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RESEARCH ARTICLE

Effects of Different Intercropping Models on Growth and Yield Traits of Maize in Red Soil Dryland

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Abstract: In order to develop the suitable planting mode of maize in red soil dryland, improve the related plant and ear characters of maize, promote high quality and high yield, and improve economic benefits. The experiment was conducted in the Science and Technology Park of Jiangxi Agricultural University from May 13, 2020 to October 18, 2020 and from May 5, 2021 to October 7, 2021. Taking maize as the control, three intercropping treatments of maize intercropping soybean, maize intercropping peanut and maize intercropping sweet potato were set up to compare their effects on agronomic characters such as plant height, stem diameter and ear width of maize and yield. The results showed that the plant height and ear height of maize intercropping soybean reached the maximum in two years, with plant height of 208.9 cm and 191.9 cm, ear height of 80.2 cm and 58.4 cm, respectively. The ear length and grain number per row of intercropping treatment were better than that of monoculture treatment. The ear length of maize intercropping and soybean reached the maximum, which were 16.5 cm and 19.0 cm respectively, and the grain number per row was also higher than that of other treatments. The yield of maize intercropping soybean was the highest, 42.1 kg and 43.5 kg respectively in two years. Compared with monoculture, intercropping can improve stem diameter, ear height, ear length, grain number per row and other ear traits, so as to improve corn yield, among which maize intercropping soybean is the best. The results of grey correlation showed that ear length and plant height had a great influence on maize yield. The comprehensive analysis shows that the use of maize intercropping soybean model is conducive to achieve high quality and high yield.

Keywords: Red soil dryland; Intercropping models; Maize; Agronomic characters; Yield

1. Introduction

Maize is the main food crop, as well as an important fodder and economic crop, and it occupies an important position in agricultural production and the national economy. Its quality and output also directly affect the development of food security and agricultural production in my country and the world [1]. The dry land in southern my country is dominated by red dry land. The southern red soil area has a tropical and subtropical climate with a long frost-free period, concentrated rain, abundant water, light and heat resources, superior natural conditions, and huge production potential [2], but for a long time, due to

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the existence of various production limiting factors such as acid, thinness, stickiness, drought, erosion, etc., coupled with extensive cultivation and unreasonable development and utilization, have resulted in low productivity and poor economic benefits in red soil dryland farmland [3]. Intercropping can maximize the utilization of resources [4-6], increase production and income [7,8], increase the productivity of arable land, and effectively alleviate the contradiction of crop land competition [9].

Intercropping, mixing, interplanting and multiple cropping are widely used in maize production to make full use of soil fertility, light, heat and water resources in time and space [10]. The land equivalent ratio of intercropping maize with dwarf grain crops such as soybean, peanut and sweet potato is higher than that of monoculture, which makes full use of spatial advantages and effectively improves the dynamic leaf area coefficient and light energy utilization rate. Intercropping corn with soybean, peanut and sweet potato has significant yield increase and high economic benefit [11]. Zhang Xiangqian et al. [12] showed that the intercropping of corn with soybean, peanut and legume crops significantly increased the economic yield and biological yield of corn per plant, significantly increased the economic yield in the field, and significantly improved the nutritional quality of corn grains. Chu Fengli et al. [13] considered that the intercropping of sweet potato and maize has obvious yield advantages. The yield of intercropping maize is 9.76% higher than that of monoculture maize, and the land equivalent ratio of intercropping treatment is 1.12.

Jiangxi is a typical area of red soil dry land, and the area of soybeans, peanuts, sweet potatoes, etc. is large, which can be used for intercropping of corn, make full use of light and heat resources, and give full play to one area for multiple purposes. Predecessors have studied corn intercropping soybeans [14], peanuts [15], and sweet potatoes [16,17], but there are relatively few reports comparing the effects of the three intercropping on agronomic traits and yield [18,19]. This study combines the actual production of maize in the arid regions of red soil in Jiangxi, and compares the characteristics of maize plants and ears, yield and other indicators under different intercropping modes, and plans to screen out the maize intercropping models suitable for planting in the drylands of red soil in Jiangxi, and make full use of land resources to promote corn quality High yield, improve economic efficiency.

2. Materials and Methods

2.1 Experimental Site

This experiment was carried out in the Science and Technology Park of Jiangxi Agricultural University (28°76′N, 115°84′E), where the terrain is flat, has a subtropical monsoon climate, and sufficient light and heat resources. The average annual rainfall is 2223.2 mm and the annual average temperature is 16.5 °C . The experimental field soil is a typical red loam, and the soil is slightly acidic. Before the experiment, the basic nutrient status of the soil was basically the same, and the plots were equally and randomly arranged. The initial soil properties of the experiment were: pH 4.68, total nitrogen 0.129%, available phosphorus 62.27 $mg \cdot kg^{-1}$, available potassium 98.79 $mg \cdot kg^{-1}$, organic matter 26.50 $g \cdot kg^{-1}$, and alkali hydrolyzed nitrogen 100.00 $mg \cdot kg^{-1}$.

2.2 Experimental Design

In this study, a randomized complete block design was adopted, and a total of 4 treatments were designed, maize monoculture (T1) control, maize intercropping soybean (T2), maize intercropping peanut (T3), maize intercropping sweet potato (T4). Three repetitions are set for each treatment, with a total of 12 plots, with a length of 6m, a width of 5.5 m and a plot area of 33.0 m^2. The corn variety is Ganxinnuo 7, the soybean variety is 75-3, the peanut variety is Huagan 1, and the sweet potato variety is Guangshu 87, which is purchased by Nanchang seed store. The row spacing between corn and corn is 35 cm, and the row spacing between soybean and soybean, peanut and sweet potato and sweet potato is 30 cm. The row spacing of beans, peanuts, sweet potatoes and corn was 50 cm. The three intercropping treatments were 2 rows of corn, 2 rows of soybean, 2 rows of peanut and 2 rows of sweet potato. The plant spacing of corn, soybean, peanut and sweet potato was 25 cm. The row spacing of maize in monoculture is 35 cm, the plant spacing is 25 cm, and the spacing between two rows of maize is 130 cm. The density of corn per unit area (667 m^2) is 3880 plants, and the density of soybean, peanut and sweet potato is 2910 plants.

2.3 Field Management

Corn, soybean, peanut and sweet potato sowed on May 13, 2020 and May 5, 2021 respectively. In 2020, corn and soybean harvested on August 5, peanut on September 6 and sweet potato on October 18. In 2021, corn and soybeans harvested on July 29, peanuts on August 30 and sweet potatoes on October 7. Base fertilizer: 1500 kg/hm^2 organic fertilizer, pure potassium sulfate (15-15-15) compound fertilizer 750 kg/hm^2, sowing in furrows after spreading. Urea 55 kg/hm^2 was applied at jointing stage of maize and 135 kg/hm^2 at heading stage. Urea 45 kg/hm^2,

potassium chloride 90 kg/hm^2, urea 30 kg/hm^2 and potassium chloride 75 kg/hm^2 were applied at branching stage of soybean combined with intercropping. Urea and potassium chloride 45 kg/hm^2 were applied at seedling stage of peanut, urea 120 kg/hm^2 and potassium chloride 90 kg/hm^2 were applied at flowering stage. Sweet potato In the middle stage, 120 kg/hm^2 urea and 75 kg/hm^2 potassium sulfate were applied. Other management is the same as land for growing field crops.

2.4 Measurement Items and Methods

2.4.1 Determination of Agronomic Characters

At heading stage, 10 plants were randomly selected from each plot to examine plant height, stem diameter, ear height, empty stem rate, lodging rate and tillinging rate. After harvest, 10 ears were randomly selected from each plot for ear length, ear width, rows per ear, grain number per row and bald tip length.

2.4.2 Determination of Yield

At the maturity stage of corn, 10 ears were selected to measure the weight of fresh ears, and the actual yield of each plot was calculated.

2.4.3 Grey Relational Analysis

For maize agronomic traits under different intercropping patterns, plant height (X1), stem thickness (X2), ear height (X3), ear length (X4), ear thickness (X5), bald tip length (X6), ear row number (X7), the number of grains in a row (X8), and the output (X0) are analyzed for correlation.

First determine the sequence and perform dimensionless processing, and then use Excel 2019 software to calculate the gray correlation degree. Suppose the yield traits of maize are the reference series X0, and the agronomic traits are the comparison series X_i, i = 1, 2, 3,..., N, and $X_0 = \{X_0(1), X_0(2), X_0(3), ..., X_0(N)\}$, $X_i = \{X_i(1), X_i(2), X_i(3),...X_i(N)\}$, then (k) is the correlation coefficient between X_0 and X_i at the k-th point:

$$\varepsilon_i = \frac{\min\limits_i \min\limits_k |X_0(k)-X_i(k)| + \rho \max\limits_i \max\limits_k |X_0(k)-X_i(k)|}{|X_0(k)-X_i(k)| + \rho \max\limits_i \max\limits_k |X_0(k)-X_i(k)|},$$

In the formula: $|X_0(k) - X_i(k)|$ represents the absolute difference between the sequence of numbers and the sequence of numbers at the k-th point, denoted as:

$\Delta_i(k) = |X_0(k) - X_i(k)|$,

Calculate the degree of relevance: $r_i = \frac{1}{N}\sum_{k=1}^{n} \varepsilon_i(k)$,

Where: $\min\limits_i \min\limits_k |X_0(k) - X_i(k)|$ is the second least difference, $\max\limits_i \max\limits_k |X_0(k) - X_i(k)|$ is the second-level maximum difference, is the resolution coefficient, N is the number of samples, the value range is 0~1, and the value is 0.5.

2.5 Data Analysis

Use Excel 2019 to statistically process the data and graph, use SPSS 20.0 to perform one-way analysis of variance on the data, use Duncan method to perform multiple comparisons and Pearson's two-tailed correlation analysis for each measurement data.

3. Results

3.1 Effects of Different Intercropping Models on Plant and Ear Characters of Maize

3.1.1 Plant Characters

There was no significant difference between the plant height and ear height of each treatment in 2020 and 2021, but the plant height of maize intercropping soybean (T2) reached the maximum value of 208.9 cm in 2020, and the ear height of maize intercropping soybean (T2) also reached the maximum value of 80.2 cm. There was no significant difference in the stem diameter of maize intercropping soybean (T2), maize intercropping peanut (T3), maize intercropping sweet potato (T4) in 2020, and the stem diameter of maize monoculture (T1) was significantly lower than that of other intercropping treatments. In 2021, there was no obvious regularity in stem diameter, and the differences in plant traits between treatments were not obvious, maintaining good stability. However, the plant height, stem diameter, and ear position of maize intercropping soybean (T2) are as high as the maximum. The plant height is 191.9 cm, the stem diameter is 2.4 cm, and the ear position height is 58.4 cm. Under different intercropping modes, the empty stem rate, tilling rate,lodging rate and reversal rate of corn are all 0. Taken together, there is no obvious difference in plant traits between different corn intercropping treatments, but the overall performance of the intercropping treatment is better than that of the monoculture treatment. Among them, the plant growth of maize intercropping soybean (T2) is better, and the plant height, stem diameter, and ear height are better (Table 1).

3.1.2 Ear Characters

Under different intercropping modes, there is no significant difference in ear width and bald tip length of maize in 2020 and 2021, and there is no obvious regularity in the

Table 1. Main plant characters under different intercropping models

Year	Treatment	Plant height(cm)	Stem diameter(cm)	Ear height(cm)
2020	T1(CK)	196.4±4.4a	1.8±0.1b	70.5±5.1a
	T2	208.9±4.1a	2.1±0.1a	80.2±2.7a
	T3	208.8±5.2a	2.0±0.1ab	77.3±2.4a
	T4	208.4±1.9a	2.1±0.1ab	76.2±1.4a
	Mean	205.63	2.04	76.05
	CV(%)	3.60	5.79	7.60
2021	T1(CK)	186.4±3.9a	2.2±0.1a	52.7±2.9a
	T2	191.9±5.5a	2.4±0.1a	58.4±4.7a
	T3	184.8±1.6a	2.2±0.3a	51.7±1.7a
	T4	186.8±2.7a	2.3±0.2a	57.7±1.3a
	Mean	187.48	2.28	55.13
	CV(%)	3.35	6.74	8.82

Note: The data in the table of agronomic traits are the average value of three repetitions. Different lowercase letters in the same column represent the level of 0.05, with significant difference.

rows per ear and the grain number per row in two years. However, the ear length and the grain number per row in the two-year intercropping treatment were better than those of the monoculture treatment. Among them, the ear length of maize intercropping soybean (T2) reached the maximum, which were 16.5 cm and 19.0 cm, respectively, and the grain number per row was also higher than other treatments. In 2021, the ear width of maize intercropping soybean (T2) reached the maximum value of 4.8 cm, the length of the bald tip was the shortest, 2.4 cm, and the grain number per row was the largest, reaching 33 grains per row. The rows per ear were not obvious compared with other treatments (Table 2).

Different intercropping treatments can increase the fresh fruit ear weight. The fresh fruit ear weight of maize intercropping soybean (T2) is the largest in two years, 219.3 g and 256.1 g respectively. According to the ear characters of two years, intercropping treatment has more advantages than monoculture treatment, and the ear characters of maize intercropping soybean (T2) are better (Figure 1).

Table 2. Main characters of ear under different intercropping models

Year	Treatment	Ear length(cm)	Ear width (cm)	Bald tip length(cm)	Rows per ear	Grain number per row
2020	T1(CK)	14.9±0.5a	4.3±0.5a	1.7±0.5a	12.3±0.2b	27.3±1.3b
	T2	16.5±0.4a	4.6±0.1a	2.6±0.3a	13.0±0.3ab	31.5±1.4a
	T3	15.4±0.3a	4.6±0.1a	1.9±0.3a	12.4±0.2b	28.4±0.8ab
	T4	15.9±0.7a	4.7±0.2a	2.4±0.2a	13.7±0.5a	28.4±0.6ab
2021	T1(CK)	17.0±0.5b	4.5±0.1a	2.7±0.5a	13.3±0.7a	26.0±1.2a
	T2	19.0±0.7a	4.8±0.3a	2.4±0.6a	13.0±0.0a	33.0±4.5a
	T3	18.1±0.3ab	4.3±0.4a	2.6±0.6a	13.3±0.3a	29.7±0.1a
	T4	18.6±0.3ab	4.5±0.6a	2.9±0.4a	13.0±0.0a	28.7±2.7a

Note: The data in the table of agronomic traits are the average value of three repetitions. Different lowercase letters in the same column represent the level of 0.05, with significant difference.

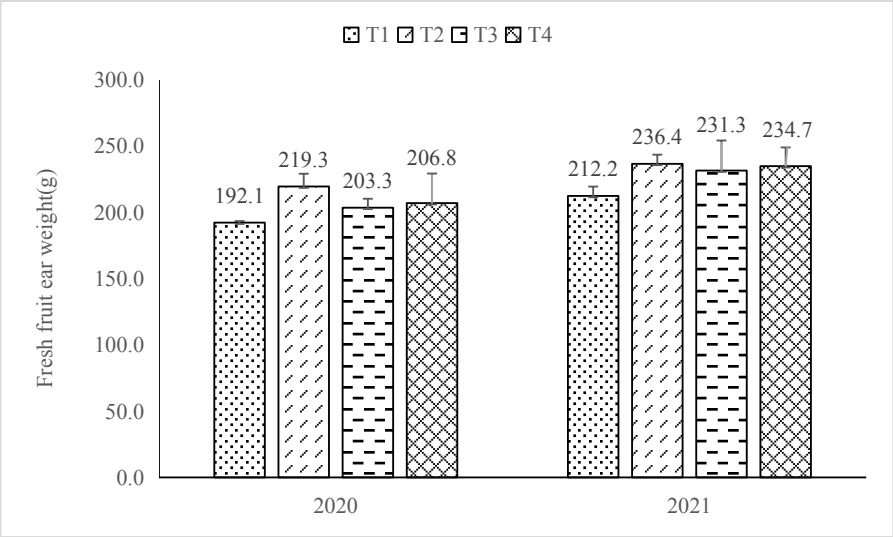

Figure 1. Ear weight of fresh fruit under different intercropping models

Note: The data in the table are SEm.

3.2 Effects of Different Intercropping Models on Maize Yield

In the two years, the yield of maize intercropping was higher than that of monoculture. Although there was no significant difference among all treatments, maize intercropping soybean (T2) showed the highest yield, with an average yield of 42.1 kg and 43.5 kg respectively, followed by maize intercropping sweet potato (T4). Corn intercropping with soybean plays a great role in increasing corn yield and is a better choice, which can improve economic benefits (Figure 2).

3.3 Grey Correlation Analysis of Agronomic Characters and Yield in Different Intercropping Models

According to the requirements of grey theory, the correlation degree and order of correlation degree of agronomic traits to yield in 2020 and 2021 are shown in Table 3. The correlation degree of all traits to yield are as follows: ear length (0.7324) > grain number per row (0.7144) > plant height (0.7073) > ear height (0.6857) > stem diameter (0.6481) > rows per ear (0.6009) > bald tip length (0.5910) > ear width (0.5461); Ear length (0.8141) >

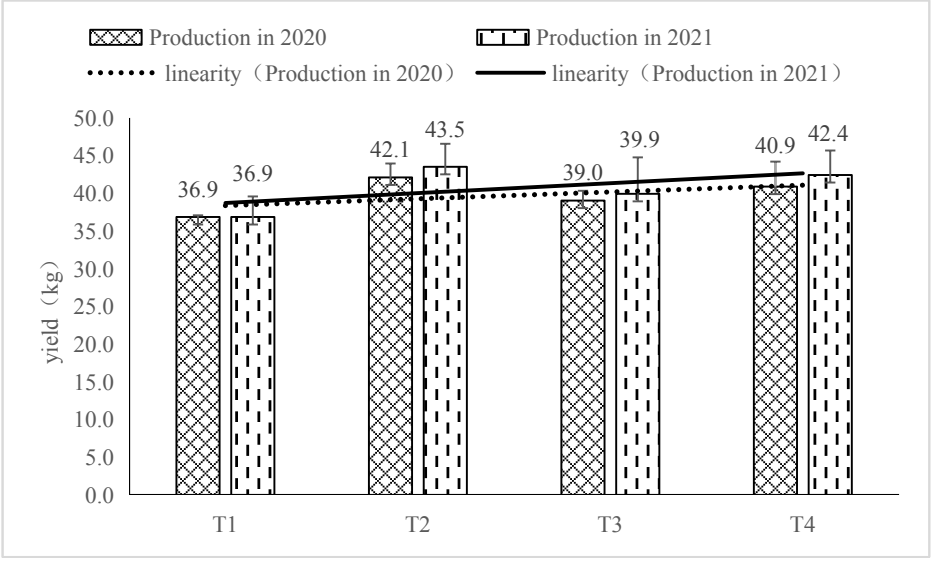

Figure 2. Yield of fresh ear plots under different intercropping models

Note: The data in the table are SEm.

rows per ear (0.8034) > plant height (0.7961) > ear height (0.7887) > ear width (0.7718) > bald tip length (0.6358) > grain number per row (0.6032) > stem diameter (0.4379). The correlation order of ear diameter, number of rows per ear, number of grains per row and yield changed greatly in different years, while the correlation order of ear length, plant height, ear position height and yield was relatively stable. The correlation between ear length, plant height and yield was the first and third in two years, indicating that ear length and plant height had a great impact on yield. The grey correlation analysis of Maize Yield and agronomic traits can explore the relationship between maize yield and agronomic traits, help to clarify the yield trait factors affecting maize high yield, and provide a basis for the theory of high yield of different intercropping maize in the later stage. The results showed that the development of different maize intercropping modes should pay attention to strengthening field management and improving ear length, plant height and stem diameter. The selection of maize intercropping mode suitable for red soil dryland is helpful to improve the yield of maize intercropping (Table 3).

Table 3. Correlation degree and order between agronomic characters and yield of Maize under different intercropping modes

Agronomic traits	2020		2021	
	Correlation degree	Correlation order	Correlation degree	Correlation order
Plant height	0.7073	3	0.7961	3
Stem diameter	0.6481	5	0.4379	8
Ear height	0.6857	4	0.7887	4
Ear width	0.5461	8	0.7718	5
Ear length	0.7324	1	0.8141	1
Rows per ear	0.6009	6	0.8034	2
Grain number per row	0.7144	2	0.6032	7
Bald tip length	0.5910	7	0.6358	6

4. Discussion

4.1 Effects of Different Intercropping Models on Agronomic Characters and Yield

Studies have shown that in intercropping systems such as maize soybean [20] and maize peanut [21,22], the yield of intercropping maize is significantly higher than that of monocropping, showing obvious advantages in intercropping yield [23]. The research results of Xie Xinghua et al. [24] showed that the yield per plant of intercropping maize was higher than that of monocropping maize. The intercropping of corn and sweet potato can increase the crop yield per unit land area, which is conducive to ensuring food security and increasing farmers' income. The research results of Shen Lei et al. [25] showed that compared with monocropping, corn intercropping can promote the growth of corn and increase the yield of corn, and it has better planting advantages. The results of this study show that corn intercropping can increase the plant height, ear height, stem diameter, ear length, number of rows and grains, and yield of corn, and has advantages in promoting corn growth and yield.

4.2 Grey Correlation Analysis of Agronomic Characters and Yield in Different Intercropping Models

The research results of Wang Pingxi et al. [26] showed that the correlation degree between the main agronomic characters and yield of each maize line was as follows: ear width > grain number per row > leaf length per ear > stem diameter > ear length > ear height > number of male ear branches > leaf width per ear > main shaft length of male ear > angle between upper ear leaves > plant height > leaf area per ear > rows per ear > bald tip length, including ear width, grain number per row, stem diameter had a great effect on maize yield. Sun Fengcheng et al. [27] applied grey correlation analysis to show that the agronomic traits closely related to maize yield are seed yield, grain number per row, ear width, 100 grain quality and plant height. The results showed that different agronomic characters would have different effects on maize, such as ear length, plant height and so on. Therefore, when developing different intercropping models of maize in red soil dryland, we should pay attention to the selection of varieties with appropriate ear length and plant height. In this study, only one variety of Gancainuo 7 was selected. There may be differences among different maize varieties. Different geographical locations, climatic conditions and cultivation and management measures can also lead to different test results.

5. Conclusions

The results showed that maize intercropping could not only improve plant height, stem diameter and ear height, promote ear length, grain number per row and other ear characters, but also improve maize yield. The main agronomic factors affecting the yield of intercropping maize are ear length and plant height. Selecting suitable varieties and strengthening field management are conducive to better correlation and improve the yield. The comprehensive

analysis shows that the intercropping advantage of maize and soybean is obvious, which is conducive to high quality and high yield.

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Conflict of Interest

The authors declare no conflict of interest.

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