Effects of intercropping different leguminous green fertilizers on navel orange yield, quality, and basic soil fertility

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Abstract. Using a field plot experiment method, the effects of intercropping three leguminous green fertilizer varieties (i.e., Chamaecrista rotundifolia (Pers.) Greene, Vigna sesquipedalis, and Indigofera hendecaphylla Jacq.) on the fruit appearance, nutritional quality, soil erosion in the topsoil layer, and basic fertility of the navel orange orchard were studied, with no intercropping green fertilizer treatment as a control. The results showed that intercropping those three green fertilizer varieties in the navel orange orchard, compared to the control treatment, the vertical diameter of navel orange fruit increased by 3.34%~11.35%, the horizontal diameter increased by 3.05%~7.46%, the single fruit weight increased by 2.45%~28.15%, and the yield increased by 6.85%~19.94%; Increasing the water-soluble total sugar content of the fruit by 19.93%~ 41.09%; The loss thickness of the surface soil of the orchard can be reduced by 0.9cm, 1.0cm, and 1.1cm, with a reduction rate of 30.6%, 27.8%, and 25.0%, respectively; Improve the organic matter of the surface soil of the orchard by 86.7%~214.9%, total nitrogen by 100.0%~238.7%, total phosphorus by 50.0%~450.0%, alkali hydrolyzed nitrogen by 90.8%~145.3%, available phosphorus by 18.4%~571.1%, and available potassium by 94.9%~205.1%. Among them, intercropping Vigna sesquipedalis treatment has a relatively better effect on improving the basic fertility of the surface soil of the navel orange orchard.

Keywords: Navel orange, Yield, Nutritional quality, Soil erosion, Basic soil fertility.

The cultivation history of citrus fruit trees in China is long, with over 4000 years of cultivation history to this day. Navel oranges are derived from sweet orange branches introduced from China to Europe and America, and are named "Navel Oranges" due to their cracked tops resembling navel eyes[1,2]. Navel orange 52 is a new variety bred by Fuzhou Institute of Agricultural Sciences and Fuzhou cash crop Technical Station, and is one of the main fruit varieties planted in Minhou County, Fujian Province at present[3,4].

However, the production and management of navel orange orchards in Minhou County is generally extensive. The orchard management is mainly based on scattered cultivation and respective business models. The orchard farmers have weak awareness of ecological orchard construction and are accustomed to the "three side light" production and management model of orchard weeding. The orchard soil is mostly exposed. In addition, due to the rising price of agricultural materials and the aging of orchard managers in recent years, the orchard planting and breeding are disjointed, and soil fertility continues to decline, The soil erosion is constantly intensifying, the ecological environment of orchards is deteriorating, and the potential for the development of ecological fruit industry needs to be explored.

Previous studies have shown that intercropping suitable varieties of leguminous green manure in orchards can effectively improve fruit yield and quality, reduce surface soil loss in orchards, and improve soil fertility[5~7]. It is an economically feasible ecological orchard cultivation technology model. This study focuses on the problems of bare, acidified, low fertility and water&soil loss in the navel orange orchard in Minhou County, focusing on the characteristic ecological fruit industry and the advantages of livability and business on both sides of the Minjiang River. By monitoring the impact of interplanting three leguminous green manure varieties(i.e., Chamaecrista

rotundifolia (Pers.) Greene, Vigna sesquipedalis, and Indigofera hendecaphylla Jacq.) in the navel orange orchard on the yield and quality of navel oranges and the soil fertility of the orchard, it explores the impact of the orchard surface soil planted Green crops. The green and efficient planting techniques for cultivating soil fertility in the cultivated layer provide a basis and demonstration for building a hilly characteristic ecological orchard construction model, achieving green coverage of orchards on both sides of the Minjiang River, and promoting the green and high-quality development of Minhou fruit industry.

1. Materials and Methods

1.1 Basic information of the test site

The test site is located in the navel orange planting base of Fuzhou Qinglianshan Agricultural Technology Co., Ltd in Baisha Town, Minhou County, Fuzhou City, Fujian Province. The soil type is mountain red soil, and the basic soil fertility status is: pH 4.32, organic matter 11.29 g·kg 1, total nitrogen 1.98 g·kg 1, total phosphorus 0.10 g·kg 1, total potassium 10.2 g·kg 1, Alkali hydrolyzable nitrogen 76.0 mg·kg 1, available phosphorus 1.57 mg·kg 1, and available potassium 84.0 mg·kg 1.

1.2 Experimental Design

Four treatments were designed for the experiment, namely non interplanting (control), interplanting Chamaecrista rotundifolia (Pers.) Greene, Vigna sesquipedalis, and Indigofera hendecaphylla Jacq. Each experimental plot has an area of 45 m2, with 4 replicates processed and randomly arranged in blocks. The tested navel orange variety is "Navel Orange 52", with a tree age of 3 years. The tested Indigofera hendecaphylla Jacq was planted using the seedling (stem) transplanting method in April 2021, with a cluster spacing of 25 cm outside the drip line at the edge of the navel orange tree crown. Two seedlings (stems) were planted in one row per cluster; In April 2021, the seed drilling method was used to sow one row of Chamaecrista rotundifolia with a row spacing of 25cm outside the drip line at the edge of the navel orange tree crown, with a sowing amount of 15 kg·hm-2; Vigna sesquipedalis are seeded using the seed hole sowing method, with holes dug at a distance of 25cm outside the drip line at the edge of the navel orange tree crown. The sowing amount is 45 kg·hm-2. Except for intercropping different varieties of green manure, all other field planting and management measures in the experiment were completely consistent. The experimental period is from April 2021 to June 2022. During the experiment, record the navel orange fruit yield and fresh grass yield of each experimental plot. The interplanted green manure is harvested and tested for yield every winter (early November), and covered between rows of navel orange trees. Regular removal of weeds without intercropping (control) treatment, and on-site coverage of the removed weeds between navel orange tree rows.

1.3 Test methods

The observation of the thickness of surface soil loss in navel orange orchards adopts the widely used pile driving method for soil and water loss monitoring[8]. Each experimental community is equipped with one pile sign, and each pile is marked to represent the current soil height. After 1 year, the height between the soil surface of each pile and the mark on the pile is measured to determine the thickness of surface soil loss at that location during the experimental year. After the completion of the experiment in each experimental community, the surface soil of the tea garden (0-20 cm) was collected from multiple points along the "S" shaped line. After thoroughly mixing the soil samples from different communities in the same treatment, 500 g of mixed soil samples were taken as the analysis and testing soil samples for this treatment.

The determination of basic soil fertility status is carried out using conventional analysis methods[9]: pH is determined using the potential method; Organic matter using potassium dichromate volumetric method; Use semi micro Kelvin method for total nitrogen; Determination of

total phosphorus using molybdenum blue colorimetry; Flame photometry for total potassium; Alkali hydrolysis diffusion method for available nitrogen; Available phosphorus was extracted with 0.05 mol·L 1 NaHCO3 and determined by molybdenum blue colorimetry; available potassium is determined by flame photometry.

1.4 Data processing

We used Microsoft Excel 2003 office software for experimental data processing, and SPSS 10.0 statistical software for analysis of variance and significance testing.

2. Results and Analysis

2.1 Effect of intercropping different leguminous green fertilizers on the apparent characteristics of navel orange fruit

Table 1. Effect of intercropping different leguminous green fertilizers on the apparent characteristics of navel orange fruit

Treatments	Vertical diameter		Horizontal diameter		Single fruit weight		Yield	
	（cm）	Increase rate （%）	（cm）	Increase rate （%）	（g）	Increase rate （%）	（t·hm -2）	Increase rate （%）
Control (without intercropping)	7.5b	\	7.4a	\	219.6Bb	\	3.21b	\
Chamaecrista rotundifolia	7.8ab	3.67	7.6a	3.56	226.5Bb	3.13	3.45ab	7.48
Vigna sesquipedalis	8.0ab	6.34	7.6a	3.05	225.0Bb	2.45	3.43ab	6.85
Indigofera hendecaphylla	8.3a	11.35	7.9a	7.46	281.4Aa	28.15	3.85a	19.94

Note:Different capital and small letters indicate the difference is significant at 0.05 and 0.01 levels, respectively (inspect by LSD). The same below.

The experimental results (Table 1) indicate that compared with the control (non interplanting) treatment, the interplanting of three technical models in orchards, Chamaecrista rotundifolia, Vigna sesquipedalis, and Indigofera hendecaphylla, can improve the apparent characteristics of navel orange fruit to a certain extent, increasing the vertical diameter, transverse diameter, single fruit weight, and yield by 3.34%~11.35%, 3.05%~7.46%, 2.45%~28.15%, and 6.85%~19.94%, respectively. Among them, the interplanting of Indigofera hendecaphylla pattern has the best improvement effect on the apparent traits of navel orange fruit, such as longitudinal diameter, transverse diameter, and single fruit weight. From the perspective of annual growth of green manure, in addition to weak growth in the early stage and time-consuming and laborious management of stem cutting and weed removal in the early stage, the intercropped Indigofera hendecaphylla in the orchard can smoothly overwinter in winter, achieving one season planting and long-term growth; The intercropped green manure varieties such as Chamaecrista rotundifolia, and Vigna sesquipedalis die around December of the year they are planted, and need to be re sown in the spring of the following year.

2.2 Effect of intercropping different leguminous green fertilizers on the nutritional quality of navel orange fruit

The experimental results (Table 2) indicate that compared with the control (non intercropping) treatment, the three technical modes of intercropping Chamaecrista rotundifolia, Vigna sesquipedalis, and Indigofera hendecaphylla in orchards can significantly or extremely significantly

increase the water-soluble total sugar content of navel orange fruit, with an increase range of 19.93%~41.09%; Intercropping with Indigofera hendecaphylla can also reduce the dripable acid and nitrate content of navel orange to a certain extent, with a reduction rate of 25.00% and 5.94%, respectively, So as to improve the flavor quality of navel orange (increase the sugar content of the fruit, reduce the dripable acid content, thereby increasing the sugar acid ratio of the fruit, which is conducive to improving the flavor quality of the fruit) and the health quality (nitrate is the precursor of the recognized carcinogen nitrite, and reducing the nitrate content is conducive to improving the health quality of the fruit).

Table 2. Effect of intercropping different leguminous green fertilizers on the nutritional quality of navel orange fruit

Treatments	Reduced Vc		Titratable acidity		Water-soluble total sugar		Nitrate	
	（mg/kg）	Increase rate（%）	（%）	Increase rate（%）	（%）	Increase rate（%）	（mg/kg）	Increase rate（%）
Control (without intercropping)	387.7a	\	0.52a	\	8.98Bc	\	388.6a	\
Chamaecrista rotundifolia	422.5a	8.98	0.61a	17.31	12.67Aa	41.09	455.7a	17.27
Vigna sesquipedalis	387.1a	-0.15	0.53a	1.92	10.77ABb	19.93	359.9a	-7.39
Indigofera hendecaphylla	402.1a	3.71	0.39b	-25.00	10.87ABb	21.05	365.5a	-5.94

2.3 Effects of intercropping different leguminous green fertilizers on soil erosion in orchards

Through the observation of the soil loss thickness of the one-year orchard surface layer under different green manure intercropping modes, the results (Table 3) show that compared with the control (non intercropping) treatment, the three technical modes of intercropping Chamaecrista rotundifolia, Vigna sesquipedalis, and Indigofera hendecaphylla in the orchard significantly reduce the soil loss thickness of the citrus orchard surface layer. The soil loss thickness decreased by 0.9cm, 1.0cm, and 1.1cm, with a reduction rate of 30.6%, 27.8%, and 25.0%, respectively.

Table 3. Effects of intercropping different leguminous green fertilizers on soil erosion in orchards

Treatments	Navel orange Orchard	
	Loss thickness(cm)	Increase rate(%)
Control (without intercropping)	3.6a	\
Chamaecrista rotundifolia	2.5b	-30.6
Vigna sesquipedalis	2.6b	-27.8
Indigofera hendecaphylla	2.7b	-25.0

2.4 Effects of intercropping different leguminous green fertilizers on the basic fertility of surface soil in orchards

Table 4. Effects of intercropping different leguminous green fertilizers on the basic fertility of the surface soil of orchards

Treatments	pH		Organic matter	
	Value	Increase rate（%）	（g/kg）	Increase rate（%）
Control (without	5.2b	\	6.3Cc	\

intercropping)				
Chamaecrista rotundifolia	5.0b	-3.8	19.2Aa	203.8
Vigna sesquipedalis	6.9a	32.7	19.9Aa	214.9
Indigofera hendecaphylla	5.6b	7.7	11.8Bb	86.7

Table 4. Effects of intercropping different leguminous green fertilizers on the basic fertility of the surface soil of orchards(continued)

Treatments	Total nitrogen,		Total phosphorus		Total potassium	
	（%）	Increase rate（%）	（%）	Increase rate（%）	（%）	Increase rate（%）
Control (without intercropping)	0.031c	\	0.010Cc	\	2.80a	\
Chamaecrista rotundifolia	0.082Aab	164.5	0.020Bb	100.0	2.15a	-23.2
Vigna sesquipedalis	0.105Aa	238.7	0.055Aa	450.0	2.85a	1.8
Indigofera hendecaphylla	0.062Ab	100.0	0.015BCb	50.0	3.31a	18.2

The experimental results (Table 4) indicate that compared with the control (non intercropping) treatment, the three technical modes of intercropping Chamaecrista rotundifolia, Vigna sesquipedalis, and Indigofera hendecaphylla in orchards can all improve the soil organic matter, total nitrogen, total phosphorus, alkaline hydrolyzed nitrogen, available phosphorus, and available potassium content to a certain extent, with the increase rates of 86.7%~214.9%, 100.0%~238.7%, 50.0%~450.0%, 90.8%~145.3%, 18.4%~571.1%, and 94.9%~205.1%, respectively. Among them, intercropping Vigna sesquipedalis in orchards has a relatively better effect on improving the basic fertility of the surface soil in navel orange orchards. However, for soil pH and total potassium content, the intercropping of Chamaecrista rotundifolia in orchards showed a decreasing trend, with a reduction rate of 3.8% and 23.2%, respectively; However, intercropping Vigna sesquipedalis and Indigofera hendecaphylla in orchards showed an improvement effect, with pH increase rates of 32.7% and 7.7%, and total potassium increase rates of 1.8% and 18.2%, respectively.

Table 4. Effects of intercropping different leguminous green fertilizers on the basic fertility of the surface soil of orchards(continued)

Treatments	lkali hydrolyzed nitrogen		Available phosphorus		Available potassium	
	（mg/kg）	Increase rate（%）	（mg/kg）	Increase rate（%）	（mg/kg）	Increase rate（%）
Control (without intercropping)	41.1Bc	\	3.8Bc	\	59Cd	\
Chamaecrista rotundifolia	100.8Aa	145.3	4.5Bc	18.4	115Bc	94.9
Vigna sesquipedalis	84.0Aa	104.4	25.5Aa	571.1	156Ab	164.4
Indigofera hendecaphylla	78.4Ab	90.8	5.5Bb	44.7	180Aa	205.1

3. Conclusion

The results of this experiment showed that compared with the control (non intercropping) treatment, intercropping three leguminous green fertilizers in navel orange orchards, including Chamaecrista rotundifolia, Vigna sesquipedalis, and Indigofera hendecaphylla, can increase the vertical diameter of the fruit by 3.34%~11.35%, the horizontal diameter by 3.05%~7.46%, the single fruit weight by 2.45%~28.15%, and the yield by 6.85%~19.94%, respectively. Among them, the intercropping Indigofera hendecaphylla mode has the best effect on improving the vertical diameter, horizontal diameter, and single fruit weight of the navel orange fruit, as well as increasing the yield; 2) It can increase the water-soluble total sugar content of the fruit by 19.93% to 41.09%, and intercropping with Indigofera hendecaphylla can also reduce the dripable acid content by 25.00% and nitrate content by 5.94%, thereby improving the flavor and hygiene quality of the navel orange; 3) The loss thickness of the surface soil of the orchard can be reduced by 0.9cm, 1.0cm, and 1.1cm, with a reduction rate of 30.6%, 27.8%, and 25.0%, respectively; 4) It can increase the organic matter of the surface soil of the orchard by 86.7%~214.9%, total nitrogen by 100.0%~238.7%, total phosphorus by 50.0%~450.0%, alkali hydrolyzed nitrogen by 90.8%~145.3%, available phosphorus by 18.4%~571.1%, and available potassium content by 94.9%~205.1%. Among them, intercropping Vigna sesquipedalis treatment has a relatively better effect on improving the basic fertility of the surface soil of the navel orange orchard.

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