Research of Optimized Fertilization Technology of Tarrocco Blood Orange based on Integrated of Water and Fertilizer

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Abstract: To evaluate effects of integrated water and fertilizer and screen the optimal application amounts and styles of chemical fertilizers, a field experiment was conducted for 9-year-old Tarrocco blood orange on 'Carrizo' citrange [*Poncirus trifoliata* (L.) Raf.]×*Citrus sinensis* Osbeck] rootstock during 2019-2020. The experiment had 8 fertilization treatments. The control trees were hole fertilized one time a year by broadcast application (CK). The results showed that, within a certain range, in the same fertilizer, CF or WFs, WFCs processed larger fruit, higher yield and quality, and late-ripening than traditional fertilization or single water-soluble fertilizer. And the differences between WFCs and CK were significant($P<0.01$). Analysis of comprehensive benefit showed that WFCs had an important role in improving fruit quality and economic benefit. WFC3 showed the highest price, fruit production value, economic benefits in all treatments. Economic benefits was reached at 117151.46 yuan/hm^2, increased 189.93% of CK. And the differences between WFC3 and the other treatments were significant($P<0.05$). Therefore, the precise and green fertilization scheme of Tarrocco blood orange in Three Gorges Reservoir Region was water-soluble fertilizer (different ratio of N, P_2O_5, K_2O) 3-4 times (0.67kg every tree in all) a year, including 2 times in July and August, and according to fruit size, one time (1.23kg every tree) compound fertilizer applied in time after raining in August, which showed the green and efficient benefit.

1 INTRODUCTION

Tarrocco blood orange (*Citrus sinensis* (L.) Osbeck) is the advantageous and characteristic citrus industry in Three Gorges Reservoir Region which was planted 33000 hm^2. Tarrocco blood orange has a long maturity period, and they are normally harvested from January to March. Among various citrus, blood orange is regarded as a unique species because of anthocyanin accumulation (Rapisarda 2001), which brought high economic benefit to fruit farmers in this area. However, after years of development, long-term application of chemical fertilizer in old orchards led to soil consolidation and acidification, lower organic matter, insufficient soil nutrients or lack of some elements bringed to element deficiency, and fruit quality has shown a downward trend. At the same time, affected by the market impact of other hybrid citrus cultivars, the overall economic benefits have declined.

In China, chemical fertilizer accounts for more than 20% of the agricultural cost, and China's annual chemical fertilizer application amount is 43 million tons, ranking first in the world (Yang 2011). However, increasing the input of chemical fertilizer does not continuously improve yield. On the contrary, unreasonable or excessive chemical fertilizer will cause a series of problems, such as decrease of fruit quality, increase of production cost, and aggravation of environmental pollution (Li 2008). Water-soluble fertilizer technology has the advantages of improving utilization rate of water and fertilizer, improving fruit quality and yield, reducing agricultural costs and reducing environmental

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pollution (Megh 2015). The technology has been adopted in apple (Sokalska 2008), citrus (Mongi-zekri 1992), pear (Quiñones 2007), grape (Hu 2016) and other fruit trees in foreign coun-tries. Fruit trees in China are mainly in apple (Zhou 2015), grape (Du 2008), citrus (An 2007), banana (Li 2014), pear (Wang 2015), jujube (Chai 2012), kiwi (Hong 2011) and blueberry (Zhang 2010) in the semi-arid areas of central and western China. Lizhong Xia et al. (Xia 2012) showed that appropriate use of drip irrigation fertilization could help improve water and fertilizer utilization rate. The utilization rate of citrus fertilizer was about 25%-35% by using traditional fertilization method, and more than 20% citrus fertilizer was saved by using water and fertilizer integration. An Huaming (An 2007) showed that water and fertilizer integration could significantly improve yield and single fruit weight of Ponkan. Wang Qiaoxian (Wang 2013) studied that soluble sugar and titratable acid contents of pear increased significan-tly after water and fertilizer was treated by half, which might be because integrated water and fertili-zer improved utilization efficiency of fertilizer, which was consistent with An Huaming's results. Xu Shujun et al. (Xu 2008) found that drip irrigation fertilization could significantly reduce fruit cracking rate of citrus, and increase fruit weight and large-fruit rate.

At present, most studies of water-soluble fertilizer are focused on the utilization efficiency of water and fertilizer. And most of them were focus on the effects of a single factor (Xu 2021). In addition, Many studies were performed in arid and semi-arid areas, mainly on the yield, quality and benefit of grain and vegetable crops (Shen 2007). However, there are few studies on the technology strategy of combine of water-soluble fertilizer and soil fertiliz-ation in late-maturing citrus in mountainous and hilly areas of the Three Gorges Reservoir area. This study chose Wanzhou District in Chongqing City which is in the central of Three Gorges to study the effects on Tarrocco blood orange under different models of fertilizer, so as to screen out the best fertilization style and amount and provide references for quality and efficiency improvement of Tarrocco blood orange.

2 METHODS AND MATERIALS

2.1 Experimental Location and Plant Material

The field experiment was conducted for Tarrocco blood orange on ‘Carrizo’citrange [*Poncirus trifoliata*(L.)Raf.]×*Citrus sinensis* Osbeck] rootstock during 2019-2020 in Yongsheng Village, Ganning Town, Wanzhou District, Chongqing City (108°15 '35.98 "E, 30°40' 22.65" N) at an altitude of 395m. Tarrocco blood orange is for 9-year-old, and the growth is uniform. The planting density is 3m×5m.

2.2 Fertilizers

Happiness coming a Large number of Water soluble fertilizer with N:P:K =34-10-10 (HLWN), N:P:K= 10-50-10 (HLWP), and N:P:K=12-6-42(HLWK), produced by SICHUAN SHIFANG YIDA CHEMI-CAL.CO.,LTD. Yanyangtian compound fertilizer (N: P:K=15-15-15, YCF) produced by Shandong Red Sun A Kang Chemical Co., LTD. KH_2PO_4(N:P: K=0-52-34) produced by SICHUAN VOLVO Che-mical Co., LTD.

2.3 Treatments

The experiment had 8 treatments WF1, WF2, WF3, WFC1, WFC2, WFC3, CF (Table 1). The control trees were hole fertilized one time a year by broadcast application (CK).

Thirty trees were selected in each treatment, and each tree was a plot. There were 30 replicates in each treatment. A total of 240 trees were tested. Set up a protection row between each processing. Water and fertilizer integration facilities were installed in the test area, and each plant was fitted with 4 droppers with a water yield of 3 L/h^{-1}. The tip of the dropper was fixed near the canopy drip line.

Table 1: Field trial fertilization scheme.

Treat	Time(day/month)	Fertilization Amount(kg/tree)	N	P_2O_5	K_2O
WF1	14/4, 22/5	0.1 HLWN	123	161	150
	25/6, 27/7, 21/8, 27/9, 27/10	0.05 HLWP, 0.05 HLWK			
WF2	14/4, 22/5	0.2 HLWN	246	320	300
	25/6, 27/7, 21/8, 27/9, 27/10	0.1 HLWP,0.1 HLWK			

WF3	14/4, 22/5	0.25 HLWN	335	470	440
	25/6, 27/7, 21/8, 27/9, 27/10	0.15 HLWP, 0.15 HLWK			
WFC1	14/4	0.1 HLWN	123	161	150
	27/7, 21/8	0.05 HLWP, 0.05 HLWK, 0.02 KH_2PO_4			
	Broadcast after raining in August	0.45 YCF			
WFC2	14/4	0.2 HLWN	246	320	300
	27/7, 21/8	0.1 HLWP, 0.1 HLWK, 0.05 KH_2PO_4			
	Broadcast after raining in August	0.9 YCF			
WFC3	14/4	0.25 HLWN	335	470	440
	27/7, 21/8	0.15 HLWP, 0.15 HLWK, 0.12 KH_2PO_4			
	Broadcast after raining in August	1.23 YCF			
CF	Hole fertilization in 14/4, 15/9, 15/11	1.0 YCF	450	450	450
CK	15/11	2.0 YCF	300	300	300

2.4 Collection of Samples and Data Determination

At different times, a total of 4 fruits were randomly collected along the central, southeast and northwest directions of each tree and mixed into one sample. A total of 30 samples were harvested of each treatment and then transported to the laboratory in Chongqing Three Gorges Academy of Agricultural Sciences (Chongqing, China). All fruit were rinsed in tap water. After air drying, the fruit were divided into two groups randomly. Transverse diameter, longitudinal diameter, pericarp thickness, single fruit weight and yield of one sample were measured. The four azimuth points on the equatorial plane of each fruit was measured by CR-10 hand-held colorimeter developed by Minolta of Japan and calculated ratio of red to yellow (a/b) for fruit colour. Total soluble solid (TSS) was determined by PAL-1 digital glucostat (ATAGO, Japan) after juice extraction. The titratable acid (TA) was determined by NaOH neutralization titration method and calculated solid acid ratio (TSS/TA). Vitamin C (Vc) and anthocyanins were respectively determined by 2, 6-dichlorophenol sodium titration method and spectrometric method. All experiments were performed in twice from 2019 to 2020.

2.5 Fruit Grading and Benefit Analysis

According to the appearance and quality, the fruits of each treatment were divided into special grade, first grade and second grade according to the market habits. The classification standards refer to Table 2. Then, the price of three grades is investigated, and the sales price and production cost of different treatments are calculated as the basis for benefit analysis.

Sales price=∑(price of each grade×ratio of each grade).

Table 2: Classification standard of Tarrocco blood orange.

Index	Special grade	First grade	Second grade
Transverse diameter	70mm-80mm	65mm-75mm	65mm-70mm
Appearance and pulp	Fruit surface is coloring with rose red above 20%, pulp with rose red	Fruit surface is coloring with rose red in 10%- 20%, pulp with rose red	Fruit surface is coloring with rose red under 20%, pulp with rose red
Fruit-shape	Neat, regular shapes	Slightly less neat, regular shapes	No obvious malformed fruit
Fruit surface	Very clean, smooth, oil cells fine, no spots	Less clean and smooth, the oil cells is a little fine, with some spots	With a large amounts of spots

Total Soluble Solid	≥11.5%	≥11%	≥10.5%
Solid acid ratio	≥11	≥10	≥9.5
Others	Rich flavor, tender slag, thin skin, aromatic	With flavor, tender slag, thin skin, aromatic	With flavor

2.6 Statistical Analysis

The database was analyzed by IBM SPSS 16.0 (New York) and and Microsoft Excel using one-way analysis of variance (ANOVA), and Tukey's HSD post hoc test for means separation. The data are means of 30 replicates in twice.

3 TEST RESULTS

3.1 Effect of Different Fertilization Treatments on Appearance of Tarrocco Blood Orange

There were significant differences in appearance of Tarrocco blood orange after different fertilization treatments (Fig.1). In terms of transverse diameter, compared with CK (69.42mm), WFC3 was the largest, with an average of 76.95mm, followed by WFC2 (74.08mm), and the lowest average was WF1 (71.43mm). The overall performance was WFC3> WFC2>WF3>WFC1>CF>WF2>WF1>CK.There was significant difference between WFC2 and WF2, WF1, WFC1, CF ($P<0.05$). The longitudinal diameter showed the same trend, the difference was not significant between WFC3 and WFC2, but extremely significant between WFC3 and other treatments ($P<0.01$). There were also extremely significant differences of single fruit weight between WFC3 and all other treatments ($P<0.01$). WFC3 got the highest yield and maximum fruit weight, WFC2 was the second and reached the extremely significant differences with other treatments ($P<0.01$) (Fig.1 left).

The results showed that 3 times of water-soluble fertilizer and compound fertilizer once in the fruit expansion period could guarantee the nutrition of the tree, and the yield increase was the most significant. However, 7 times in a year, 0.1kg water-soluble fertilizer each time could not meet the nutrition of the trees and showed that the fruit size was smaller than other treatments. At the same amounts of fertilizer, divided into three times of water-soluble fertilizer and one time of compound fertilizer, fruit size were extremely significant different. Among all treatments, WF1 and WF2 had the lowest amounts of fertilizer, and CF had the highest amounts. However, WFC3 got the optimal fruit size and yield, and CF only got the fifth in all tests. WFC1 and WF1, WFC2 and WF2, WFC3 and WF3 had the same amounts of nutrition, but WFC1, WFC2 and WFC3 decreased times of water-soluble fertilizer and increased compound fertilizer which could effectively add fruit size and yield (Fig. 1 left).

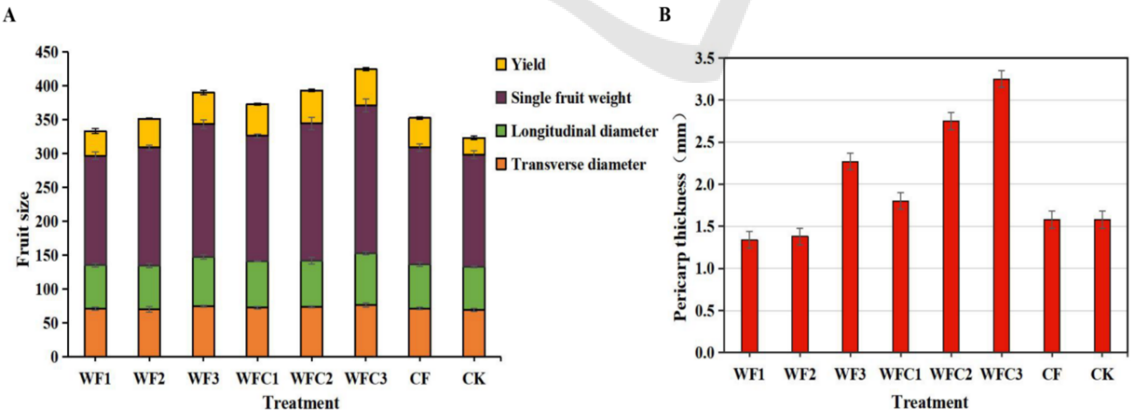

Figure1: Effect of different treatments on fruit size (left) and pericarp thickness (right) of Tarrocco blood orange.

The pericarp thickness of WFC3 was the highest (3.25mm), and then was the WFC2. WF1 was 1.34mm, which was the lowest among all treatments (Fig.1 right). Combined with Fig.1A, the result showed that the greater the single fruit weight, the greater the peel thickness.

3.2 Effects of Fruit Quality of Tarrocco Blood Orange Under Different Fertilization Patterns

Different quality indexes were tested at different times (Fig.2), and the results showed that TSS in WF1, WF2 and WF3 were slightly lower on January 20th, both below 11%, while TSS in other treatments were above 11%, and WFC3 was the highest. By March 20th, TSS of all treatments reached more than 12%, and WFC3 and CF reached more than 13%. The CK had a certain increase in the three detection times, but was not obvious. The results indicated that TSS of treatments with water-soluble fertilizer were lower in the early stage and higher in the later stage, while the treatments with compound fertilizer accumulated higher TSS in the early stage and the accumulation rate was slower in the later than that of the pure water-soluble fertilizer treatments. Regardless of WFCs, WFs or CF treatments, the late TSS were all accumulated to more than 12% (Fig.2A).

On January 20th, the TA content of WF1, WF2, WF3 and WFC1 were significantly higher than that of other treatments. As times go on, the TA content of the treatments gradually decreased. Till March 20th, the TA content of WFC3 was the lowest 0.59, and that of WF1 was the highest 0.81, CK was 0.7(Fig. 2B). TSS/TA also showed the similar trend with TSS of which WFC3 was the highest on March 20th, while CF remained a steady level (Fig. 2C).

The a/b value of different treatments increased with the extension of time. On January 20th, reaching 0.78 of CF and CK, and was mainly rose red on fruit surface. The other treatments were below 0.5, indicating that the colour of fruit surface was mainly orange at this time and the second color transformation was not sufficient. By March 20th, a/b of all treatments were above 0.8, indicating obvious rose red of fruit surface (Fig. 2D).

Above results indicate that WF1, WF2, WF3 in the early days, performed high TA, low TSS, fruit colored slowly. And after less water-soluble fertilizer input, more compound fertilizer input, the overall trend was characterized by mature earlier, TSS accumulation and red-turning were faster, faster drop acid.

There were differences of Vc in treatments, among which the difference between WFC3 and WFC1 was not significant, and the other treatments were extremely significant ($P<0.01$). There was no obvious difference in juice yield. WFC2 had the highest anthocyanin content (43.6 mg/kg), while the CK had the lowest (29.76 mg/kg). There were significant differences($P<0.01$) between treatments

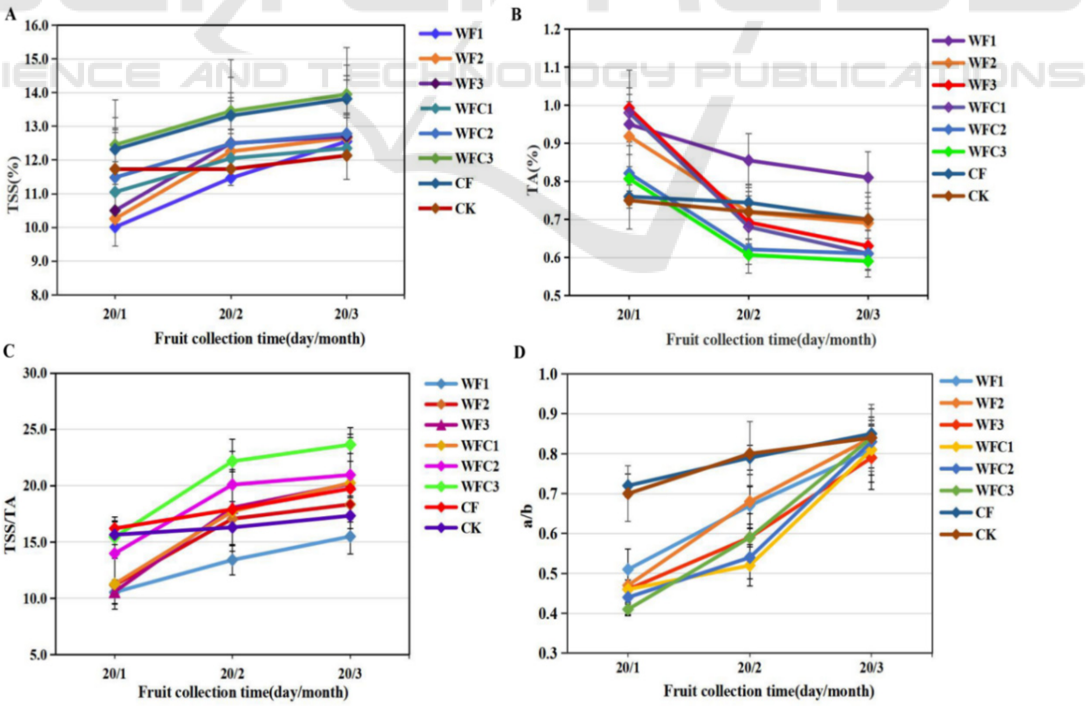

Figure 2: Effects of citrus quality of different treatment.

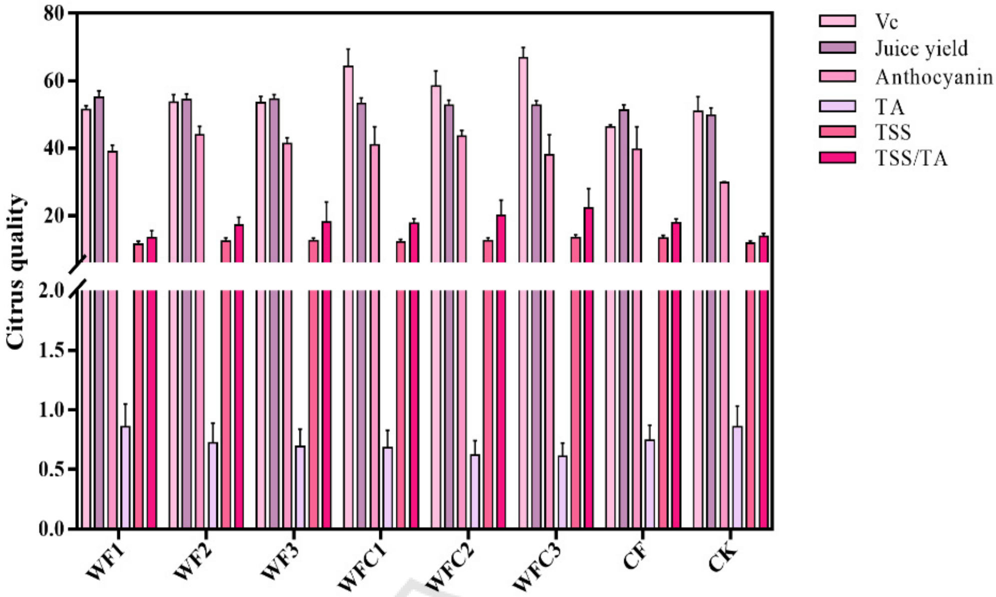

Figure 3: Effects of citrus quality of different treatment on March 20th.

and the CK. But there was no significant difference among the treatments, which was indicating that increasing the amount of fertilizer could increase the accumulation of anthocyanin in different degrees, but the difference was not significant (Fig.3).

3.3 Economic Benefit of the Treatments

The results suggested that special grade ratio of WFC3 and WFC2 were the highest in all tests which respectively reached 47.9% and 46.1%, while the first and second grade ratio of CK were up to 40.2% and 38.3%. By the price, WFC3 was 4.24 yuan/kg, which was 1.3 times of CK. The special grade ratio and price of WF1, WF2 and WF3 as a whole were lower than WFC1, WFC2, WFC3 and CF (Table 3). The results showed that compound fertilizer could increase the proportion of special grade ratio effectively on the basis of applying proper amount of water-soluble fertilizer. In terms of input cost, CK was the lowest, and CF was the highest. Input cost of CF is 3.02 times of CK and 1.21 times of WFC3(Table 4). For economic benefit, there were significant differences ($P<0.05$) between

Table 3: Fruit Radio and price of different grades.

Treatment	Ratio of each grade (%)			Price of each grade (yuan/kg)			Price (yuan/kg)
	Special grade	First grade	Second grade	Special grade	First grade	Second grade	
1	30.5	30.8	28.7	6	3	2	3.32
2	30.5	31.5	38	6	3	2	3.53
3	41.7	32.1	26.2	6	3	2	3.98
4	31.1	34.2	34.7	6	3	2	3.58
5	46.1	32.4	21.5	6	3	2	4.16
6	47.9	33.1	19.0	6	3	2	4.24
7	31.2	32.2	36.6	6	3	2	3.56
CK	21.5	40.2	38.3	6	3	2	3.26

Table 4: Input cost for each treatment of different fertilization patterns(yuan/hm^2·year).

Treatment	Fertilizer	Pesticide and Material	Irrigation equipment depreciation	Labor	Total cost
1	4326.3	2500.0	2250.0	13750.0	22826.3
2	8652.6	2500.0	2250.0	13750.0	27152.6
3	12391.5	2500.0	2250.0	13750.0	30891.5
4	2590.5	2500.0	2250.0	20500.0	27840.5
5	5181.0	2500.0	2250.0	20500.0	30431.0
6	7279.8	2500.0	2250.0	20500.0	32529.8
7	4950.0	2500.0	2250.0	29750.0	39450.0
CK	3300.0	2500.0	500.0	6750.0	13050.0

Table 5: Economic benefits one year.

Treatment	Yield (kg/hm^2)	Fruit production value (yuan/hm^2)	Economic benefit (yuan/hm^2)	Increase in economic Benefits (%)
1	23977.8±2420.0^{e}	79798.1±8053.7^{g}	56971.8±8053.8^{g}	40.99
2	28116.0±660.0^{d}	99390.1±2333.1^{f}	72237.5±2333.1^{e}	78.77
3	30696.6±2200.0^{bc}	122448.7±8775.8^{c}	91557.2±8775.8^{c}	126.59
4	30907.8±770.0^{bc}	110866.3±2761.9^{d}	83025.8±2761.9^{d}	105.47
5	32194.8±1287.0^{b}	134187.9±5364.2^{b}	103756.9±5364.2^{b}	156.78
6	35244.0±1540.0^{a}	149681.3±6540.4^{a}	117151.5±6540.4^{a}	189.93
7	28822.2±1100.0^{cd}	102866.4±3925.9^{ef}	63416.4±3925.9^{fg}	56.94
CK	16387.8±1870.0^{e}	53457.0±6099.9^{g}	40407.0±6099.9^{fg}	

the treatments. The WFC3 treat got benefits of 2.9 times of CK, and increased 189.93% than CK. However, WF1 (incre-ased 40.99%) was the lowest in all treatments and followed by CF and WF2. In all treatm-ents, the total fertilizer input of CF was the highest, followed by WFC3 and WF3, and WF1 and WFC1 were the lowest (Table 5). The results indicated that the fertilization mode of compound fertilizer combined with water-soluble fertilizer played an important role in improving fruit quality and economic benefits.

4 DISCUSSION

Fertilization management should provide supplementary nutrients according to the cha-racteristics of fertilizer requi-rements in different citrus peri-ods (Tan 2019). If water and fertilizer are not reple-nished in time, it is easy to cause weak growth, low fruit setting rate, poor quality and low yield (Yang 2014). Conventional fertilization had problems of low fertilizer efficiency and large labor consumption (Lu 2016). Yield and economic benefits of integrated water and fertilizer treatment were significantly higher than those of CK. Deep application of 40 cm water and fertilizer is the best pattern to improve mango yield, quality and economic benefit (Liu 2021).

There were some researches shown that the integration of water and fertilizer can not only save water and fertilizer, but also increase production and improve quality. It is an important means to develop fruit industry in mountainous and hilly areas of the

Three Gorges Reservoir area. The average water requirement for citrus annual growth was 1187.0mm (Tan 2019). Although annual rainfall in Three Gorges Reservoir area of Chongqing is more than 1200 mm, there was regular extreme high temperature or drought in summer and autumn. Which leaded to shortage of water in flower bud differentiation phase, and autumn- shoot delayed and not mature, affecting the yield and bring serious losses.

This experiment was conducted based on different amounts and types of fertilization. It was found that combined fertilization with water and fertilizer could not only effectively solve the drought problem from July to September, but also improve the yield, quality and benefit of citrus. The fruit and economic traits of different treatments were significantly different from those of ck. This experiment was only carried out for two years, and there was no statistical information of nutrient elements in fruit and tree body, which was needed further research.

5 CONCLUSION

In this study, the fruit appearance, quality and economic benefit of Tarrocco blood orange were analyzed in different models, and the conclusions are obtained as below:

(1) The results indicated that, in the same fertilizer, the water-soluble fertilizer and compound fertilizer treatments (WFCs) proce-ssed larger fruit, higher yield, better quality and late-ripening than traditional fertilization or single water-soluble fertilizer.

(2) Analysis of comprehensive benefit show-ed the scheme of Tarrocco blood orange in Three Gorges Reservoir Region was that water-soluble fertilizer (different ratio of N, P_2O_5, K_2O) 3-4 times (0.67kg every tree in all) a year, including 2 times in July and August, and according to fruit size, one time (1.23kg every tree) of compound fertilizer was applied in time after raining in August, which increased 189.93% in economic benefits than CK.

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