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Application Effect of Integrated Water and Fertilizer Technology for Tomato

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Abstract Integrated water and fertilizer technology has the advantages of saving water, fertilizer and labour, which is widely applied in tomato plantation. Integrated water and fertilizer technology in topdressing and whole process of big and small tomatoes were studied, and their application effects were contrasted and analyzed, and application advantages and scopes of the two models were concluded.

Key words Tomato, Integrated water and fertilizer technology in whole process, Integrated water and fertilizer technology in topdressing

1 Introduction

Water resources are seriously short in China, and per capita water resource is ranked the 109th in the world, which is only quarter of the world average level. China is the biggest production and consumption country of chemical fertilizer in the world, and fertilizing amount per unit area stays in a high position without going down, with low fertilizer use efficiency and large environmental pollution risk. Under the dual pressure of resources and environment, inevitable choice of transforming agricultural production manner and realizing agricultural sustainable development is developing the agriculture of saving water and fertilizer[1]. Integrated water and fertilizer technology is a new water and fertilizer-saving agricultural modernization technology integrating irrigation and fertilizing, with the advantages of quantitatively supplying fertilizer and water and increasing water-fertilizer use efficiency, and it could accurately adjust soil moisture and nutrients based on soil feature, crop root system feature and water requirement law. Compared with traditional irrigation and fertilizing, water use efficiency of integrated water and fertilizer technology could improve by 40% – 60%, and fertilizer use rate could increase by 30% – 50%[2]. It is currently recognized technology of improving use efficiency of water and fertilizer, and has been widely applied in vegetable and fruit production of Zhejiang Province, showing good development momentum.

Tomato has unique flavor, rich nutrition, higher yield and rich profit, and it is widely planted in Zhejiang, with plantation area of 1777 thousand ha and annual yield of 0.852 million tons. Compared with traditional irrigation and fertilization, integrated water and fertilizer technology for tomato has higher requirements on facilities, water and fertilizer management, and application techniques. There is certain blindness in actual production process in each area, which affects tomato's yield and quality. At present, integrated water and fertilizer technology for tomato mainly contains two kinds of models. One is integrated water and fertilizer technology in topdressing, and fertilizer is dominated by organic fertilizer and compound fertilizer in base fertilizer, and topdressing is fertilized by drip irrigation at fruiting stage[3–5]. The other is integrated water and fertilizer technology in whole process, and proper organic fertilizer is only used in base fertilizer to improve soil quality, and nutrition is supplied in production process according to nutrition demand of tomato during different growth periods[6]. In this paper, by combining actual situation of tomato production in Zhejiang, advantages and disadvantages of two integrated water and fertilizer techniques and their application conditions were analyzed by contrasting application effects of the two techniques in big and small tomatoes, which could provide reference basis for integrated water and fertilizer technique management of tomato.

2 Materials and methods

2.1 Materials The test was conducted in Zhejiang Wuwangnong Seed Science Research Institute during 2013 – 2014, and test region was newly reclaimed beach, and soil type was coastal saline soil. The connected greenhouse with drip irrigation and integrated water and fertilizer facility was used, and natural rainfall in rainwater collecting pool was used for irrigation. Irrigation used the pump with variable frequency, and underground pipe was paved, and fertilization used MixRite series of proportional pump. Field pipe network system used the branch with the diameter of 3 cm, and capillary was inlay type of drip irrigation pipe. Tomato was test crop, and big tomato variety was Qiantang Xuri, while cherry tomato variety was Qianjiang Hongzhu. Organic fertilizer in the test was made of pig manure, and N, P, K content was 4%; compound fertilizer was Sanyuan compound fertilizer, and N, P, K contents were respectively 15%; water soluble fertilizer was Huile macroelement water soluble fertilizer. High nitrogen formula (N, P, K contents were respectively 25%, 13% and 18% + Te) was used at seedling and flowering stages, while high potassium formu-

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la (N, P, K contents were respectively 16%, 12% and 30% + Te) was used at fruiting and harvesting stages.

2.2 Processing design Both big and small tomatoes had two treatments. T1 treatment was integrated water and fertilizer in topdressing, and base fertilizer was dominated by organic fertilizer and compound fertilizer, and topdressing was fertilized at fruiting stage by drip irrigation. T2 treatment was integrated water and fertilizer in whole process, and base fertilizer only used proper organic fertilizer to improve soil quality, and nutrition was supplied in production process according to nutrition demands during different growth periods of tomato. They were marked as big T1, big T2, small T1 and small T2. Fertilizing period and amount of each treatment were as below: 28.5 t/ha of organic fertilizer and 675 kg/ha of compound fertilizer were used in base fertilizer of big T1 treatment, and 420 kg/ha of water soluble fertilizer of high potassium formula was fertilized for four times at fruiting stage. 7.5 t/ha of organic fertilizer was fertilized in base fertilizer of big T2 treatment, and 600 kg/ha of water soluble fertilizer of high nitrogen formula was fertilized for three times at seedling and flowering stages, with interval time of 10 d – 15 d. 975 kg/ha of water soluble fertilizer of high potassium formula was fertilized for five times at fruiting stage, with interval time of 15 d – 20 d. 28.5 t/ha of organic fertilizer and 675 kg/ha of compound fertilizer were used in base fertilizer of small T1 treatment, and 420 kg/ha of water soluble fertilizer of high potassium formula was fertilized for four times at fruiting stage. 7.5 t/ha of organic fertilizer was used in base fertilizer of small T2 treatment, and 180 kg/ha of water soluble fertilizer of high nitrogen formula was used for three times at seedling and flowering stages, with interval time of 10 d – 15 d. 630 kg/ha of water soluble fertilizer of high potassium formula was used for five times at fruiting stage, with interval time of 15 d – 20 d.

The connected greenhouse with even fertility was used in test region. Sowing and seedling raising in tray were conducted on December 1, 2013, and then it was transplanted in nutrition bowl on December 22. The connected greenhouse was used as top membrane, and moderate membrane was used as the second one, while arch membrane was used as the smallest one for growing seedlings. Field planting was conducted on February 21, 2014, and shelf was constructed timely after field planting. Each mound was one treatment, 150 m long and 1.5 m wide, with the area of 225 m^2 and three repeats. Other conventional management measures were same. The first harvest started from May 4, and harvest season was from first dekad of June to July 14.

2.3 Investigation items Plant growth situation of each treatment was tracked and recorded in production process, and 60 plants in each treatment were randomly selected for counting the yield, and harvesting time, number and yield were recorded.

Partial productivity of fertilizer was crop yield produced by the nutrition of per unit input. Partial productivity of fertilizer = the obtained crop yield after fertilization /fertilizer input amount.

3 Results and analyses

3.1 Tomato yield Tomato harvest continued from May 4 to July 14, 2014, with harvesting time of 71 d. Table 1 showed that big tomato yield in T2 was more than that in T1, that is to say, the yield by integrated water and fertilizer processing in whole process was higher than that in topdressing, which rose by 7.4%. The performance was more fruiting number and more single fruit weight. Small tomato yield also showed that T2 was more than T1, which increased by 4.3%. It is clear that integrated water and fertilizer in whole process could play the coupling effect of water and fertilizer, and was favorable for fast absorption of nutrient by plant and improving crop's yield.

3.2 Tomato quality Table 1 showed that total sugar and soluble solid of big and small tomatoes by integrated water and fertilizer treatment in topdressing were all more than that in whole process. Total sugar in big T1 treatment was 5.1% more than that in big T2 treatment, and soluble solid was 4.5% more than that in big T2 treatment; in small T1 treatment, total sugar and soluble solid were respectively 11.5% and 2.8% more than that in small T2 treatment. It is clear that large use amount of organic fertilizer in integrated water and fertilizer management model in topdressing was favorable for the improvement of tomato quality.

Table 1 The impacts on tomato yield and quality by each treatment

Treatment	Yield//t/ha	Single fruit weight//g	Total sugar//%	Soluble solid//%
Big T1	103.2	140	2.89	4.65
Big T2	110.8	145	2.75	4.45
Small T1	42.4	–	4.66	7.05
Small T2	44.2	–	4.18	6.86

3.3 Economic benefit Partial productivity of fertilizer indicates crop yield produced by the fertilizer of per unit input. Seen from Table 2, base fertilizer proportion in integrated water and fertilizer processing in topdressing was high, and topdressing amount had smaller accommodation. Big and small tomatoes had the same chemical fertilizer amount in the integrated water and fertilizer in topdressing, and partial productivity of fertilizer in big T1 treatment was more than that in small T1 treatment, illustrating that yield increase effect of big tomato by fertilizer was more than that of small tomato under the same fertilization condition. Partial productivity of fertilizer in big T1 treatment was smaller than that in big T2 treatment, and partial productivity of fertilizer in small T1 treatment was also smaller than that in small T2 treatment. It was because that the two treatments had different input amounts of organic fertilizer. Large investment of organic fertilizer made that nutrition supply amount under T1 treatment was larger, and yield increase effect of fertilizer declined.

Table 2 Fertilizer effect, fertilizer cost and tomato output value in each treatment

Treatment	Fertilizer input amount // kg/ha	Yield // t/ha	Partial productivity of fertilizer // kg/kg	Fertilizer cost // yuan/ha	Output value // $\times 10^4$ yuan/ha
Big T1	1631	103.2	63.26	21960	30.95
Big T2	1310	110.8	84.52	37995	33.23
Small T1	1631	42.4	26.00	21960	33.93
Small T2	785	44.2	56.32	19875	35.37

Note: Organic fertilizer was converted into fertilizer input amount according to the contained nutrient purity, and chemical fertilizer was counted by nutrient purity. Fertilizer costs were as below: organic fertilizer of 600 yuan/t, compound fertilizer of 3500 yuan/t and water soluble fertilizer of 20000 yuan/t. Output value was counted as below: big tomato of 3 yuan/kg and small tomato of 8 yuan/kg.

Two models were contrasted at cost and benefit aspects. Due to higher cost of water soluble fertilizer, when fertilizer requirement was more, fertilizer cost of integrated water and fertilizer model in whole process was higher, showing as that fertilizer cost in big T2 treatment was higher than that in big T1 treatment, which increased by 16035 yuan/ha. When fertilizer requirement was smaller, fertilizer cost of integrated water and fertilizer in whole process could decline. For example, fertilizer cost in small T2 treatment was lower than that of small T1 treatment, which decreased by 2085 yuan/ha. Under integrated water and fertilizer in whole process, fertilizer was applied for many times according to different growth stages of crop, with larger accommodation. The coupling effect of water and fertilizer was conducive to improving crop yield, showing that yield in big T2 treatment was higher than that in big T1 treatment, and yield in small T2 treatment was higher than that in T1 treatment. Therefore, economic benefit in T2 treatment was still more than that in T1 treatment, and output value in big T2 treatment increased by 6705 yuan/ha than that of big T1 treatment, while output value in small T2 treatment increased by 16515 yuan/ha than that of small T1 treatment.

3.4 Physical-chemical properties of soil Fertilization affects crop yield and residual quantity of nutrient in soil, and residual quantity of nutrient could affect soil fertility. Additionally, if residual quantity is too much, long-time accumulation is easy to cause soil salinization[7]. Soil analysis result before and after the test (Table 3) showed that available potassium accumulation of soil was less under the two models, illustrating that application amount was relatively rational. Available phosphorus declined, indicating that it could properly increase phosphorus fertilizer in the region. Total nitrogen content after the test all increased, and total nitrogen content in big tomato plantation region was higher than that in small tomato plantation region, indicating that nitrogen input amount in fertilization scheme could be properly declined. Test region was reclamation beach, and soil showed alkalinity. pH declined somewhat after planting crop, which was conducive to improving soil acidity and alkalinity.

Table 3 Physical-chemical properties of soil before and after the test in each treatment

Treatment	pH	Organic matter // g/kg	Total nitrogen // g/kg	Available phosphorus // mg/kg	Available potassium // mg/kg
Big T1	8.0	10.9	0.62	10.6	118
Big T2	8.0	10.8	0.70	11.0	128
Small T1	8.3	8.7	0.54	10.3	108
Small T2	8.2	9.2	0.54	11.4	130
Background value in test region	8.7	11.0	0.48	46.0	116

4 Conclusions and discussion

Integrated water and fertilization production technique for tomato had good economic and ecological benefit. Firstly, it could decrease fertilizer use and increase yield. By controlling total fertilization amount and process management under integrated water and fertilizer condition of tomato, it avoided blind and excessive fertilization, and promoted production level. During 2014 – 2015, fertilization situation in 15 tomato plantation regions of Zhejiang Province was investigated. Average chemical fertilizer application amount of traditional fertilization of tomato was 877.5 kg/ha, and average yield was 77.4 t/ha. Compared with nutrient demand of tomato[8-9], more fertilization by farmers accounted for 47%, less fertilization occupied 26%, while rational fertilization only occupied 27%. Compared with traditional fertilization, application amount of chemical fertilizer under the integrated water and fertilizer model in topdressing was 511.5 kg/ha, while application amount of chemical fertilizer under integrated water and fertilizer in whole process was 696 kg/ha, which respectively decreased by 41.7% and 20.7% than traditional fertilization, while yield increased by more than 20%. Secondly, it saved labor and cost. When transforming traditional artificial fertilization into mechanized fertilization, and applying the integrated water and fertilizer technology, it could save 4 – 6 times of artificial topdressing cost. Thirdly, ecological benefit was significant. Under the integrated water and fertilizer technology, it not only saved water and fertilizer but also could effectively decline air humidity in the facility and salt accumulation of protected cultivation soil, declined occurrence probabilities of diseases and insect pests, decreased pesticide dosage, slowed down secondary salinization of soil, and maintained continuous output ability of land.

The integrated water and fertilizer model of tomato in topdressing was dominated by sufficient organic fertilizer and compound fertilizer in base fertilizer, and water soluble fertilizer of high potassium was applied at swelling stage. The method had more fertilization times and simple operation. Large amount of organic fertilizer was used to replace chemical fertilizer to decrease input amount of chemical fertilizer, which was favorable for consumption and use of agricultural waste. The model was suitable for the region with lower basic soil fertility level, limited auto fertilization level and rich organic fertilizer resource, and was conducive to consuming local agricultural waste and realizing resource utilization. The integrated water and fertilizer model in whole process had less organic fertilizer in base fertilizer. According to fertilizer requirement rule of tomato at growth stage, fertilization scheme and fertilizer proportion were made to realize synchronous management of precision water and fertilizer. The feature of the method was that staged fertilization could be conducted according to target yield of tomato and nutrient requirement of different periods, and topdressing could be conducted according to crop growth situation. Fertilization was flexible, and total nutrient input was lower, and water and fertilizer had high utilization rates. The model was suitable for the region with higher basic soil fertility level, rich organic matter content of soil, high curing degree of soil and higher auto fertilization level, and was conducive to controlling nutrient input amount and declining secondary salinization risk of soil. Meanwhile, it is expected to realize fully automatic control, thereby greatly declining artificial cost.

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