Effects of Different Water-soluble Fertilizers on Yield and Quality of Strawberry under Integrated Application of Water and Fertilizer

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Abstract Taking Hongyan strawberry as the material and PE drip irrigation tape and fertilizer applicator as the tool of integrated application of water and fertilizer, this experiment studied the effects of six fertilizers including Batian, Jiashili, Wanglefeng, Stanley, volfertile and calcium protein on yield and quality of strawberry. The experimental results showed that different water-soluble fertilizers had different effects on the main economic traits of strawberry. For the maximum single fruit mass, the highest was volfertile treatment (28.72 g), followed by calcium protein treatment, and the lowest was Stanley treatment (23.89 g). The fruit treated with Batian, volfertile and calcium protein was hard in the texture, the fruit treated with Wanglefeng was harder, that of Stanley was softer, and that of Jiashili was soft. The strawberry fruit treated with Wanglefeng and calcium protein was sweet, the fruit treated with volfertile and Batian was sweet, that treated with Jiashili was sour and sweet, and that treated with Stanley was slightly sour. The fruit treated with calcium protein, volfertile and Batian showed strong storage resistance. Strawberry plants treated with Batian, Wanglefeng, Stanley, and calcium protein showed stronger growth, and strawberry plants showed a semi-opening pattern. The yield of strawberry treated with volfertile was highest (17 400 kg/ha), which was significantly increased compared with other treatments, followed by that treated by Stanley (13 140 kg/ha).

Key words Water soluble fertilizer, Integrated application of water and fertilizer, Strawberry, Yield, Economic traits

1 Introduction

Strawberry is a perennial herb and has high economic value. Its fruit is small berries, soft and juicy, sweet and sour. Strawberry is rich in nutrients, beautiful in appearance, rich in aroma, high in sugar content, rich in organic acids and pectin, Vitamin B, vitamin C, niacin, calcium, phosphorus, magnesium and many other minerals that play an important role in the human body; especially, phosphorus and iron content is 3 to 5 times higher than that in grapes and apples[1].

Nitrogen, phosphorus and potassium are the three essential elements for plant growth and play an important role in cultivation management of plants. In the opinion of Zhao Huijie et al. [2], in the process of fertilizer application, excessive application of nitrogen, phosphorus and potassium fertilizers can increase the yield and improve quality of crops, but will pollute the environment and waste fertilizer and increase costs. According to study of Li Sha [3], the effect of fertilization is not only related to the fertilization period, methods, and amount of nitrogen, phosphorus and potassium fertilizers, but also closely related to the ratio of nitrogen, phosphorus and potassium. Fertilizer is an essential factor affecting the yield of strawberry, and its components are mutually promoted and restrained. Only through grasping the relationship between each factor and the yield, can we adjust the components of fertilizers in an effective and balanced manner, so as to obtain a scientific and reasonable fertilization method[4-5].

Integration of water and fertilizer application is a technology for simultaneous control of water and fertilizer. At the same time of absorbing water, crops also absorb nutrients. Crops can supply the nutrients and water necessary for crops, which can make the water and fertilizer infiltrate deeper and wider according to needs of crops. However, in the fertilization of strawberry, many studies only recommended the application of potassium fertilizer, and did not involve the ratio of nitrogen, phosphorus and potassium. Therefore, through implementing the integrated cultivation of water and fertilizer for strawberry, we carried out this experiment for six market available water-soluble fertilizers, in order to make clear the trend of demands for nitrogen, phosphorus and potassium nutrients in the strawberry topdressing process, guide local farmers to strictly control the fertilizer amount, make the fertilizer application structure and the fertilization period reasonable, realize simultaneous control of water and fertilizer, accordingly to provide theoretical basis for pollution-free and high quality and high efficient cultivation of strawberry.

2 Materials and methods

2.1 Experimental materials Experimental strawberry variety adopted Hongyan, bought from Baotou City Qingmiao Agricultural Development Co., Ltd. We adopted six kinds of water soluble fertilizers: Batian (13-6-35, Shenzhen Batian Ecological Engineering Co., Ltd., CK), Jiashili (15-7-28, Jiashili Fertilizer Co., Ltd.), Wanglefeng (15-3-7, Dongguan Baode Bioengineering Co., Ltd.), Stanley (20-20-20, Stanley Fertilizer Co., Ltd.), calcium protein (containing 40% amino acid, Tian...
jin New Agricultural Technology Co., Ltd.), volfertile (16-6-36, Linyi volfertile Compound Fertilizer Co., Ltd.). We adopted PE drip irrigation tape to apply fertilizers.

### 2.2 Experiment design

The specific experimental design scheme is shown in Table 1. Each treatment was repeated 3 times, and the random block group is arranged with a plot area of 20 m².

### 2.3 Experiment methods

We carried out the experiment during October 2015 and June 2016, used high ridge planting, with ridge width of 50 cm, ridge height of 25 cm, ridge spacing of 30 cm, 2 rows of strawberries per ridge, one row planted on each side, black plastic film covered. The total water flow of the drip irrigation was 5 m³/h, and the fertilization time was 30 min per treatment. In addition to fertilization and irrigation, irrigation was carried out depending on the weather conditions. Fertilization ratio; first diluted 10 times, according to 2% of the fertilizer absorption, namely, diluted 50 times for irrigation. After the transplanting of strawberry seedlings, the first topdressing was carried out 70 d after transplanting, and the different treatments of water-soluble fertilizer were drip-irrigated according to the optimized fertilizer mode, and unified management was carried out with conventional fertilization.

### 2.4 Determination of yield indicator

In the integrated water and fertilizer mode, 6 different water-soluble fertilizers were used, an 18 m² was determined as a sampling area in 3 replicates (plots), the yield was measured during the strawberry fruiting stage, and unified harvest was carried out every 3 d. The malformation rate, main economic traits, yield, maximum single fruit mass and average single fruit mass were calculated for each plot. The occurrence of powdery mildew and Botrytis cinerea in each plot was investigated. The leaf grading standards of powdery mildew and Botrytis cinerea were as follows (6-8): Grade 0; no disease spot; Grade 1; disease spot area less than 5%, indicated by " + " ; Grade 3; disease spot area 6% to 10%, denoted by " ++ " ; Grade 5 and above; disease spot area > 11%, denoted by " +++ ". Data analysis was performed with the aid of SPSS software.

### 3 Results and analysis

#### 3.1 Effects of different water soluble fertilizers on economic traits of strawberry

In the integrated water and fertilizer mode, different water-soluble fertilizers have different effects on the main economic traits of strawberry (Table 2). For the maximum single fruit mass, the highest was volfertile treatment (37.29 g), followed by Wangdefeng treatment (35.18 g), and the third was Stanley treatment. For the average single fruit mass, the highest was volfertile treatment (28.72 g), followed by calcium protein treatment (26.38 g), and the third was Stanley treatment (23.89 g). The fruit texture treated with Batian, volfertile and calcium protein was hard in the texture, the fruit treated with Wangdefeng was harder, that of Stanley was softer, and that of Jiashili was soft. For the fruit flavor, the strawberry fruit treated with Wangdefeng and calcium protein was sweet, the fruit treated with volfertile and Batian was sweet, that treated with Jiashili was sour and sweet, and that treated with Stanley was slightly sour. For the storage resistance, the fruit treated with calcium protein, volfertile and Batian showed strong storage resistance, that treated with Wangdefeng was moderate, and that treated with Jiashili and Stanley was weak.

### 3.2 Effects of different water soluble fertilizers on growth characteristics and disease resistance of strawberry

In the integrated water and fertilizer mode, different water-soluble fertilizers have different effects on the growth characteristics and disease resistance of strawberry (Table 3). Strawberry plants treated with Batian, Wangdefeng, Stanley, and calcium protein showed strong growth, and that treated with Jiashili and volfertile showed stronger growth, the strawberry plants all showed a semi-opening pattern; for the plant height, the strawberry plants treated with Batian showed the best growth, the plant height was 53 cm, followed by

### Table 2 Comparison of main economic traits of different treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fruit shape</th>
<th>Max single fruit mass / g</th>
<th>Average single fruit mass / g</th>
<th>Fruit texture</th>
<th>Flavor</th>
<th>Storage resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batian (CK)</td>
<td>Conical</td>
<td>29.63</td>
<td>25.94</td>
<td>Hard</td>
<td>Sweet</td>
<td>Strong</td>
</tr>
<tr>
<td>Jiashili</td>
<td>Conical</td>
<td>29.13</td>
<td>25.14</td>
<td>Soft</td>
<td>Sour and sweet</td>
<td>Weak</td>
</tr>
<tr>
<td>Wangdefeng</td>
<td>Conical</td>
<td>35.18</td>
<td>24.92</td>
<td>Harder</td>
<td>Sweet</td>
<td>General</td>
</tr>
<tr>
<td>Stanley</td>
<td>Conical</td>
<td>30.41</td>
<td>23.89</td>
<td>Softer</td>
<td>Slightly Sour</td>
<td>Weak</td>
</tr>
<tr>
<td>volfertile</td>
<td>Conical</td>
<td>37.29</td>
<td>28.72</td>
<td>Hard</td>
<td>Sweet</td>
<td>Strong</td>
</tr>
<tr>
<td>Calcium protein</td>
<td>Conical</td>
<td>34.48</td>
<td>26.38</td>
<td>Hard</td>
<td>Sweet</td>
<td>Strong</td>
</tr>
</tbody>
</table>

Note: single fruit mass refers to the average value of 10 fruits randomly selected.
Stanley; plants treated with Jiashili had the height of 46 cm. Through investigation, after treatment with Stanley, serious powdery mildew occurred, other treatments also had occurrence of powdery mildew and Botrytis cinerea, but the diseases were not serious, which is possibly because the high nitrogen content in Stanley. Some studies have shown that the application of a large amount of nitrogen fertilizer can promote the occurrence of strawberry powdery mildew and increase the incidence. The yield of strawberry treated with volfortile was the highest, the plot yield was 23.2 kg, converted to 17 400 kg/ha, the difference was significant compared with other water-soluble fertilizers; the second was Stanley treatment, the plot yield was 17.52 kg, converted to 13 140 kg/ha; the lowest was Jiashili treatment, the plot yield was 11.92 kg, converted to 8 940 kg/ha.

### 3.3 Effects of different water soluble fertilizers on strawberry yield

In the integrated water and fertilizer mode, different water-soluble fertilizers have significant effects on the strawberry yield. The yield of strawberry treated with volfortile was the highest, the plot yield was 23.2 kg, converted to 17 400 kg/ha, the difference was significant compared with other water-soluble fertilizers; the second was Stanley treatment, the plot yield was 17.52 kg, converted to 13 140 kg/ha; the lowest was Jiashili treatment, the plot yield was 11.92 kg, converted to 8 940 kg/ha.

### Table 3 Comparison of growth characteristics and disease resistance of strawberry treated with different fertilizers

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Growth status</th>
<th>Plant morphology</th>
<th>Plant height // cm</th>
<th>Powdery mildew</th>
<th>Botrytis cinerea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batian (CK)</td>
<td>Strong</td>
<td>Semi-open</td>
<td>53</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Jiashili</td>
<td>Stronger</td>
<td>Semi-open</td>
<td>46</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Wangdelfeng</td>
<td>Strong</td>
<td>Semi-open</td>
<td>49</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Stanley</td>
<td>Strong</td>
<td>Semi-open</td>
<td>51</td>
<td>+ +</td>
<td>+</td>
</tr>
<tr>
<td>volfortile</td>
<td>Stronger</td>
<td>Semi-open</td>
<td>50</td>
<td>+ +</td>
<td>+</td>
</tr>
<tr>
<td>Calcium protein</td>
<td>Strong</td>
<td>Semi-open</td>
<td>49</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

### Table 4 Comparison of yield of strawberry treated with different fertilizers

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plot yield // kg</th>
<th>Ranking</th>
<th>Yield // kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batian (CK)</td>
<td>18.96 18.72 11.04</td>
<td>3</td>
<td>12 180</td>
</tr>
<tr>
<td>Jiashili</td>
<td>9.84 12.48 13.44</td>
<td>6</td>
<td>8 940</td>
</tr>
<tr>
<td>Wangdelfeng</td>
<td>13.92 19.68 14.64</td>
<td>4</td>
<td>12 060</td>
</tr>
<tr>
<td>Stanley</td>
<td>19.20 16.56 16.80</td>
<td>2</td>
<td>13 140</td>
</tr>
<tr>
<td>volfortile</td>
<td>19.20 30.24 20.16</td>
<td>1</td>
<td>17 400</td>
</tr>
<tr>
<td>Calcium protein</td>
<td>15.36</td>
<td>13.36 bA</td>
<td>5</td>
</tr>
</tbody>
</table>

### 4 Conclusions and discussions

Studies have shown that reasonable integration of water and fertilizer can increase the yield of strawberry. In the integrated water and fertilizer mode, there were differences in the fruit texture of strawberry. The fruit treated with Batian, volfortile and calcium protein was hard texture, the fruit treated with Wangdelfeng was harder, that of Stanley was softer, and that of Jiashili was soft.

For the fruit flavor, the strawberry fruit treated with Wangdelfeng and calcium protein was sweet, the fruit treated with volfortile and Batian was sweet, that treated with Jiashili was sour and sweet, and that treated with Stanley was slightly sour. In terms of the storage resistance, the fruit treated with calcium protein, volfortile and Batian showed strong storage resistance, that treated with Wangdelfeng was moderate, and that treated with Jiashili and Stanley was weak, which is mainly due to the different nutrients contained in different water-soluble fertilizers. Potassium, as a quality element for plant growth, can improve fruit quality, amino acids can increase fruit aroma, and calcium as an invariable element can increase fruit hardness. Strawberry plants treated with Batian, Wangdelfeng, Stanley, and calcium protein showed strong growth, and that treated with Jiashili and volfortile showed stronger growth. The strawberry plants all showed a semi-opening pattern; for the plant height, the strawberry plants treated with Batian showed the best growth, the plant height was 53 cm, followed by Stanley; plants treated with Jiashili had the height of 46 cm. Through investigation, after treatment with Stanley, serious powdery mildew occurred, other treatments also had occurrence of powdery mildew and Botrytis cinerea, but the diseases were not serious, which is possibly because the high nitrogen content in Stanley. Some studies have shown that the application of a large amount of nitrogen fertilizer can promote the occurrence of strawberry powdery mildew and increase the incidence. The yield of strawberry treated with volfortile was the highest, the plot yield was 23.2 kg, converted to 17 400 kg/ha, the difference was significant compared with other water-soluble fertilizers; the second was Stanley treatment, the plot yield was 17.52 kg, converted to 13 140 kg/ha; the lowest was Jiashili treatment, the plot yield was 11.92 kg, converted to 8 940 kg/ha. In summary, in the integrated water and fertilizer mode, the application of volfortile water soluble fertilizer (N-P-K = 16-6-36) has significant effects on strawberry yield and quality. Besides, the integration of water and fertilizer has certain effects on the economic traits, growth characteristics, disease resistance and yield of strawberry.

### References

effect of selenium on crop agronomic traits and quality traits to avoid the problem of selenium content, especially the problem that the content of organic selenium not up to standard. According to the comprehensive analysis of the results of this study, when using bio-organic selenium for exogenous bio-enhancement of rice, it is recommended to use 4,500 mL/ha (22.5 g of Se), and the application concentration is 30–50 mg/L; the leaves should be sprayed once in the early stage of rice filling.

References