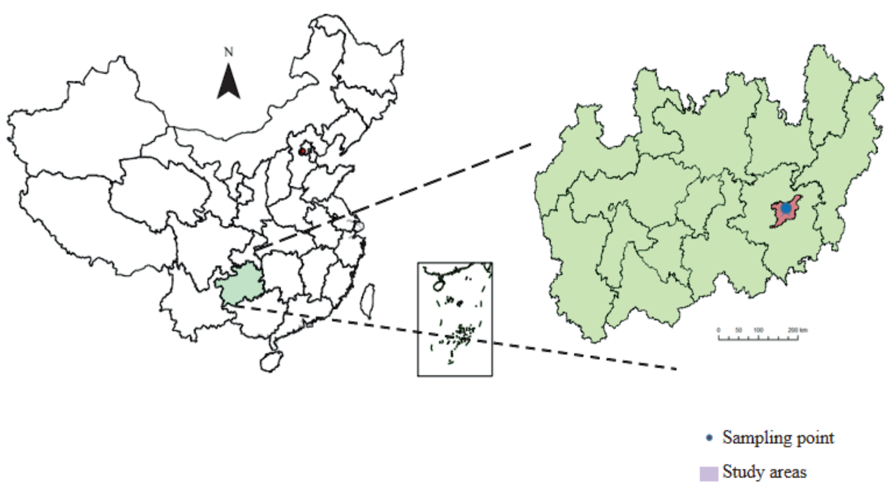

Fig. 1. Location of study area and sampling points.

humid, warm environment, slightly acidic sandy loam with a heavy soil texture. Yellow soil developed from metamorphic rocks has a thick soil layer (1-3 m). The soil is loose and moist, and the texture is mostly loam, with multi granular structure and high content of organic matter [11,12]. It is mainly distributed at an altitude of 450-1250 m. The habitat of Uncaria rhynchophylla is mainly the slope land under the forest, with a slope of 30-70°, and about 66.67% of them live on the slope land with a slope of 50-70°. Because the slope is relatively large, the retention time of water in the soil is short. Most of the Uncaria rhynchophylla plants grow on the half shade side of the slope, and few grow on the sunny side. The habitat temperature is 15-23ºC and the light intensity is 2600-4000lx. Due to its superior natural conditions, the eastern part of Qiandongnan Prefecture, Guizhou Province, has become a large production area rich in Uncaria rhynchophylla.

Sample Collection and Processing

The soil of three different land use patterns (Uncaria rhynchophylla base, forest land and wasteland) was selected as the research object, and the local topography, soil type and natural conditions were considered as the influencing factors. A certain number of representative soil layers (0-20 cm) are randomly selected from each sample plot. The shaking method of Riley and Barber is adopted for soil sample collection. Dig the soil mass with complete root system (the main distribution range of root system) in the typical sample plot selected above, shake off a large piece of soil without root system slightly, use a knife to take down the soil around the root system as non-rhizosphere soil, put it into a plastic bag and mix it well, then use a sterile brush to brush down the soil adhering to the root circumference (0-5 mm from the root circumference) as rhizosphere soil [13], and take the rhizosphere soil to minimize damage to plant roots, the roots mixed in the rhizosphere soil should be completely removed.

Non rhizosphere soil sampling method is to randomly select the soil where uncaria crops grow without roots. Remove the 0~2 cm soil from the surface layer, take the 0~20 cm deep soil layer, sample by four point method, wrap and seal the sample with sterilized kraft paper after mixing, take it back to the laboratory for storage at 4ºC, and complete the analysis within one week. Spread the retrieved soil sample on a clean newspaper, remove stones, stumps and other sundries, dry it naturally, grind it, pass a 0.84mm nylon sieve, and then store it in a self-sealing bag for standby. 55 rhizosphere soil samples and 55 non rhizosphere soil samples were collected, 25 samples were collected from the base of Uncaria rhynchophylla, 15 samples were collected from the forest land and 15 samples were collected from the wasteland, and 110 samples were collected from the rhizosphere and non-rhizosphere soil samples at each collection point.

Sample Index Determination Method and Data Processing

Rhizosphere soil bulk density in the rhizosphere near the underground part of the 5 to 15 cm soil, non-rhizosphere soil bulk density in the absence of rhizosphere soil to take soil, soil process in strict accordance with the ring knife to take soil. The soil bulk density is measured by the ring knife method: soil bulk density (g/cm^3) = $\frac{\text{Mass of dried soil sample/g}}{\text{Ring knife bulk desity/cm}^3}$; The numerical calculation of soil capillary porosity is calculated directly based on the known soil bulk density and specific gravity. The measured value of soil total porosity is the percentage of the volume of pores in a certain volume of soil to the whole soil volume, soil total porosity/% = $(1-\frac{\text{Soil bulk density/g·cm}^{-3}}{\text{Specific gravity of soil/g·cm}^{-3}}\times 100)$; Measurement and numerical calculation of non-capillary porosity: total porosity - capillary porosity = non capillary porosity/%; Specific gravity of soil use the pyknometer method to weigh the dried soil screened by 1 mm with a 0.001 g balance, pour the soil into a 50 mL pyknometer, add distilled water to about half the volume of the bottle, shake the pyknometer to mix the soil sample with water evenly, place the pyknometer on an electric heating plate, heat it for 1 h, shake the pyknometer from time to time to expel the air from the soil and water, cool it, fill it with cooled distilled water to expel the air, wipe the water outside the bottle with filter paper, and weigh it as m_1; Pour out the soil in the pycnometer, wash it, fill it with cooling distilled water to remove air, wipe the water outside the pycnometer with filter paper, and weigh it in m_2. According to the formula, soil specific gravity = dry soil weight / (dry soil weight + m_2 – m_1); Soil water content was determined by drying method [14].

Excel 2010 software was used to classify and summarize the data. SPSS 26.0 software was used to calculate the mean value, standard deviation, coefficient of variation, skewness coefficient, kurtosis coefficient and variance analysis of soil physical indexes in Uncaria base, forest land and wasteland by classical statistical description method. Spearman correlation analysis and plotting were performed using Origin 8.0 software.

Results and Analysis

Descriptive Analysis of Soil Physical Indexes in Rhynchophylla-Producing Areas

The results of descriptive analysis of soil physical indexes of Uncaria rhynchophylla under different land use patterns in Jianhe are shown in Table 1. The average soil bulk density of wasteland was 1.46 g/cm^3 higher than that of other sample plots. The general standard level of soil bulk density of surface soil (0-20 cm) in China was 1.0-1.5 g/cm^3. The soil bulk density in the study area was lower than the average level of soil bulk density in China. The total soil porosity of Uncaria rhynchophylla base was 50.33 %, which was larger than that of forest land and wasteland. The proportion of forest land and water content reached the maximum in three different underground: 2.67 g/cm^3 and 21.59 %. If the coefficient of variation≤0.10 is weak variation, if the coefficient of variation (CV) 0.10≤CV≤1.00 is moderate variation, if the coefficient of variation≥1.00 is strong variation [15, 16]. It can be seen from Table 1 that the variation of soil bulk density and soil specific gravity in the study area was weak, while the variation of soil porosity and soil water content was moderate. It can be seen that the dispersion degree of soil physical indexes of Uncaria rhynchophylla is between weak variation and medium strong variation.

Distribution Characteristics of Bulk Density and Specific Gravity of Rhizosphere and Non-rhizosphere Soils under Different Land Use Patterns

The distribution characteristics of bulk density and specific gravity of rhizosphere and non-rhizosphere soil under different land use patterns are shown in Fig. 2. Soil bulk density in the rhizosphere was the lowest (1.27 g/cm^3) in the Uncaria rhynchophylla base, and the highest (1.45 g/cm^3) in the wasteland. The soil specific gravity of non-rhizosphere Uncaria rhynchophylla base was the smallest (2.60 g/cm^3), and that of forest land was the largest (2.68 g/cm^3). The soil bulk density of non-rhizosphere wasteland was the largest (1.46 g/cm^3), and that of the base was the smallest (1.35 g/cm^3). Soil specific gravity was the highest in Uncaria rhynchophylla base (2.68 g/cm^3) and the lowest in wasteland (2.62 g/cm^3). SPSS analysis of variance showed that there were significant differences in bulk density of rhizosphere and non-rhizosphere soil between the three different underground Uncaria bases and forest land and wasteland ($p<0.05$).

Distribution Characteristics of Porosity and Water Content in Rhizosphere and Non-rhizosphere Soil under Different Land Use Patterns

Fig. 3. shows the distribution characteristics of capillary porosity, non-capillary porosity and water content of rhizosphere and non-rhizosphere soils under different land use patterns. The soil water content in the rhizosphere was the highest (21.09%) and that in the wasteland was the lowest (19.19%); The soil capillary porosity in Uncaria rhynchophylla base was the highest (45.04%) and that in wasteland was the lowest (22.51%); The non-capillary porosity of Uncaria rhynchophylla base was the highest (21.97%) and that of wasteland was the lowest (6.01%). In the non-rhizosphere region, the soil water content of forest land was the highest (22.99%) and that of wasteland was the lowest (18.68%); The non-capillary porosity of forest land was the largest (22.95%) and the Uncaria rhynchophylla base was the smallest (12.71%); The soil capillary porosity in Uncaria rhynchophylla base was the largest (36.91%) and that in wasteland was the smallest (23.26%). According to Fig. 2 and SPSS variance analysis, there is no significant difference in soil moisture content between rhizosphere and non-rhizosphere soil in Uncaria

Table 1. Descriptive analysis of soil physical indexes of Uncaria rhynchophylla producing area in study area.

Samples	Indexes	Minimum	Maximum	Average value ± Standard deviation	CV	Skewness coefficient	Kurtosis coefficient
Base	Soil bulk density (g/cm^3)	1.20	1.44	1.31±0.057	0.04	0.06	-0.42
	Capillary porosity (%)	27.92	50.25	40.97±5.92	0.14	-0.55	-0.18
	Non capillary porosity (%)	0.36	22.03	9.36±5.49	0.59	0.43	-0.49
	Soil specific gravity (g/cm^3)	2.49	3.23	2.64±0.12	0.04	4.25	21.35
	Soil water content (%)	14.58	41.68	21.09±5.34	0.25	2.22	6.90
Forest land	Soil bulk density (g/cm^3)	1.34	1.43	1.38±0.03	0.02	0.35	-0.93
	Capillary porosity (%)	20.05	36.49	27.86±6.11	0.22	-0.02	-1.49
	Non capillary porosity (%)	10.15	25.7	20.15±4.49	0.22	-1.36	2.02
	Soil specific gravity (g/cm^3)	2.48	3.13	2.67±0.23	0.09	1.58	1.17
	Soil water content (%)	18.47	27.50	21.59±2.63	0.12	1.43	2.20
Wasteland	Soil bulk density (g/cm^3)	1.41	1.49	1.46±0.03	0.02	-0.45	-0.11
	Capillary porosity (%)	17.67	30.03	22.88±5.16	0.23	0.71	-1.71
	Non capillary porosity (%)	16.68	26.86	21.50±4.31	0.20	0.14	-1.89
	Soil specific gravity (g/cm^3)	2.45	2.76	2.62±0.10	0.04	-0.56	1.98
	Soil water content (%)	14.21	21.73	18.94±3.00	0.16	-1.02	-0.77

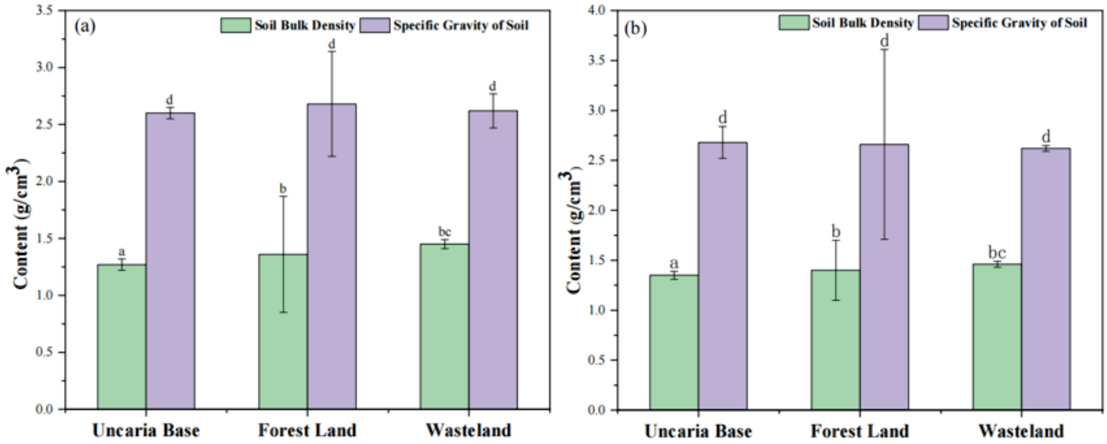

Fig. 2. Distribution Characteristics of bulk density and specific gravity of rhizosphere a) and non-rhizosphere b) soil under different land use patterns.

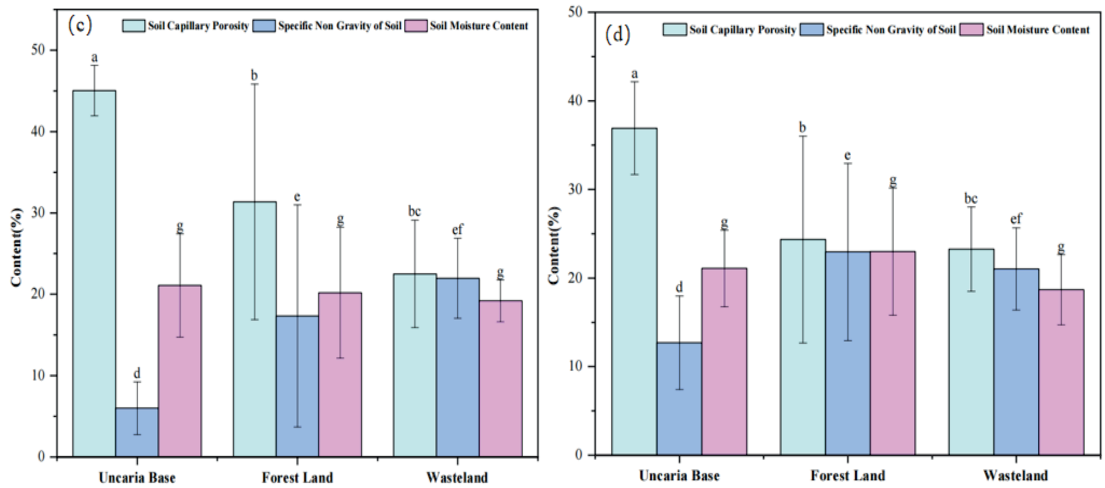

Fig. 3. Distribution characteristics of capillary porosity, non-capillary porosity and water content of rhizosphere c) and non-rhizosphere d) soil under different land use patterns.

rhynchophylla base, forest land and wasteland. There was a significant difference (p<0.05) in the soil capillary porosity between the base and the forest land, between the rhizosphere and non-rhizosphere of the wasteland, but there was no significant difference between the forest land and the wasteland. Therefore, the impact of artificial disturbance on soil environment under different land use modes is greater.

Correlation Analysis of Soil Physical Indexes under Different Land Use Patterns

Correlation Analysis of Physical Indexes of Rhizosphere Soil under Different Land Use Patterns

The correlation analysis between rhizosphere soil bulk density, soil specific gravity, soil porosity and soil water content under different land use patterns is shown in Fig. 4. It can be seen from Fig. 4a) that the soil water content of Uncaria rhynchophylla base has a significant negative correlation with soil capillary porosity and soil specific gravity (P<0.05), and a positive correlation with non-capillary porosity (P<0.05); There was a significant negative correlation between soil capillary porosity and non-capillary porosity (P<0.01); Soil bulk density has a weak and significant negative correlation with soil specific gravity and soil non capillary porosity. Fig. 4b) showed that soil water content was weakly and significantly positively correlated with soil bulk density and soil capillary porosity, while soil capillary porosity was weakly and significantly negatively correlated with non-capillary porosity. Fig. 4c) shows that soil water content in wasteland has a weak and significant positive correlation with soil bulk density and capillary porosity, and a weak and significant negative correlation with non-capillary porosity. Soil non-capillary porosity was negatively correlated with soil bulk density and capillary porosity.

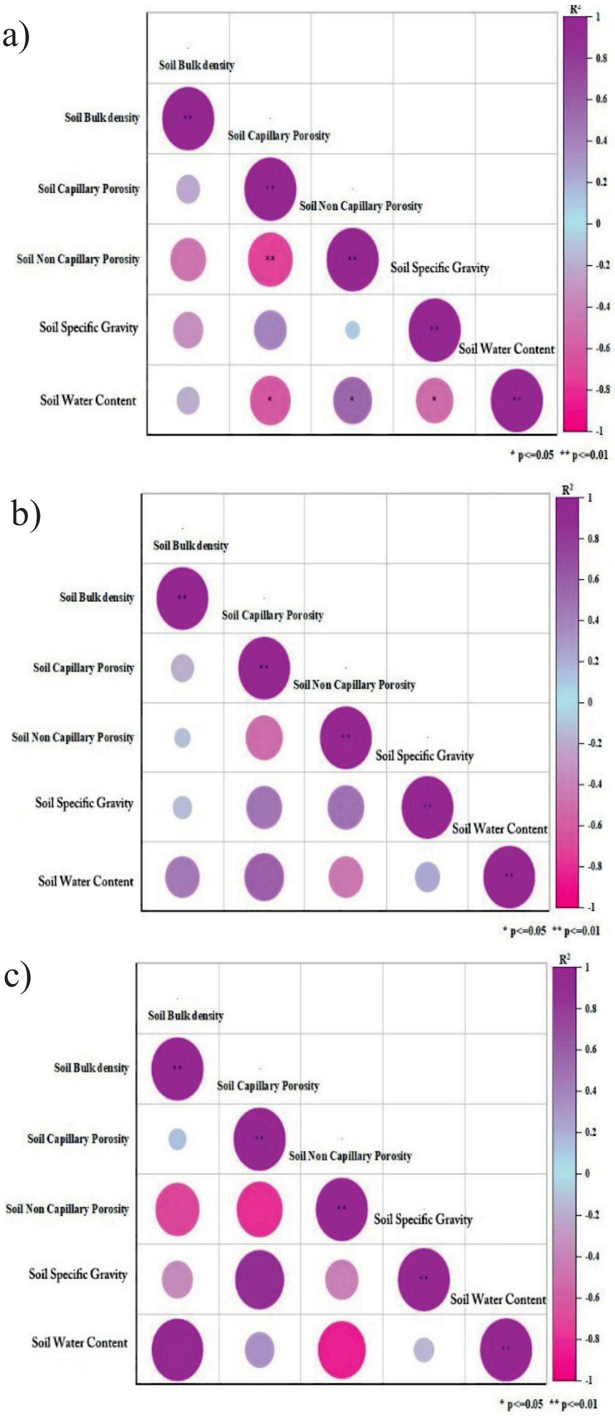

Fig. 4. Relationship between physical indexes such as bulk density and specific gravity of rhizosphere soil under different land use patterns a) Uncaria rhynchophylla base, b) Forest land and c) Wasteland.

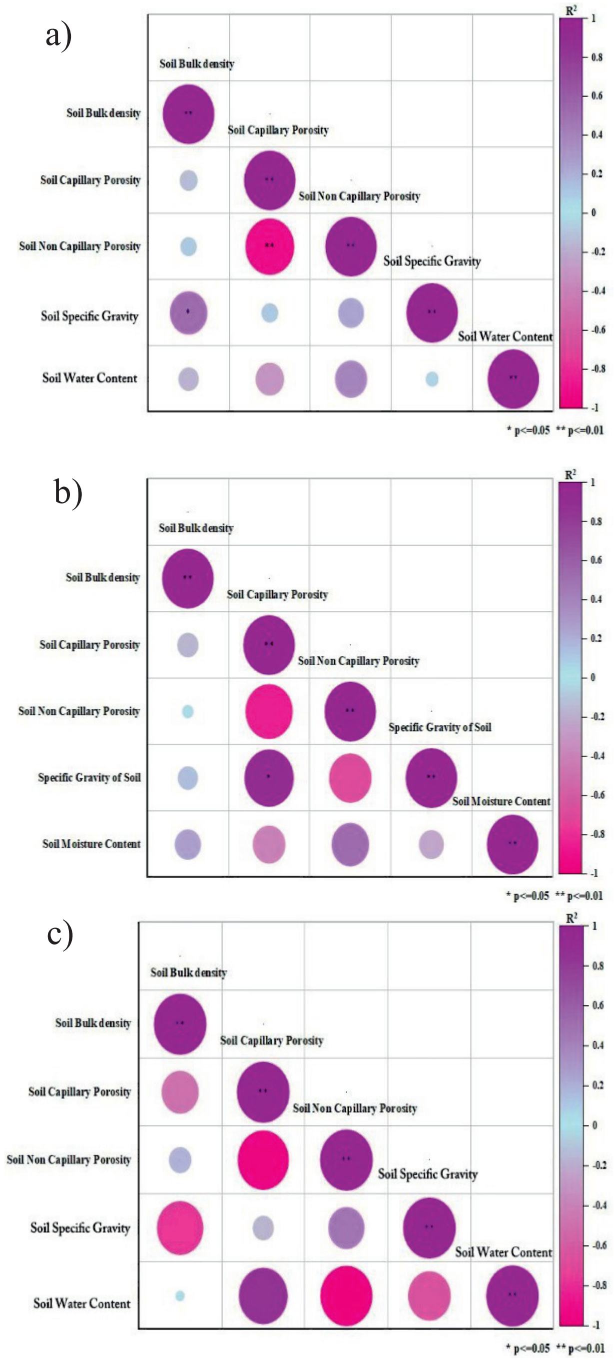

Fig. 5. Relationship between physical indexes such as bulk density and specific gravity of a) Uncaria rhynchophylla base, b) Forest land and c) Wasteland non rhizosphere soil under different land use patterns.

Correlation Analysis of Non-rhizosphere Soil Physical Indexes under Different Land Use Patterns

The correlation analysis between non rhizosphere soil bulk density, soil specific gravity, soil porosity and soil water content under different land use patterns is shown in Fig. 5. As shown in Fig. 5a), soil capillary porosity and soil non capillary porosity are significantly negatively correlated ($P<0.01$), and soil bulk density is significantly positively correlated with soil specific gravity ($P<0.05$); There was a weak and significant correlation between soil water content and capillary porosity and non-capillary porosity. As shown in Fig. 5b), the soil capillary porosity of forest land is significantly correlated with the soil specific gravity ($P<0.05$), and is weakly significantly negatively correlated with the non-capillary porosity; There was a weak significant positive correlation with soil water content, soil bulk density and soil non capillary porosity, and a weak significant negative correlation with soil capillary porosity. Fig. 5c) shows that the soil water content of wasteland has a weak and significant positive correlation with soil capillary porosity, and a weak and significant negative correlation with soil non capillary porosity and soil specific gravity; soil bulk density and soil specific gravity showed a weak and significant negative correlation; There was a significant weak correlation between soil capillary porosity and soil non capillary porosity. On the whole, different land use patterns affect the soil environment. Due to the influence of human activities, natural environment, geographical location and other factors, there is a certain correlation between soil physical environment indicators in different places.

Discussion

Distribution Characteristics of Soil Physical Indexes in the Habitat of Uncaria Rhynchophylla under Different Land Use Patterns

Human activities are different under different land use patterns, thus affecting soil texture and structure [17]. Different land use patterns have different impacts on the soil of Uncaria rhynchophylla-producing areas, and the overall impact degree is as follows: Uncaria rhynchophylla base>forest land>wasteland. The soil bulk density of Uncaria rhynchophylla base is relatively smaller than that of forest and wasteland, which indicates that human activities often plow the soil and apply fertilizer, which destroys soil aggregates and reduces soil compactness. This study is basically consistent with previous studies. [18]. The forest and wasteland are slightly disturbed by human activities, and the soil compactness tends to be stable. Due to the large amount of plant litter on the surface and the absence of human activities, the original properties of the soil can be effectively maintained [19]. The proportion of soil in the forest and wasteland is lower than that in Uncaria rhynchophylla base, which indicates that this may be related to the geographical location, such as long-term rain washing, water and soil loss, or the soil is not cultivated [20]. The soil capillary porosity and water content of Uncaria rhynchophylla base are significantly higher than those of forest and wasteland, and there is no significant difference in soil capillary porosity and water content between forest and wasteland. It may be that artificial vegetation can significantly improve soil properties, and the improvement effect of artificial vegetation on soil properties is better than that of natural vegetation [21]. The capillary porosity and water content of the soil in Uncaria rhynchophylla base are significantly higher than those in forest land and wasteland, but the non-capillary porosity is lower than that in forest land and wasteland, which indicates that the artificial deep tillage rotary tillage and rotation tillage can increase the soil water content of the soil layer, hinder the passage of soil gas, and have poor ventilation. The deep tillage rotary tillage can break the plough bottom layer, increase the capillary porosity of the soil in the plough layer, and make the soil bulk density small and the capillary porosity large, which is easy for the crops to absorb water, non capillary porosity decreases [22-25], and soil water content increases with the decrease of soil bulk density, indicating that soil water content will change with the change of soil bulk density, which is consistent with the research results of Lin Shaoxia et al. [3, 26, 27]. The forest land has abundant vegetation with dense and developed root systems, resulting in the soil capillary porosity and water content significantly higher than that of the wasteland soil. On the one hand, the wasteland soil may not improve the soil structure due to the poor soil and hardening soil, and on the other hand, it may have fewer soil organisms and fewer vegetation types [28, 29]. Therefore, the soil capillary porosity and water content of the forest land are higher than that of the wasteland soil. The specific gravity of soil is determined by the content and species of soil solid components. On the whole, the physical properties of the soil in Uncaria rhynchophylla base are more affected than those in forest land and wasteland. The research result of non-significant correlation of soil physical properties between forest and wasteland is consistent with the research results of different land use areas in Guizhou Province studied by Chen Chao et al. [30], but different from the research results of Yin Gangqiang et al. [31] in hilly areas in central Hunan, which may be related to the formation process of soil in the study area. The karst mountain areas in southwest China are carbonate strata; The soil in the hilly area of central Hunan belongs to the acidic red soil developed from the Quaternary reticulated parent material. Compared with the karst mountain area dominated by carbonate, the soil is quite different in formation, occurrence and evolution. To sum up, the research results show that the artificial planting crop base has changed the soil environment, which is the same as the previous research results that the difference in physical characteristics is considered to be the impact of different land uses [32], which leads to the difference in the distribution of soil physical environmental indicators.

Relationship between Soil Physical Indexes such as Soil Bulk Density and Specific Gravity under Different Land Use Patterns

The interaction between soil and vegetation system stabilizes the soil [33]. It is pointed out that the changes of soil properties are different in different land use types. In addition, the age and growth of vegetation will greatly affect the soil properties [34]. The soil bulk density, water content, porosity, etc. represent the permeability, water permeability and fertility of the soil, as well as the resistance to the extension of the tree root system, which is consistent with the research results of Wang Jianmin et al. [35]. According to the results of this study, the correlation of soil physical indexes between rhizosphere and non-rhizosphere Uncaria rhynchophylla base is stronger than that between forest land and wasteland. Among them, there is a significant difference between the soil bulk density of the Uncaria rhynchophylla base and the study area of forest and wasteland, and there is a weak significant correlation with other physical indicators. The possible reason is that the long-term manual tillage operation in the Uncaria rhynchophylla base makes soil solid particles fill the soil pores, and the research result of increasing soil bulk density is consistent with previous research [35], but contrary to the research results of Wang Jiaxu et al. [36], this research result points out that due to the disturbance of soil by long-term tillage, therefore, the soil structure is loose, which leads to a significant negative correlation with soil porosity. It can be seen from the correlation that the soil water content of the rhizosphere Uncaria rhynchophylla is the highest, and it is found that the capillary porosity of the Uncaria rhynchophylla base is small, which indicates that it is easy to promote the absorption of water by the crop root system, which is beneficial to the growth and development of crops, and conversely, it can inhibit the growth of crops and affect the soil quality [37]. The diversity of forest vegetation has an impact on soil water content and specific gravity, which is mainly caused by the strong root system of the forest [38]. The more forest vegetation types, the more root systems in the soil layer, and the more components, leading to the greater cohesion of the surface root soil complex in the vegetation combination area than in the single vegetation area [39]. Because of the complex forest structure, high surface vegetation coverage, high litter volume and rich vegetation roots in the forest land can improve the physical properties of the soil. Forest litter can protect the topsoil and prevent the loss of fine particles [40]. Therefore, different land use methods affect the internal changes of soil physical environment, which is related to natural geographical environment and human activities. Tillage measures can affect soil conditions, for example, tillage can improve soil physical properties and enhance soil aeration [41-43].

Conclusions

The results of this study showed that the soil physical environment of the artificial Uncaria rhynchophylla base was relatively good. The rhizosphere soil water content and soil capillary porosity reached the maximum (21.09 g/cm^3) and (45.04 g/cm^3), and the overall performance was as follows: Uncaria rhynchophylla base>forest land>wasteland. Under the influence of human activities, different land use patterns can improve the soil physical environment and promote the growth and development of Uncaria rhynchophylla crops. Farming operation, application of pesticides and repeated tillage will affect the soil. Cultivated land increases the amount of soil organic matter destroyed by ploughing, which makes soil aggregates collapse into small soil aggregates. The decrease of organic matter leads to an increase in bulk density and a decrease in total porosity, thereby reducing soil infiltration. Forest and wasteland can improve soil physical properties due to less human interference and well-developed rhizosphere. Different soil use patterns lead to significant differences between rhizosphere and non-rhizosphere soil physical indicators. Due to environmental factors, the correlation between various indicators may have potential uncertainty and accuracy. From the correlation analysis of soil physical indicators, it can be seen that there is a strong correlation between the various rhizosphere and non-rhizosphere soil physical indicators in the artificial cultivation base of Uncaria rhynchophylla.

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Conflict of Interest

The authors declare no conflict of interest.

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