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Production Mode and Economic Benefit of Improved No-tillage Intercropping with Potato in New Mode Citrus Orchard

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Abstract [**Objectives**] In terms of increasing the utilization of land in agriculture and the per unit area yield, intercropping is the most popular farming method. [**Methods**] Based on the climate and soil conditions in Zhaoqing, this experiment explored the improved mode of no-tillage intercropping winter potato with citrus in the new high-ridge, wide-row and dense-plant cultivation mode citrus orchard. Taking the conventional tillage and film-mulched intercropping as the control, it studied the adaptability of intercropping, evaluated the quality, and analyzed its economic benefits. [**Results**] The early emergence rate of improved no-tillage intercropping cultivation was slightly higher than that of conventional tillage and film-mulched intercropping, but the difference of final emergence rate was not significant, indicating that improved no-tillage intercropping cultivation could provide excellent potato emergence environment. Under the conventional tillage and improved no-tillage intercropping cultivation mode, the change trend of the potato's plant height, main stem thickness, crown diameter and number of leaflet is the same. The change rule of the crown diameter of the film-mulched intercropping cultivation method is similar to that of the plant height, both have a large increase in the late growth stage. The potato yield of improved no-tillage intercropping cultivation were 22 747.5 kg/ha, and the proportions of potatoes of each grade were 11.85%, 35.61%, 37.63% and 14.91%, respectively. The content of dry matter, Vc, soluble protein, starch and amino acid in the main nutrients of the potato under the improved no-tillage intercropping mode is not significantly different from that of the film-mulched intercropping cultivation. The changing trend of reducing sugar content showed that the reducing sugar content of no-tillage intercropping cultivation was the highest (0.466%). Through evaluating the eating characteristics of potatoes from the flavor, taste, texture and appearance after chewing, the three cultivation methods have little difference. In the no-tillage intercropping cultivation technology, the growth of potatoes consumes part of the nutrients in the soil between the rows of the citrus orchard, but it does not exerts a significant impact on the surrounding citrus trees. Compared with the film-mulched intercropping cultivation, the improved no-tillage intercropping cultivation method does not require the expense of mulched, the cost of fertilizer is low, and labor costs are saved, so a net income of 27 075 yuan/ha can be obtained. [**Conclusions**] From the perspective of orchard intercropping, it has achieved the effect of improving soil utilization and increasing output without reducing the edible quality of potatoes.

Key words Citrus orchard, Intercropping, Potato, Mode, Economic benefits

1 Introduction

The new citrus orchard cultivation mode adopts high-ridge, wide-row and dense-plant cultivation. In the flat land between rows, there are natural grasses, but seldom artificially planted grasses, and there is no report of interplanting with other cash crops. As early as 1989, some scholars interplanted different crops in young orchards and planted them together with forage crop, to develop the breeding industry, so as to improve soil fertility and promote the growth and development of fruit trees[1]. Liang Mingfeng[2], Lin Tao *et al.*[3] conducted experiments in the interplanting mode of "citrus + watermelon + dryland rice + potato" and "citrus + watermelon" in the citrus orchard, in which the potato was cultivated by ridge mulched. Rong Siwen[4] carried out deep plowing and interplanting of potatoes in young orange orchards in the citrus industrial zone in the upper and middle reaches of the Yangtze River. The average yield of potatoes was 9 900 kg/ha, and the output value reached 36 900 yuan/ha. Lu Rongfen[5] interplanted potatoes with black film in the pitaya orchard in Wuming County, Nanning City of Guangxi; Zhu Peiying[6] interplanted potatoes with no-tillage straw mulched technique in a greenhouse vineyard in Haiyan County, Zhejiang Province, realizing the income increase by 18 000 yuan/ha. Through planting potatoes in the middle of green fresh maize, the potato yield reached 18 750 kg/ha, and the income reached 56 250 yuan/ha[7]. There are different modes of intercropping in citrus orchards, but most of them remain in the experimental stage, and it is still difficult to promote, mainly because the production of citrus in China is mainly concentrated in economically underdeveloped areas. If the intercropping increases excessive cost input, in addition to the fluctuation of the economic value of the output, the fruit growers will be less willing to acceptance of intercropping.

In recent years, Guangdong Province has developed winter

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potato relatively rapidly. The planting area has increased from 44 800 ha in 2014 to 67 000 ha in 2016. Suitable areas include Zhanjiang, Maoming, Huizhou, Xinyi, Yangchun and Zhaoqing[8]. Located in the central and western part of Guangdong Province, Zhaoqing City has a subtropical monsoon climate, its soil belongs to the southern red soil and the fertile land provides favorable conditions for citrus planting. The citrus industry in Zhaoqing is the pillar industry of Zhaoqing's agriculture, and the average winter temperature is 13 – 15 ℃, the extreme low temperature is 3.5 – 5.5 ℃, showing Zhaoqing is a suitable area for winter potato planting[7-8]. In the newly promoted wide-row, dense-plant and high-ridge cultivation mode, no scholars studied the flat land between rows of citrus orchards, and there are still many disadvantages in the production practice of many intercropping modes, so the promotion is limited. In view of the climate and soil conditions in Zhaoqing, we conducted a winter improvement experiment of no-tillage intercropping of potatoes in high-ridge, wide-row and dense-plant cultivation mode citrus orchards. No-tillage cultivation technology[9-10] is a labor-saving, high-quality and high-yield technology that has been successfully tested in many provinces and regions in recent years and has been quickly promoted. It is mainly no-tillage rice straw covered cultivation without disturbing the soil except for sowing or fertilization. This experiment improved the no-tillage technology. On the one hand, rice is not planted around some orchards, so it is difficult to obtain straw. On the other hand, some counties already have economic recycling channels for the straw after planting rice, and the purchase of orchards requires additional costs. In view of these problems, we directly used the raw grass and sandy soil in the citrus orchard to replace rice straw, and the cost of fertilizers and pesticides was reduced. We tested the improved no-tillage intercropping mode taking the conventional cultivation and film-mulched intercropping as comparison. The test included potato plant height, stem diameter, number of leaves and other growth indicators, to study the adaptability of interplanting citrus and potato in Zhaoqing. Besides, we calculated the yield, output value, evaluated the quality, analyzed its economic benefits, so as to provide reference and experience for the production mode of improved no-tillage intercropping potatoes with citrus in the high-ridge, wide-row and dense-plant cultivation mode citrus orchards in winter in Zhaoqing.

2 Materials and methods

2.1 Source of materials The potato seeds used in this experiment were provided by Snowvalley Agricultural Development Co., Ltd.

2.2 Experimental method

2.2.1 Open field ridge cultivation and conventional tillage cultivation method (CK). Before planting, conducted plowing and ridging and applied the organic fertilizer necessary for the full growth period at one time. The planting row spacing was about 30 cm, and the seed potato spacing was about 15 cm. At the uniform seedling stage, applied one time of fertilizer. Later, applied fertilizer two times. When the seedling height reached about 15 cm, earthed up, and kept the production conditions stable in the planting period, and ensured the normal water supply.

2.2.2 Film-mulched intercropping cultivation mode (CK). This mode was carried out on flat ground between rows of citrus under high ridge cultivation. Performed plowing and slightly ridging on the flat land, applied organic fertilizer required for the full growth period at one time. The planting area was about 1.2 m away from the canopy of the citrus tree, arranged in triangular form, and the spacing between seed potatoes was about 15 cm. Applied fertilizer between rows of potatoes (prevent fertilizer from getting into contact with the seed potatoes), installed water hose, covered with mulch, and compacted the mulch with a little soil on the ridge surface.

2.2.3 Improved no-tillage intercropping cultivation mode. This mode was carried out on flat ground between rows of citrus under high ridge cultivation. In the whole year, grasses naturally grow between rows and harvested four times. Ridging is not required before planting potato in winter. The planting area was about 1.2 m away from the canopy of the citrus tree, arranged in triangular form, and the spacing between seed potatoes was about 15 cm. Applied fertilizer between rows of potatoes (prevent fertilizer from getting into contact with the seed potatoes). Covered the seed potatoes with a small amount of soil on the ridge surface of the citrus tree, and then covered the harvested and crushed grass on the top. Cultivated the soil when the seedling height was 15 cm. After harvesting, the remaining grasses and soil between the rows were backfilled on the ridge surface of the citrus tree.

2.3 Testing indicators

2.3.1 Determination of potato growth status. After the potato was sowed, made a record of the potato emergence every five days, and calculated the emergence rate by the formula [Emergence rate (%) = Number of seedlings/Number of sowing × 100]; after seedlings became uniform, measured the plant height (cm), crown diameter (cm), stem diameter (cm), number of leaf every 10 d; at harvesting, measured the number, fresh weight (kg), longitudinal diameter (cm), transverse diameter (cm), and circumference (cm) of extra large potato (above 150 g), large potato (100 – 150 g), medium potato (50 – 100 g), and small potato (below 50 g); observed the tuber trait indicators (skin smoothness, uniformity of tuber size, and irregular shape potato); calculated the commodity rate [Commodity rate (%) = Weight of large and medium potatoes/Total weight of potatoes × 100], green potato rate [Green potato rate (%) = Number of green potatoes/Total number of potatoes ×100], and bad potato rate [Bad potato rate (%) = Number of bad potatoes/Total number of potatoes ×100], and the yield.

2.3.2 Evaluation of potato nutritional quality and flavor traits. The testing of potato nutritional quality mainly includes testing of dry matter, starch, reducing sugar, Vc, soluble protein and phenolic substances; the evaluation of flavor traits mainly includes the evaluation of tuber integrity, appearance, hardness, degree of easy breakage, graininess, powdery, roughness, firmness, wet viscosi-

ty, stickiness, earthy smell, *etc.*).

2.3.3 Economic benefit indicators. The cost input mainly includes seed potato cost, fertilization cost, pest control cost and labor cost. The total revenue mainly includes potato output value; net revenue = total revenue − cost input.

2.3.4 Determination of the nutrient content of soil and citrus leaves. (i) Soil samples: The pH value was determined by the potentiometric method (at the soil-water ratio of 1∶2.5); the organic matter was determined by the oil bath heating potassium dichromate oxidation volumetric method; the available nitrogen was determined by the alkaline solution diffusion method; the available phosphorus was determined by ammonium fluoride-hydrochloric acid extraction molybdenum antimony colorimetric method; available potassium was determined by flame photometric method with neutral ammonium acetate extraction[11]. The standard soil sample adopted GBW07417a (ASA-6a), Guangdong paddy soil. (ii) Leaf samples: Total nitrogen was determined by H_2SO_4-H_2O_2 digestion Kjeldahl method; total phosphorus was determined by H_2SO_4-H_2O_2 digestion molybdenum-antimony anti-colorimetric method; total potassium was determined by H_2SO_4-H_2O_2 digestion flame photometric method[11].

3 Results and analysis

3.1 Effects of different intercropping modes on potato growth indicators From Fig. 1, it can be known that there is no significant difference in the emergence rate between the conventional tillage cultivation (CK) and the intercropping film-mulched cultivation mode and no-tillage cultivation mode. The emergence rate of the seedlings was the fastest in the first 25 d. The emergence rate of three modes was 50%, 53.1% and 59.2%, respectively, all were all over 50%. On the 40th day, the emergence rate of each cultivation mode was 82.7%, 83% and 84.8%, respectively. The emergence rate of no-tillage intercropping cultivation mode at the early stage was slightly higher than that of conventional tillage cultivation and film-mulched intercropping cultivation mode.

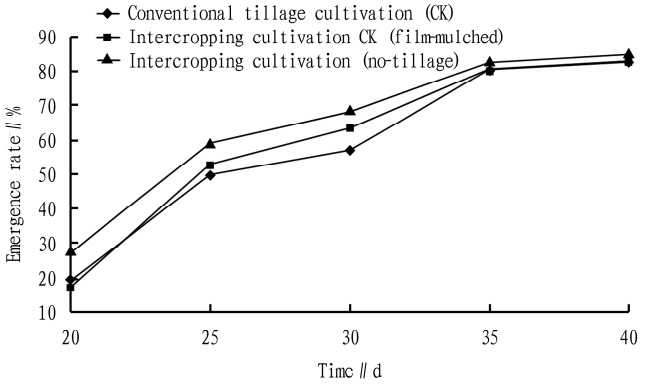


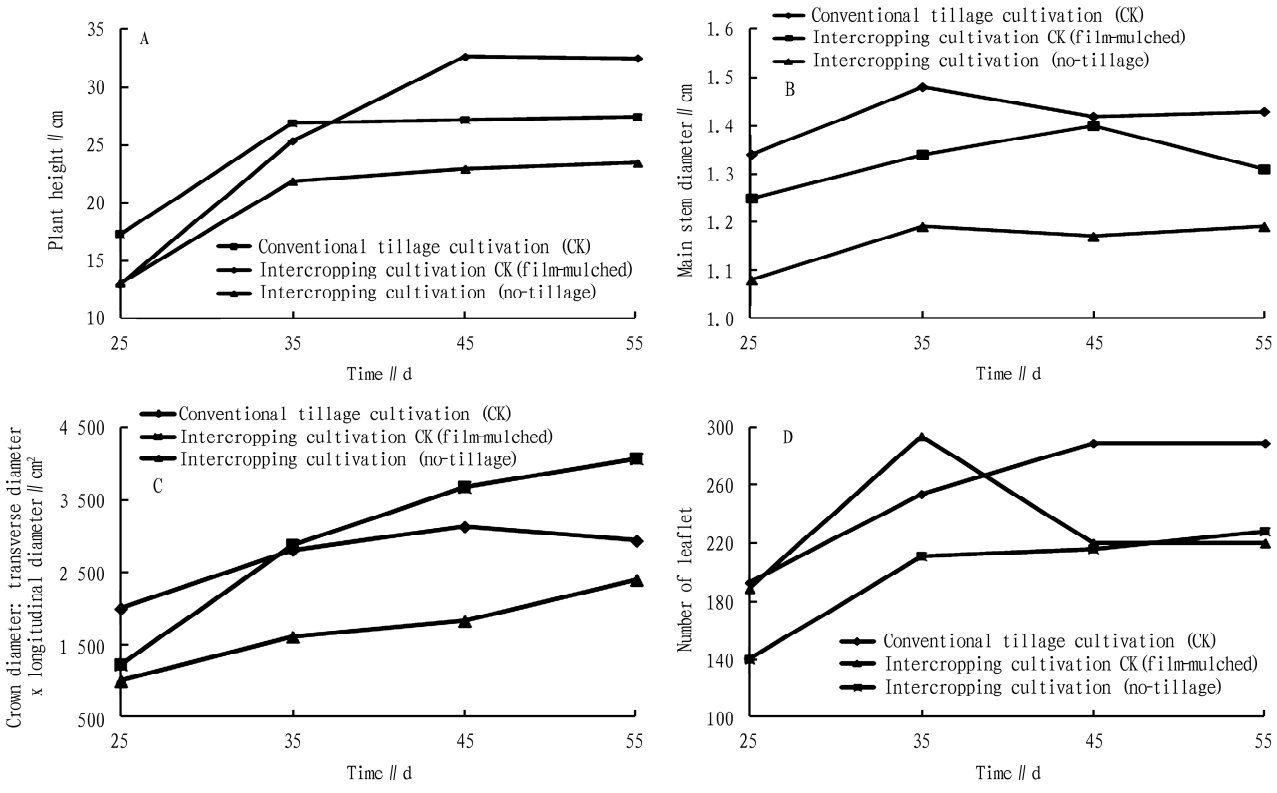
Fig. 1 Effects of different intercropping modes on emergence rate of potato

3.2 Effects of different intercropping modes on potato plant traits According to Fig. 2, from the 25th day to the 55th day of the potato growth period, the plant height, main stem diameter, crown diameter and number of leaflets and leaves of potatoes in the improved no-tillage intercropping and conventional tillage culivation (CK) models showed the same change trend, but the value was slightly lower than that of the conventional tillage cultivation. Compared with the film-mulched intercropping cultivation mode, the number of leaflet at early stage of no-tillage intercropping cultivation mode grew less fast, but after 35 d, there was no difference between them.

3.3 Effects of different intercropping modes on potato tuber traits After harvesting, potatoes were divided into extra large, large, medium, and small potatoes according to the fresh weight. The yield of potatoes from improved no-tillage intercropping cultivation was 22 747.5 kg/ha, and the proportion of each grade of potatoes was 11.85%, 35.61%, 37.63% and 14.91%, respectively. Among the potatoes harvested under conventional tillage cultivation conditions, extra-large potatoes and large potatoes were the majority, while large and medium potatoes were the majority under the improved no-tillage intercropping cultivation and film-mulched intercropping cultivation modes. Under the improved no-tillage intercropping cultivation mode, the flat land between rows of ridge cultivation was adopted, no base fertilizer was applied during plowing, fertilizer was applied only between the seed potatoes and a small amount of fertilizer was applied in the later management. The fertilization method was different and the amount of fertilizer was much lower than that of the conventional tillage cultivation mode, so the yield was lower than that of the conventional tillage cultivation mode (Table 1).

3.4 Effects of different intercropping modes on potato quality After harvesting, the main nutrient content of potatoes was tested, including the content of dry matter, Vc, soluble protein, starch and amino acids. Except for the amino acid content, the difference between the improved no-tillage intercropping mode and the intercropping control (film-mulched cultivation) mode did not reach a significant level. The changing trend of reducing sugar content was opposite to other indicators, showing that the reducing sugar content of no-tillage intercropping cultivation was the highest (0.466%). Studies have shown that the dry matter content of potato is positively correlated with starch content, but has no correlation with the reducing sugar content[12]. In this study, if the dry matter content is high, the Vc content, soluble protein content, starch content and amino acid content were also high under different cultivation modes. Statistical analysis showed a significant positive correlation (correlation coefficient was 0.982, 0.986 5, 0.982 4, 0.984 5, and 0.983 3, respectively) (Table 2).

According to the results of the difference analysis, the dry matter content is the most important quality of potato tubers, there were certain differences between the three cultivation modes, but there was no significant difference between the two intercropping modes. The Vc content, starch content, and amino acid content of potato cultivated under conventional tillage cultivation (CK) were significantly higher than the other two intercropping modes. The reducing sugar content of potatoes in intercropping improved no-tillage cultivation was significantly higher than that in conventional tillage cultivation, but the difference between that of film-mulched cultivation was not significant.



Note: A. plant height, B. main stem diameter, C. crown diameter, D. number of leaflet.

Fig. 2 Effects of different intercropping modes on potato plant traits

Table 1 Effects of different intercropping modes on potato tuber traits

Cultivation mode	Tuber size uniformity	Tuber smoothness	Potato weight // kg/ha				Green potato rate // %	Bad potato rate // %	Commercial potato rate // %	Longitudinal/transverse diameter // cm				Circumference // cm			
			EL	L	M	S				EL	L	M	S	EL	L	M	S
A	Medium, order	Smooth	27 031.65	12 515.40	2 874.15	1 455.30	8.74	0	96	12.12/7.36	8.72/6.46	7.62/5.44	4.96/4.00	21.34	18.88	15.94	11.94
B	Medium, uniform	Smooth	12 052.50	15 461.25	10 605.30	5102.55	9.00	1.27	88	10.08/7.38	7.40/5.78	6.46/5.14	4.36/3.96	22.36	18.80	16.52	12.50
C	Medium, quite order	Quite smooth	2 695.80	8 101.20	7 614.90	3 401.70	4.18	2.51	85	11.20/6.62	8.58/6.36	6.86/4.96	4.38/3.32	19.92	18.40	14.64	10.48

Note: A means the conventional tillage cultivation (CK), B stands for the intercropping cultivation CK (film-mulched), C represents the intercropping cultivation (improved no-tillage); EL means extra large, L denotes large, M denotes medium, and S means small.

Table 2 Effects of different intercropping modes on nutritional quality of potatoes

Cultivation mode	Dry matter content // %	Vc content mg/100g	Soluble protein content // %	Reducing sugar content // %	Starch content // %	Amino acid content // %
Conventional tillage cultivation (CK)	20.167^{a}	24.109^{a}	1.124^{a}	0.123^{b}	18.972^{a}	0.238^{a}
Intercropping tillage cultivation CK (film-mulched)	19.167^{ab}	13.424^{b}	1.106^{ab}	0.373^{a}	16.834^{b}	0.188^{b}
Intercropping cultivation (improved no-tillage)	18.267^{b}	12.011^{b}	0.993^{b}	0.466^{a}	15.266^{b}	0.147^{c}

Note: $P<0.05$ means significant difference.

The evaluation results of potato flavor traits under the three cultivation modes were listed in Table 3. The flavor traits of potatoes were evaluated from multiple indicators such as flavor, taste, texture and appearance after chewing. The three cultivation modes showed no much difference, but the potato of the conventional tillage cultivation (CK) had high viscosity and poor graininess, slight earthy smell, the potato earthy smell of the intercropping film-mulched cultivation (CK) was the strongest, and the potatoes under the improved no-tillage intercropping showed the driest chewing texture. The potato flavor is a complex trait, and flavor, especially bad flavor and taste are the main factors leading to the difference in flavor. The texture of cooked potato tubers is mainly determined by the dry matter content, starch particle size and starch structure in the tubers, and the dry matter content determines the final quality of the potato[13]. In this study, there were no significant differences in the dry matter content and starch content of potatoes in the three cultivation modes. This determines that the main flavor of potatoes is consistent, but individual flavor traits such as taste are different. Therefore, the potatoes used in the intercropping mode of citrus orchards can meet the requirements of commercial potatoes and are similar to those in conventional tillage cultivation.

Table 3 Evaluation of potato flavor traits under different intercropping modes

Cultivation mode	Tuber integrity	Appearance acceptance level	Hardness (cooked)	Degree of easy breakage (cooked)	Graininess	Powdery	Roughness	Firmness	Wet viscosity	Stickiness	Earthy smell
Conventional tillage cultivation (CK)	7.4	7.8	8.4	7.4	7.8	7.6	8.0	6.0	5.2	4.4	5.0
Intercropping cultivation (film-mulched)	7.4	7.0	7.8	5.8	6.4	5.4	6.2	8.0	6.3	6.2	8.8
Intercropping cultivation (no-tillage)	9.0	9.4	8.2	6.6	4.4	5.4	4.4	7.6	8.0	8.0	5.4

3.5 Effects of different intercropping modes on soil and plant of citrus orchard Under the conventional tillage cultivation mode, the fertilization is sufficient, and the content of organic matter, alkali-hydrolyzable nitrogen, available phosphorus (mg/kg), and available potassium are higher than those of the soil between rows of citrus orchards. Compared with the soil of flat land between rows of the same plot without intercropping with potatoes, the soil between rows of citrus orchards in intercropping (CK) with plastic film mulching was slightly higher in organic matter, alkali-hydrolyzable nitrogen and available phosphorus (Table 4), indicating that the amount of fertilizer applied to the potato was sufficient for the potato growth, without taking away the nutrients in the soil between the rows of the citrus orchard. However, the content of available potassium was slightly lower than that of the control, indicating that the amount of potassium fertilizer applied in the intercropping film-mulched cultivation mode was slightly insufficient and could not meet the growth needs of potatoes, so the growth of potatoes absorbed part of the potassium in the soil between rows of citrus orchards. The intercropping improved no-tillage cultivation mode adopted the measures of soil covering and grass covering between rows, and the amount of fertilizer was small. The amount of grass harvested each time was about 2 kg/m^2, and it could be harvested more than 4 times a year. After covering, the soil pH and the organic matter was slightly higher than that of the control. However, the nitrogen, phosphorus and potassium used cannot meet the growth of potatoes, and nutrients need to be obtained from the soil, which is represented by soil alkali-hydrolyzable nitrogen and available phosphorus (mg/kg), available potassium content were lower than the control. It was measured the nitrogen, phosphorus and potassium content of citrus leaves in the no-tillage area and the control area separately. The total nitrogen content of citrus leaves in the no-tillage area was 24.05 g/kg, the total phosphorus content was 1.12 g/kg, and the total potassium content was 8.65 g/kg, the total nitrogen content of citrus leaves in the control area was 25.28 g/kg, total phosphorus content was 1.27 g/kg, and total potassium content was 9.15 g/kg. Although there were differences between the two, they did not reach the level of significant difference. These indicate that in the intercropping improved no-tillage cultivation technology, the growth of potatoes consumes part of the nutrients in the soil between the rows of the citrus orchard, but it does not exerts a significant impact on the surrounding citrus trees.

Table 4 Changes of soil nutrients in citrus orchard under different intercropping modes

Treatment	pH value	Organic matter content//g/kg	Alkali-hydrolyzable nitrogen//mg/kg	Available phosphorus//mg/kg	Available potassium//mg/kg
Conventional tillage cultivation	6.44	38.01	136.15	359.99	361.84
Intercropping cultivation (film-mulched)	6.70	27.42	113.75	317.54	352.61
Film-mulched (CK)	6.95	18.44	105.35	42.33	389.53
Intercropping cultivation (improved no-tillage)	7.02	21.78	132.65	42.33	183.23
No-tillage (CK)	6.26	20.90	144.55	173.93	243.23

3.6 Effects of different intercropping modes on potato yield and economic benefits Yield and cost are the factors determining the economic benefits. Table 5 shows that the cost of the improved no-tillage intercropping cultivation mode was 29 340 yuan/ha, which is 25 318.5 yuan/ha less than the intercropping control (film-mulched), in which the film and hose costs were zero, fertilizer and other inputs were low, 19 822.5 yuan/ha less than the intercropping control (film-mulched), and the net income was 27 075 yuan/ha. From the perspective of intercropping in orchards, it has achieved the effect of improving soil utilization and increasing the yield (Table 5).

Table 5 Potato yield and economic benefit evaluation under different cultivation modes

Cultivation mode	Yield kg/ha	Output value yuan/ha	Seed potato yuan/ha	Film, hose yuan/ha	Fertilizer, pesticide, ratsbane//yuan/ha	Labor yuan/ha	Total cost yuan/ha	Net income yuan/ha
Conventional tillage cultivation (CK)	43 876.5	108 810	5 400	0	34 312.5	12 000	52 162.5	57 097.5
Intercropping tillage cultivation CK (film-mulched)	43 221.6	107 190	5 400	3 996	32 512.5	12 750	54 658.5	52 531.5
Intercropping cultivation (improved no-tillage)	22 747.5	56 415	5 400	0	12 690.0	11 250	29 340.0	27 075.0

Note: The output value was calculated based on the wholesale price of 2.48 yuan/kg in February 2019, the price of seed potatoes was 2.4 yuan/kg, and 750 kg/ha of seed potatoes were used. The area was calculated based on the plots where potatoes were actually planted.

4 Discussions

Seedling emergence is an important factor influencing potato yield. The low emergence rate of no-tillage cultivation has always been a problem[14]. In this experiment, the emergence of no-till-

age cultivation is earlier than the other two cultivation modes, but the final emergence rate is not much different. It indicates that improved no-tillage intercropping mode can provide a good environment for the emergence of seed potatoes, but it is not a key factor affecting its subsequent yield and quality. In the process of potato growth, plant height, crown diameter and stem diameter reflect the growth status of the plant, and the vigorous growth will bring high yield[15-17]. Under the premise of consistent varieties, if irrigation is insufficient, or it is dry and rainless in winter, the field water holding capacity is reduced, it will affect the absorption of N, P, and K, which will influence the growth of potatoes, accordingly leading to dwarf potato plants[18]. Under the improved no-tillage intercropping cultivation mode, the soil moisture fluctuates greatly, roots are attached to the soil surface, and the amount of fertilizer is limited. In consequence, the plants are relatively short. As an organ for photosynthesis of green plants, leaves are mainly used to accumulate plant dry matter and produce nutrients needed for growth and development. Therefore, the number of leaflets of potato will also affect its yield. Compared with the intercropping CK (film-mulched), there was no difference between them after 35 d.

Different ecological environments have a certain influence on the quality of potatoes. Different ecological environments have greater influence on reducing sugar content than the difference between varieties, and reducing sugar content is obviously affected by environmental conditions. The genetic differences among varieties of dry matter content play a leading role[19]. The three cultivation modes are all tested in the same ecological environment, but different cultivation modes have led to large differences in soil temperature and humidity. The potato plants under intercropping no-tillage cultivation mode will be affected of the temperature and humidity of the soil more than that of the other two cultivation modes, which may be one of the reasons why its reducing sugar content is higher than the other two modes. However, the difference with the intercropping control (film-mulched) did not reach a significant level. The frying method in potato processing requires that the reducing sugar content be less than 0.4% to reduce the production of brown pigment and avoid affecting the color of food[12, 20]. Therefore, the potato obtained by the improved no-tillage intercropping mode may be slightly less commercial in frying.

In terms of increasing the utilization of land in agriculture and the per unit area yield, intercropping is the most popular farming method. The biological structure characteristics of the young citrus orchard intercropping mode are better than the single citrus planting mode, the biomass and productivity are greatly improved, and a mutually beneficial symbiosis relationship is formed in the process of spatial distribution and time utilization[21]. As a highly adaptable and suitable intercropping crop, potato is widely used in intercropping with other crops, and has obtained high benefits, such as Guilin in Guangxi, Hubei and Qinghai. In this experiment in Zhaoqing, Guangdong, the improved no-tillage intercropping cultivation mode of potato also reached the same conclusion. The yield of potatoes harvested in the improved no-tillage intercropping cultivation mode was about 22 747.5 kg/ha, which was close to 23 386.5 kg/ha obtained in potato intercropping with young citrus through ridging and film mulching obtained by Liang Mingfeng *et al.* [2] and 22 800 kg/ha to 24 150 kg/ha of potato obtained by Xin Huiying *et al.* [22] in the paddy field of no-tillage cultivation, obviously higher than 9 900 kg/ha of potatoes obtained by Rong Siwen *et al.* [4] in young citrus orchards in deep plowing and interplanting peanuts with autumn potatoes. The research of Zhao Chunyan *et al.* [23] and Feng Yanqing *et al.* [24] also showed that the yield of potato is in the range of 19 455 – 38 700 kg/ha under various cultivation modes, and the yield of the improved no-tillage intercropping cultivation in this experiment is within this range.

5 Conclusions

In terms of cost-saving and efficiency increase, the improved no-tillage intercropping of potato can obtain high economic value. Besides, from the perspective of resource utilization and ecological benefits, the improved no-tillage intercropping potatoes can increase the ground coverage of citrus orchards, and reduce ground water evaporation and soil erosion. As to the promotion of intercropping in orchards, it is not necessary for fruit growers to find additional materials for intercropping. They only need to obtain orchard grass and other materials based on local conditions. The use of grass, harvesting and mulching can increase soil fertility and make full use of natural resources in the citrus orchard, to improve the overall economic benefits of the citrus orchard. In terms of the quality, the potatoes obtained through the improved no-tillage intercropping cultivation have the intrinsic quality of potatoes and high commodity. However, as raw materials for frying, it is necessary to make further study on the traits of finished products.

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onal experiment, it was concluded that the optimal combination of the stabilizers was 0.04% gellan gum, 0.020% carrageenan, 0.020% sodium carboxymethyl cellulose and 0.20% microcrystalline cellulose. In order to reduce the impact of the shear force of the production line on the viscosity and avoid the destruction of the stable system, within the adjustable ranges of equipment parameters, the four process points that affect the stability of the system, batching temperature, hydration time, homogenization pressure, and filling temperature, were adjusted to achieve the optimal process. The best combination of parameters obtained through orthogonal experiment was as follows: batching temperature 50 ℃, hydration time 40 min, homogenization pressure 30 MPa and filling temperature 15 ℃. Under the optimal process, the milk supplemented with whole oat kernels has uniform suspension, fine taste, uniform texture and good quality.

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