Different Fertilization Modes of Sugarcane in Latosolic Red Soil of Guangxi

Shixie MENG¹, Xiaomin WANG¹*, Guosheng HUANG², Yanfei LU², Pingxi HUANG², Guoying LU³

Abstract [Objectives] This study aimed to compare the effects of water-fertilizer integrated drip irrigation modes and traditional fertilization mode on growth, yield, production costs and economic benefit of sugarcane in latosolic red soil of Guangxi. [Methods] A field test was conducted. [Results] The agronomic traits and comprehensive economic benefit of sugarcane under the water-fertilizer integrated drip irrigation modes were superior to those under the traditional fertilization mode. Among them, the comprehensive economic benefit of sugarcane with special granular fertilizer as the base fertilizer and water-fertilizer integrated drip irrigation as topdressing were the highest, increased by 15 813 kg/ha, an increase of 15.8%. Considering the cost input, the comprehensive economic benefit increased by 5 676 yuan/ha. [Conclusions] Taking the production cost, economic benefit and input-output ratio into account, it is recommended to promote the application of water-fertilizer integrated drip irrigation mode in bases with water and fertilizer equipment conditions.

Key words Latosolic red soil, Fertilization mode, Water-fertilizer integration, Drip irrigation

1 Introduction
Sugarcane is the largest strategic cash crop and a pillar industry in Guangxi. It is the most important source for farmers' income, and is the related to development of the peasant economy. According to statistics, from 2013 to 2014, the sugarcane planting area in Guangxi is about 1 115 200 ha, and the total output is 789,693 million t. The number of employees in the sugar industry in Guangxi accounts for nearly 40% of the total population, about 20 million people.

Studies have shown that water and nutrients are key factors limiting sugarcane production. Appropriate water conditions and reasonable nutrient supply are the basic guarantee for high yield and quality of sugarcane. Water stress, nutrient deficiency and the unsynchronized supply of both are not conducive to sugarcane growth. Water is an important factor affecting the elongation and sugarcane stems. Many studies have shown that precipitation contributes the most to sugarcane elongation. Water shortage often leads to reduced production and even harvest failure of sugarcane. The demand for nutrients in sugarcane production is also large, but here are differences between different stages. Water and fertilizer integration technology can meet the different requirements of sugarcane for water and nutrients, achieving efficient use of water and fertilizer. Compared with the traditional mode, water and fertilization integration technology can reduce the loss of fertilizer volatilization, fixation and leaching. Fertilizer utilization can be increased by 30% – 50%, and water use efficiency can be increased by 40% – 60%.

At present, there are not many reports on the water and fertilization integration technology in sugarcane. For different varieties, regional climate, soil and other conditions, the water and fertilizer supply parameters will also vary. Therefore, it is necessary to find a reasonable water and fertilizer supply model for the major sugarcane varieties growing in the latosolic red soil of Guangxi. At the same time, through soil testing and plant testing, the nutrients in soil and sugarcane will be comprehensively grasped. Studying and testing the special water-soluble fertilizer according to the fertilizer demand rules of sugarcane, constructing fertilizer stations and water-saving irrigation facilities according to different soil conditions and planting intensive conditions, guiding farmers in the demonstration base to drip fertilization according to the growth process of sugarcane, and establishing a complete and operable water and fertilizer integrated drip irrigation technology for sugarcane will be the future development trend of the sugarcane industry.

2 Materials and methods
2.1 Test materials
2.1.1 Test site. The test site is located at Plot 13# in the north section of the 18th team of Xinfu Village, Ningwu Town, Wuming District, Nanning City, Guangxi.
2.1.2 Test variety. The test variety was Yuetang 93/159.
2.1.3 Test fertilizers. "New Direction" sugarcane special water-soluble fertilizer 25-7-18 + TE, powder, produced in Nanning, Guangxi.
"New Direction" sugarcane special baser fertilizer 7-12-6S, solid particles, produced in Nanning, Guangxi.
"Gao Er Zhuang" compound fertilizer 13-6-10, solid particles, produced in Chongzuo, Guangxi.
"Gao Er Zhuang" compound fertilizer 21-7-18, solid parti-
cles, produced in Chongzuo, Guangxi.

Urea, 46% content, produced in Hechi, Guangxi.

2.1.4 Test soil. The test soil was latosolic red soil, quaternary red soil parent material. The previous crop was sugarcane.

The contents of organic matter, available nitrogen, available phosphorus, available potassium, available calcium, available magnesium, available zinc and available boron in the test soil were 29.71%, 87.29, 26.02, 74.82, 916.80, 240.50, 1.49 and 0.69 mg/kg, respectively. The pH of the test soil was 5.5.

2.2 Test design and methods There were three treatments; A. "New Direction" sugarcane special water-soluble fertilizer, drip irrigation; B. "New Direction" sugarcane special base fertilizer 7-12-6S +, base fertilization; "New Direction" sugarcane special water-soluble fertilizer, drip irrigation at elongation stage; C. "Gao Er Zhuang" compound fertilizer 13-6-10 +, baser fertilization; "Gao Er Zhuang" compound fertilizer 21-7-18, topdressing at elongation stage. There were three replications in each treatment. Each replication covered an area of 2 ha (one rotational irrigation plot), and all the rotational irrigation plots were arranged randomly.

The sugarcane in the test site was planted on April 10, 2017. It was earthed up on June 19, 2017. In the A treatment, from June 15 to October 14, total 12 times of drip irrigation were carried out at an interval of about 10 d, and the fertilization amount was 1 095 kg/ha. In the B treatment, the fertilization amount of the base fertilizer was 1 500 kg/ha; and total 12 times of drip irrigation were carried out from June 15 to October 14 at an interval of about 10 d, and the fertilization amount was 720 kg/ha. In the C treatment, the application amount of the base fertilizer was 1 500 kg/ha; and topdressing ("Gao Er Zhuang" compound fertilizer 21-7-18, 1 500 kg/ha; urea, 300 kg/ha) was carried out by the means of drip irrigation on June 15 along with cultivation and banking.

2.3 Measured indicators After planting, the seedling emergence rate and tillering rate of sugarcane were investigated during the germination and tillering stages. The plant height, stem diameter, effective stem number, field brix and yield of sugarcane were investigated at the time of sugarcane harvest.

2.4 Statistics and analysis The test data were processed using Excel 2007 and analyzed by one-way ANOVA of DPS 7.05 software.

3 Results and analysis

3.1 Effects of different fertilization modes on seedling and tillering stages of sugarcane As shown in Table 1, among different treatments, the emergence rate of B treatment was the highest, with an average of 54.02%, significantly higher than those of A (44.23%) and C (47.21%) treatments. The difference between A and C treatment was not significant, but the emergence rate of C treatment was higher than that of A treatment. It indicated that the application of base fertilizer in the early stage could promote the emergence of sugarcane. In particular, the products of the B treatment had high phosphorus content and contained sulfur.

In addition, the tillering rate of A treatment in which the water-fertilizer integrated drip irrigation was conducted in the early stage of tillering was significantly higher than those of other treatments. The tillering rate of B treatment in which base fertilizer was applied and water-fertilizer integrated drip irrigation was conducted at the tillering stage was also higher than that of C treatment. It was proved that water-fertilizer integrated drip irrigation is beneficial to sugarcane tillering.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>May 12</th>
<th>June 14</th>
<th>July 15</th>
<th>August 17</th>
<th>Emergence rate/%</th>
<th>Tilling rate/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3 538 b</td>
<td>5 971 b</td>
<td>5 169 b</td>
<td>4 752 b</td>
<td>44.23 b</td>
<td>69.24 a</td>
</tr>
<tr>
<td>B</td>
<td>4 322 a</td>
<td>6 755 a</td>
<td>6 015 a</td>
<td>5 405 a</td>
<td>54.02 a</td>
<td>56.29 b</td>
</tr>
<tr>
<td>C</td>
<td>3 777 b</td>
<td>5 659 b</td>
<td>4 759 b</td>
<td>4 336 b</td>
<td>47.21 b</td>
<td>49.83 b</td>
</tr>
</tbody>
</table>

3.2 Effects of different fertilization modes on plant height and monthly growth rate of sugarcane Table 2 shows the effects of different fertilization modes on plant height and monthly growth rate of sugarcane. The results in Table 1 have shown that water-fertilizer integrated drip irrigation was beneficial to tillering of sugarcane. As shown in Table 2, the advantage of water-fertilizer integrated drip irrigation was further obvious when conducted at jointing stage. The plant heights and monthly growth rates of A and B treatments were significantly higher than those of C treatment. When the water-fertilizer integrated drip irrigation mode was used at the jointing stage, the monthly growth rate of sugarcane increased steadily. Under the traditional mode, sugarcane grew fast first and then slowly. It indicated that continuous supply of nutrients and water and topdressing in the mode of water-fertilization integrated drip irrigation were more conducive to the growth of sugarcane.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>June 14</th>
<th>July 15</th>
<th>August 17</th>
<th>September 21</th>
<th>October 21</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>25.9</td>
<td>86.2</td>
<td>162.0</td>
<td>242.6</td>
<td>283.3</td>
<td>60.3</td>
<td>75.8</td>
<td>80.6</td>
<td>40.7</td>
</tr>
<tr>
<td>B</td>
<td>44.2</td>
<td>115.6</td>
<td>199.3</td>
<td>283.6</td>
<td>323.8</td>
<td>71.4</td>
<td>83.7</td>
<td>84.8</td>
<td>40.2</td>
</tr>
<tr>
<td>C</td>
<td>35.1</td>
<td>107.7</td>
<td>172.9</td>
<td>237.7</td>
<td>276.7</td>
<td>72.6</td>
<td>65.2</td>
<td>64.4</td>
<td>39.0</td>
</tr>
</tbody>
</table>

3.3 Effects of different fertilization modes on yield and sugar content of sugarcane As shown in Table 3, the effective stem number of B treatment was significantly greater than those of A and C treatments. This might be because that the base fertilizer...
had high phosphorus content and contained sulfur, which was related to the emergence, tillering and formation of effective stems of sugarcane. The differences in plant height and stem diameter between the three treatments were not significant. The plant height and stem diameter of B treatment were highest, followed by those of A treatment, and the plant height and stem diameter of C treatment were lowest.

Among the three treatments, the yield of B treatment was highest, with an average of 115 830 kg/ha, higher than those of A (107 901 kg/ha, P > 0.05) and C (100 017 kg/ha, higher by 15 813 kg/ha, an increase of 15.8%) treatments. The yield of A treatment was higher than that of C treatment by 7 884 kg/ha, an increase of 7.9%. The difference between A and B treatments was not significant.

The field brix differed insignificantly among the three treatments. It indicated that neither water-fertilizer integrated drip irrigation mode nor traditional solid granular fertilization mode had great impact on sugar content of sugarcane.

### 3.4 Comparison of sugarcane economic benefits among different fertilization modes

Table 3 shows the economic benefits of sugarcane in different fertilization modes. The purchase price of raw sugarcane was 450 yuan/t, and the artificial cutting cost was 150 yuan/t, so the net income was 300 yuan/t. Compared with that of C treatment, the incomes of A and B treatments were increased by 2 365.5 and 4 734 yuan/ha, respectively. Taking the cost of fertilizer input into account, the comprehensive economic benefits increased by 4 086 and 5 676 yuan/ha, respectively. The investment in water and fertilizer equipment was about 9 000 yuan/ha, so calculating the economic benefits like this was not ideal. However, the investment in water and fertilizer equipment is only a one-time investment, and the service life of the equipment can be more than 10 years. Therefore, if A and B treatments, especially B treatment can maintain such economic benefits, the input cost of water and fertilizer equipment will be recovered within two years, really achieving the purpose of saving water, reducing fertilizer, and increasing farmers’ income.

### 4 Conclusions and discussions

The above research results show that water-fertilizer integrated irrigation mode has a significant promotion effect on the growth of sugarcane. Whether it is used throughout the growth period or used at the elongation stage, the yield of sugarcane can be significantly improved.

Whole-process water-fertilizer integrated drip irrigation can save manure during base fertilization and billing, achieving cost savings. However, no application of base fertilizer in the early stage have a certain impact on the germination, rooting and emergence of sugarcane, the emergence rate is significantly lower than the base fertilization treatments, indicating the importance of base fertilizer on sugarcane emergence and seedling growth. The soil testing formula that has high phosphorus content and contains sulfur is preferred.

From the perspective of economic benefit, the treatment which applies "New Direction" sugarcane special base fertilizer 71-2-6S+ as base fertilizer and conducts topdressing with "New Direction" sugarcane special water-soluble fertilizer by means of water-fertilizer integrated drip irrigation at the elongation stage is superior to traditional fertilization mode without water-fertilizer integrated drip irrigation. The average increase is 15 813 kg/ha, an increase of 15.8%. Considering the cost input, the comprehensive economic benefit increases by 5 676 yuan/ha.

As can be seen from the above results, the agronomic traits and comprehensive economic benefit of sugarcane under water-fertilizer integrated drip irrigation mode are superior to the traditional fertilization mode. The comprehensive economic benefit of the treatment that applied special granular fertilizer as base fertilizer and conducted topdressing under the mode of water-fertilizer integrated drip irrigation is the highest. Therefore, according to the soil nutrient status of the target plot, the nutrients needed by sugarcane can be supplemented to improve the emergence rate of sugarcane. In the middle and late stages, according to the nutrient and water needs of sugarcane growth stages, water-fertilizer integrated drip irrigation can be carried out to ensure effective stems, thereby maximizing sugarcane production and improving sugarcane sugar content. Therefore, it is recommended to promote the application of water-fertilizer integrated drip irrigation mode in bases with water and fertilizer equipment conditions.
3.5 Effects on development of underground roots of Jinzhong apple trees  The root parameters of 5-year-old Jinzhong apple trees in the treatment and control groups were analyzed. The results showed that the main distribution area of apple roots under the ridge covering mode was 15–55 cm underground. Among them, the quantities of hair roots (root diameter \( \leq 0.1 \) cm), fine roots (0.1 cm < root diameter \( \leq 1.0 \) cm) and coarse roots (root diameter > 1.0 cm) were 565, 13, and 11 respectively. In the conventional cultivation mode, the main distribution area of apple roots was 15–35 cm underground. Among them, the quantities of hair roots (root diameter \( \leq 0.1 \) cm), fine roots (0.1 cm < root diameter \( \leq 1.0 \) cm) and coarse roots (root diameter > 1.0 cm) were 378, 32 and 16 respectively. Under the ridge covering mode, the distribution area of roots (15–55 cm) of apple trees significantly moved down (by 15–20 cm), there were fewer coarse roots but more hair roots and fine roots. Under the conventional cultivation mode, the roots of apple trees were distributed in the range of 15–35 cm underground, apple trees had more coarse roots but less hair roots and fine roots, and the total quantity of roots was reduced by 49% (Table 6).

Table 6  Distribution of underground roots of 6-year-old Jinzhong apple trees

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Main distribution area/cm</th>
<th>Hair root (root diameter ( \leq 0.1 ) cm) Quantity</th>
<th>Compared to CK/%</th>
<th>Fine root (0.1 cm &lt; root diameter ( \leq 1.0 ) cm) Quantity</th>
<th>Compared to CK/%</th>
<th>Coarse root (root diameter &gt; 1.0 cm) Quantity</th>
<th>Compared to CK/%</th>
<th>Total root weight Quantity</th>
<th>Compared to CK/%</th>
<th>Quantity of roots (rooting depth &gt; 55 cm) Quantity</th>
<th>Compared to CK/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge covering</td>
<td>30–55</td>
<td>565</td>
<td>49.5</td>
<td>13</td>
<td>-59.5</td>
<td>11</td>
<td>-31.3</td>
<td>589</td>
<td>38.3</td>
<td>5</td>
<td>66.7</td>
</tr>
<tr>
<td>CK</td>
<td>15–35</td>
<td>378</td>
<td>-</td>
<td>32</td>
<td>-</td>
<td>16</td>
<td>-</td>
<td>426</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

4 Conclusions and discussions

Compared with conventional cultivation mode, ridge covering can improve the initial fruit-bearing rate, yield and single fruit weight of fruit trees, achieving the purpose of early fruiting, early yielding and high yielding. In addition, ridge covering also has pest-repelling, illumination-enhancing and tillage-free effects.

Under the ridge covering mode, the available phosphorus, available nitrogen, available potassium and organic matter contents in the soil 20–40 cm beneath the surface were increased. This data was only measured from one-time twice re-samplings of 5-year-old Jinzhong apple trees, and its reliability needs to be further verified. Ridge covering can significantly improve the yield. With the aging of apple trees, the amount and time of fertilization and irrigation should be further explored. If can be inferred from this experiment that ridge covering can also be applied to other fruit trees, especially small shrubs, berries and dwarfed trees.

References


