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The effects of planted and plowed *Stylosanthes guianensis* on degrading soil fertility in hilly countries of dry-hot valley

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ABSTRACT

The development of rural economy and ecological restoration were restricted with high temperature and drought in the dry-hot valley of Yuanmou country. The climate and human practice made a degrading ecosystem, and one marked question here was soil fertility degradation. Leguminous forage *Stylosanthes guianensis* were introduced for years in degraded mountainous dry-hot valley of Yuanmou. Aims to reveal devotions of planting and plowing *S. guianensis* to degraded mountainous soil fertility, three soil types and two treatments planting experiment were tested in the dry-hot valley of Yuanmou country. The results show that: 1. *S. guianensis* could adapt to degraded mountain soil. There was a large number of nodules and root in three soil types, number of root nodule was 174.048–650.667 grain/individual plant, root biomass was 214.667–1710.000 kg/hm^2. 2. With nitrogen fixation of root nodule, rot and decomposing of dry branches and fallen leaves, organic matter, total nitrogen, pH and germ of degrading soil tended to rising after *S. guianensis* planting and plowing. Increasing root biomass and rhizobium nodules had been repaired and improved microenvironment of soil, especially made an significant increase for germs, in 0–20 cm soil from 0.020×10^5–1.54×10^5 to 1.880×10^5–70×10^5,and 20–40 cm soil from 0.020×10^5–0.380×10^5 to 1.100×10^5–52.5×10^5. 3. *S. guianensis*, either planting or plowing into soil as green manure planting, could significantly ($P < 0.05$) improve total nitrogen, organic matter, available phosphorus, available K of degraded soil in the fruit tree canopy drip line.

1. Introduction

Yuanmou arid-hot valley zone is a region of dry and hot climate, mountainous with degraded soil fertility, extremely vulnerable ecosystems, which seriously restricted regional sustainable development of ecological restoration, agriculture and rural economy, also the intent of plateau characteristic agriculture (proposed by Yunnan Provincial Government, 2013). The essence of sustainable agriculture was using the ubiquitous relationship between organisms and environment in nature and rules of material recycling and energy shift in ecosystems to reduce adverse effects of extensive of fertilizers and pesticides in conventional agriculture systems. It was an effective measure that using organic fertilizers to improve nutrient recycling or soil fertility in agricultural ecosystems to achieve the gain of sustainable agriculture. As one of quality organic fertilizer [1], green manure planting can activate and fix soil nutrients, also leguminous green manure fix atmospheric nitrogen for crop, and directly increase available nutrient sources after turning over into soil. Green manure contains large amounts of clean, fresh organic matter, which effectively increase and update the soil organic matter, therefore can significantly improve soil physical structure and microbial traits [2].Reports showed that the *Stylosanthes guianensis* has adapted to the natural environment conditions of dry-hot valley [3–6], and improved the soil traits with the formation of tubercles – a symbiosis structure of nitrogen-fixing bacteria and plant roots, which displayed a significant increase in plots soil nutrient after planting *S. guianensis* for 2 years by soil testing. *S. guianensis* even can grow up in barren acidity soil then raising the planting plots pH [7]. *S. guianensis* planting has its advantages, like brief management, with high crude protein content to either direct feeding or hay powder making for livestock, and can be planted with other kinds of crops in intercropping or rotation, also as green manure for forest (fruit) line covering. However, studies found that *S. guianensis* planting improve soil fertility [3,7] with lower raise rates [8]. To accelerate the regression of soil fertility in degradation soil nutrients, this paper tested, observed and analyzed the contributions of planted and plowed *S. guianensis* on degrading soil fertility, and focused on the effects of the process as green manure crops in the dry hot valley degraded upland soils. Also it was designed to provide a possible way to support *S. guianensis* planting agriculture for degraded mountain soil fertility regression and ecological vegetation restoration in dry and hot valley zone.

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Table 1
Fertility of soil in the experimentation land (background investigation).

Soil fountains	Soil depth (cm)	Soil texture	Organic matter (%)	Total nitrogen (%)	Available phosphorus (mg/kg)	Available K (mg/kg)	Soil bulk density (g/cm^3)	Total porosity (%)	PH
Ground soil	0–20	Sandy loam	0.44	0.034	7.55	37.5	1.64	30.80	6.72
	20–40	soil	0.62	0.027	11.4	24.9	1.68	47.70	6.30
Platform	0–20	Sandy loam	0.44	0.035	1.16	77.8	1.77	38.25	6.28
soil	20–40	soil	0.58	0.034	<1.00	52.6	1.73	31.27	6.23
Hillside soil	0–20	Sandy loam	0.76	0.048	2.72	57.7	1.79	39.80	6.56
	20–40	soil	0.10	0.041	<1.00	50.1	1.68	39.70	6.61

2. Materials and methods

2.1. The test area's properties

Testing area was provided in nest base of Yangkaiwo (E101°49′54″–N 25°51′09″, altitude of 1016 m), and testing plots in Huangguayuan (E101°49′19″, N25°50′42″, altitude of 1073 m), Yuanmou dry and hot valley. The climate was unique there, with annual average temperature of 22.0 °C to the hottest month June of 28.5 °C and coldest month December of 15.9 °C, annual sunshine time of 2670.4 h, ≥10 °C annual accumulated temperature of 8552.7 °C, low annual average rainfall of 645 mm, rainy season from May to October and of total annual rainfall 94.6%, and, thus, it was four times of annual evaporation than annual rainfall. The background investigation was covered in December 2008 and the result of nutrition concentrations of testing soil was displayed in Table 1. The table showed a terrible shortage of nutrient element of soil. Comparing with the standard of nutrient concentrations of degraded soil in Table 2, testing soil showed an N disadvantage in mind to strong degree, organism strong degree, and degraded traits of density and porosity in strong degree.

2.2. Experimental design

2.2.1. Effects of planting on soil fertility

Experiment setting: Two treatments, either planting or plowing plant individuals into degraded soil, and there different planting fields, ground marked plot 1, platform plot 2 and original degraded hillside plot 3 were set to test the effects of *S. guianensis* on degrading soil. Then, an area of 0.2 km^2 plot in each fields were divided into 6 cell (2 m × 2.5 m, I–VI) and 20 per cell individuals of *S. guianensis* cv.Reyan No.2 were planted, and every cell was protected by vegetable bar. All *S. guianensis* were planted in June 2009. Marked II, III, IV cells' individuals in plots were collected for tubercles traits and root biomass testing in September 29, 2009, and soil samples from I, V, VI cells for chemical properties testing in August 2010.

Planting and management: Planting and management processing see references [9–11].

2.2.2. Effects of plowing on soil fertility

Experiment setting: Test plots were located in a longan orchard, which was an eco-agricultural technology demonstration area named Yangkaiwo, Institute of Tropical Ecological Agriculture science, Yunnan Academy of Agricultural Sciences. Individuals of *Dimocarpus longan* Lour., varieties as "Chuliang", were transplanted with a density of 5 m × 6 m in July 2006, planting hole sized in length × width × depth = 1 m × 1 m × 1 m and 100–150 kg organic were fertilized before conventional management. Individuals of *S. guianensis* cv.Reyan No.2 were inter-longan planted in space of 50 cm × 50 cm, 2 plants/pond, in June 2009. Seeds of *S. guianensis* were hot watered at 80 °C for 3–5 min, then soaked in 0.1% carbendazim solution for 10–15 min before seeding. In June 2010, the area between *D. longan* trees line were caved with length × width × depth = 40 cm × 40 cm × 40 cm, and 2 kg *S. guianensis* biomass were turned directly into holes. Testing soil samples, mixing with soil and decomposition of *S. guianensis* organisms, were collected after four months from 20 to 40 cm under surface. Plowing depth of the green manure was generally 20–30 cm. In the research *S. guianensis* plowing were used of 40 cm depth for considering of the decay effect.

Planting and management: *S. guianensis* planting and management see references [9–11]. *D. longan* cultivation and management see references [12,13].

2.3. Data analysis

Excel was used to data collection and one-way or multi-way ANOVA was operated on SPSS, handheld GPS tester for altitude, latitude and longitude testing. Meteorological elements data provided by the Bureau of Meteorology of Yuanmou County, soil nutrients were measured by the Kunming-Seoul letter Agricultural Analysis and Testing Technology Co., Ltd., and soil microbial bacteria classified and counted by the Institute of Life Sciences, Yunnan University.

3. Results and analysis

3.1. Adaption of plants to degraded mountain soil

3.1.1. Traits of root-rhizobium nodule

As displayed in Table 3, plants from 3 plots had formatted root-rhizobium nodules, but the color, numbers and seizes of nodule and root mass were distinguished between different site and one key factor was soil moisture. In comparison with plot 3 (hillside soil), plot 1and plot 2 (ground and platform soil) were relatively water rich, naturally, plant root mass, quantity and quality of root-rhizobium nodules were more advantaged. Root-rhizobium nodules could grow into mature stage and turned into pink spots for biological nitrogen fixation, but

Table 2
Index number of degraded land degree.

Degraded degree	Soil texture	Organic matter (%)	Total nitrogen (%)	Soil bulk density (g/cm^3)	Total porosity (%)	Field capacity (%)
Moderate degradation	Sandy loam soil	1–2	0.05–0.1	1.30–1.45	51–46	35–30
Strength degraded	Heavy loam soil	0.5–1	0.02–0.05	1.50–1.80	44–35	30–20

Note: The data of this table come from the achievements in National Scientific Key Project of the Tenth Five-Year Plan "The dry-hot valleys ecological recovery technology and demonstration" (2001BA606A-07, 2004BA606A-07).