Research on Well Cellar Type Crop Transplanting Technology

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Abstract: To alleviate the restriction of shortages of labor force and technology on agricultural development in China, the technology of crop transplanting in well cellar was proposed. This technology was that the holes for transplanting in well cellar were made with dedicated tools for making well cellar, and the seedlings were placed into the well cellar vertically during transplanting. This new technology integrates heat preservation, management of rising temperature, early transplanting and deep planting. Results showed that the technology of transplanting in well cellar improved the growing environment of crops after transplanting through elevation of temperature and heat preservation, and tempered the dramatic change in the temperatures encountered by transplanted seedlings. This technology significantly reduced labor force requirement by 98.06%, 58.96% and 64.44% in tobacco, maize and pepper, respectively. Transplanting in well cellar without mulching film further lowered the labor force requirement, with decrease by 121.77% and 115.40% in maize and pepper, respectively. In addition, this technology significantly promoted crop growth, reduced the time until marketing for maize and pepper by 11 d and 6 d, respectively, and increased economic benefits by 67.03% and 44.24%, respectively. Thus, the technology of transplanting in well cellar showed strong promise for improving upon existing technologies to provide greater economic returns, particularly in areas where labor force shortage threatens to hamper agricultural production.

Key words: Flue-cured tobacco, maize, pepper, transplanting in well cellar.

1. Introduction

Due to migration of large numbers of young laborers from rural areas to cities, shortage of labor force is threatening agricultural production in China [1]. In rural areas affected by this issue, land for crop production is being abandoned at a rapid pace. Even in places where irrigation conditions are good, lands have been left uncultivated [2]. In addition to limitation of climate, soil properties and forms of agricultural production in China, other bottlenecks for transplanting crops include difficulty in cultivating satisfactory seedlings in the best transplanting time, slow progression of transplanting, large costs of labor forces and long periods of seedling recovery after transplanting [3]. All of these problems restrict further improvement of agricultural production. Transplanting seedlings under a mulching film permits timely transplanting [4]. This technology not only improves resistance to drought and promotes earlier rooting and sprouting, but also reduces the cost of growing seedlings [5]. However, because of its complicated operation and tremendous labor requirements, it is unpopular among farmers. In addition, low air temperatures during the spring in the mountainous regions in Northeastern, Northwestern and Southwestern China create unfavorable conditions for the sowing, sprouting, transplanting of crops and earlier rooting and recovery after transplantation. Consequently, growth, yield and quality of crops as well as subsequent economic benefit are hampered. Thus, sustainable development of agriculture in these areas is hugely restricted.

Transplanting is crucial to crop production, enhancing crop yield and quality [6, 7]. Proper transplanting technology requires not only solutions to problems encountered in production, but also consideration for reducing workloads and costs. Therefore, in order to adapt to the transformation of
modern agricultural production, to achieve reduction of workloads and costs and to improve quality and efficiency, a new type of transplanting technology must be developed so that farmers can be relieved from heavy manual labor. Here, a new transplanting technology, i.e., transplanting in well cellar, was proposed to enable early and deep transplanting at a proper time while reducing workload and cost.

2. Material and Methods

2.1 Experimental Design

All experiments were conducted in Wulong county, Chongqing municipality, China in 2013 and 2014. The experimental site had an altitude of 1,200 m with a subtropical humid monsoon climate and four distinct seasons. The mean annual temperature was 15 °C to 18 °C, and the annual precipitation was 1,000-1,200 mm upon the weather situation. The experimental crops were flue-cured tobacco (K326 variety, 1,100 plants/ha), waxy maize (Yunuo 7 variety, 60,000 plants/ha) and pepper (Yidu Red variety, 150,000 plants/ha) produced according to standard practices used in the region. Three groups with different transplanting technologies were set up. In group control experiment (CK), local conventional transplanting of ridging and covering was performed. In first treatment group (T1), transplanting of ridging in well cellar without covering with mulching film was performed. In second treatment group (T2), transplanting of ridging in well cellar with mulching film was performed. Three parallel experiments were conducted for each group, with each experiment covering an area of 667 m².

2.2 Technology of Transplanting in Well Cellar

Soil preparation, fertilization and ridging were performed according to the requirements of different crops. After that, on the ridges with and without mulching film, holes for transplanting in well cellar (Fig. 1) based on planting distances that fit for the different crops were made with dedicated tools for making well cellar, e.g., sharpened stick. During transplanting, the seedlings were placed into the well cellar vertically. A small amount of water, fertilizer and pesticide were applied, during which some soil on the wall of the well cellar was washed to the bottom so that the roots of the seedlings were covered. Thus, transplanting was completed. After the seedling’s interior leaves grew above the mouth of the well cellar by 50 mm, the well cellar was filled with fine earth. The diameter of the mouth of the well cellar was 60-80 mm. With a wider mouth, preservation of heat and moisture would be ineffective; with a narrower mouth, the irradiation time for seedlings would be short and the efficiency of photosynthesis would be low. The depth of the well cellar was decided by the height of the seedling. Generally, the depth of the well cellar was between 160 mm and 220 mm to guarantee that after transplanting the distance between the interior leaves and the mouth of the well cellar was no more than 40 mm. In order to keep the seedling upright after being placed, the bottom of the well cellar was designed to be cone-shaped. In addition, the bottom was located in the fertilization layer to make sure that the seedling roots had easy access to nutrients for recovery.

3. Results and Discussion

3.1 The Effect of Heat Preservation and Rising Temperature on Transplanting in Well Cellar

The experiments were conducted in April in 2013 and 2014 in Wulong county, Chongqing. Well cellars were made according to the standard, as shown in Fig. 1. The seedlings of flue-cured tobacco were transplanted into them. Automatic thermometers were employed to measure temperatures outside the well cellar in the last one-thirds of April and at 5 cm and 10 cm inside the well cellar. The average temperature for every 10 d period at each measuring spot is displayed in Fig. 2.

Average daily temperature outside the well cellar was the lowest in 2014 at 15.61 °C (Fig. 2). The average
Fig. 1  Schematic diagram of a well cellar.

Fig. 2  The effect of rising temperature on transplanting in well cellars.

daily temperature at 5 cm inside the well cellar was 19.27 °C, and the average daily temperature at 10 cm inside the well cellar was the highest at 20.99 °C for the same year. The observed drop in temperature in 2014 may be due to persistent rainy weather in April and May of that year. By contrast, temperatures inside the well cellars were higher, because they can preserve heat, which is helpful for crop growth, especially in early stages. According to the result of the experiment conducted in 2013, the range of temperature change was smaller inside the well cellar, resulting in more stable temperatures. This indicated that the environment inside the well cellar was more favorable for seedling growth. Between 9:30 and 16:30, the temperature outside the cellar was higher, while that inside the cellar was lower. Compared with temperatures at 5 cm and 10 cm inside the well cellar, the temperature outside was 9.68% and 14.94% higher, respectively. Between 18:00 and 8:00, the temperature outside was 47.89% and 60.92% lower compared with the temperatures at 5 cm and 10 cm inside the well cellar, respectively. This phenomenon can be explained as follows. During daytime, the heat of the sunlight was absorbed and kept in the soil by ridges,
and heat loss was the minimal because of obstruction posed by the mulching film \[8\]. The temperature inside the well cellar was lower due to lesser exposure to the sun’s radiation. However, at night, the heat preserved in the soil was emitted through the walls of the well cellar, increasing the temperature inside.

3.2 Effects of the Technology of Transplanting in Well Cellar on Flue-Cured Tobacco Production

Transplanting technology had a remarkable effect on the agronomic and economic characteristics of flue-cured tobacco (Table 1). In T2, the dry weight of root, plant height, stem girth and the number of leaves were all obviously superior to those in CK and T1. In CK, the dry weight of root, plant height and the number of leaves were all significantly inferior to those in T1 and T2. This was mainly because in the early stage of transplanting of tobacco seedlings in the well cellar, the temperature and humidity of the environment was favorable. After transplanting, the seedlings recovered fast, and since their roots were placed in the fertilization layer, the seedlings could readily absorb nutrients to enter a rapid growth phase. In addition, through transplanting in well cellar, deep planting of tobacco seedlings was achieved, which promotes the growth of adventitious roots \[9\], strengthening the tobacco plants’ nutrient absorption capacity \[10\].

In terms of yield and output value, flue-cured tobacco from T2 had the best performance, followed by those in T1. Plants from CK had the lowest yield and output. Significant differences were observed between the three groups. The yield of T2 was higher compared to T1 and CK by 35.10% and 9.20%, respectively, and the output was higher by 43.08% and 11.80%, respectively. Because of the long-lasting rainy weather in 2014 in the experimental areas, the yield and output of flue-cured tobacco were generally lower. Under this circumstance, the advantage of the technology of transplanting in well cellar became more evident. Moreover, adoption of the technology of transplanting in well cellar significantly decreased the labor force necessary, which was just 49.51% of that in CK, demonstrating remarkable efficacy at reducing workload and cost. Taken together, the results in this study indicated that transplanting flue-cured tobacco seedlings in well cellar yielded significantly better results compared to the conventional technology of transplanting on mulching film. Thus, the technology of transplanting in well cellars shows strong promise for application in transplanting of flue-cured tobacco.

3.3 Effects of Transplanting in Well Cellar on the Production of Maize

The influence of transplanting technologies on the size of labor force employed for transplanting, growth period and yield of waxy maize is shown in Table 2. The main target of transplanting of waxy maize was acquisition of fresh and tender ears. In general, the earlier the waxy maize can be brought to the market, the better it sells. With T2, fresh ears could be harvested and sold in the market after just 87 d, which is 11 d earlier than that for CK (Fig. 2). No remarkable difference in growth period was observed among T1, T2 and CK. However, differences in labor

<table>
<thead>
<tr>
<th>Table 1: Effects of different transplanting technologies on the agronomic and economic characteristics of flue-cured tobacco (2014).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transplanting technology</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>CK</td>
</tr>
<tr>
<td>T1</td>
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<tr>
<td>T2</td>
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Different capital letters stand for significant differences at 0.01 levels.
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Table 2  Influences of different transplanting technologies on the growth period and yield of maize (2013).

<table>
<thead>
<tr>
<th>Transplanting technology</th>
<th>Labor (day/ha)</th>
<th>Silking stage</th>
<th>Harvest waxy maize</th>
<th>Growth stages (days)</th>
<th>Waxy maize yield (kg/ha)</th>
<th>Output (yuan/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>19.25&lt;sup&gt;C&lt;/sup&gt;</td>
<td>July 9-12</td>
<td>August 3-5</td>
<td>98 ± 1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22,553.99&lt;sup&gt;A&lt;/sup&gt;</td>
<td>27,063.49&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>T1</td>
<td>8.68&lt;sup&gt;A&lt;/sup&gt;</td>
<td>July 6-8</td>
<td>July 30-31</td>
<td>94 ± 2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>23,904.30&lt;sup&gt;B&lt;/sup&gt;</td>
<td>35,856.45&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>12.11&lt;sup&gt;B&lt;/sup&gt;</td>
<td>July 4-6</td>
<td>July 24-26</td>
<td>87 ± 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26,592.11&lt;sup&gt;C&lt;/sup&gt;</td>
<td>45,206.58&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Different litter letters and capital letters stand for significant differences at 0.05 and 0.01 levels.

Table 3  Influences of different transplanting technologies on the biological characteristics, yield and output of pepper (2013).

<table>
<thead>
<tr>
<th>Transplanting technology</th>
<th>Labor (day/ha)</th>
<th>Bloom stage</th>
<th>Full fruit period</th>
<th>Number of fruit per plant (fresh ears/plant)</th>
<th>Yield (kg/ha)</th>
<th>Output (yuan/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>22.38&lt;sup&gt;C&lt;/sup&gt;</td>
<td>May 19</td>
<td>June 16</td>
<td>49.41&lt;sup&gt;A&lt;/sup&gt;</td>
<td>24,205.81&lt;sup&gt;A&lt;/sup&gt;</td>
<td>31,465.56&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>T1</td>
<td>10.39&lt;sup&gt;A&lt;/sup&gt;</td>
<td>May 15</td>
<td>June 13</td>
<td>53.24&lt;sup&gt;B&lt;/sup&gt;</td>
<td>24,547.09&lt;sup&gt;B&lt;/sup&gt;</td>
<td>36,823.92&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>13.61&lt;sup&gt;B&lt;/sup&gt;</td>
<td>May 13</td>
<td>June 10</td>
<td>57.37&lt;sup&gt;C&lt;/sup&gt;</td>
<td>25,215.19&lt;sup&gt;C&lt;/sup&gt;</td>
<td>45,384.93&lt;sup&gt;C&lt;/sup&gt;</td>
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Different capital letters stand for significant differences at 0.01 levels.

force requirement were observed among transplanting technologies. Significantly fewer laborers (8.68 d/ha) were employed in T1 compared to T2 and CK. The labor force necessary for CK was 19.25 d/ha, which obviously exceeded that of the other two groups.

Yield of waxy maize was the greatest for T2 (26 592.11 kg/ha), and marking increases of 17.90% and 11.24% compared with T1 and CK, respectively (Table 2). This might be that maize seedlings transplanted in well cellar were in an environment where temperature and humidity were appropriate. As a result, the growth was fast and the roots could reach and absorb the nutrients supplied by fertilizer immediately after they protruded. After the well cellar was filled with fine earth, deep planting could be achieved, which promoted root growth and thereby strengthened the nutrient absorption capacity of the maize seedlings. The technology of transplanting in well cellar also improved the output of waxy maize. Compared with T1 and CK, the output of T2 increased by 26.08% and 67.03%, respectively. This was mainly attributed to the earlier marketing and higher prices of waxy maize obtained using the T2 technology.

In summary, analysis of the effect of transplanting maize in well cellars indicated that this technology significantly shortened the growth period, increased yield and reduced the labor force necessary for transplanting waxy maize. Thus, this technology shows promise for improved effectiveness in transplanting of waxy maize.

3.4 Effect of Transplanting in Well Cellar on the Production of Pepper

The technology of transplanting in well cellar significantly reduced the labor force necessary for transplanting pepper (Table 3). Compared with CK, T2 and T1 achieved labor force reduction of 39.19% and 53.57%, respectively. The full bearing period of T2 came 3 d and 6 d ahead of those of T1 and CK, respectively. Transplanting technology influenced fruit production from individual plants. Plants of CK had the smallest number of fruits, with an average of 49.41 fruits per plant, followed by T1 (53.24 fruits per plant). The number of fruits of individual plants in T2 was the highest, with an average of 64.87 fruits per plant. Yield of T2 was significantly higher than that of CK, but no difference was observed between T1 and T2. Moreover, there were significant differences in output among the three technologies of transplanting. Yield of T2 was 23.25% and 44.24% higher than those of T1 and CK, respectively. This was mainly because through transplanting in well cellar, rapid growth, earlier full bearing period, rich roots, strong absorption capacity and large number of fruits could be achieved.

Thus, it was indicated that the effect of
transplanting in well cellar on the production of pepper was positive and was marked by reduction in the labor force necessary for transplanting, increase in yield and greater economic benefit. Taken together, these findings reveal great value in promoting this technology in the production of peppers.

4. Conclusions

In this study, effectiveness of the technology of transplanting in well cellar was investigated in flue-cured tobacco, maize and pepper in comparison with conventional methods. The study results showed that the technology of transplanting in well cellar not only promoted the growth of the crops and allowed them to be brought to market earlier (maize, pepper), but also produced significant increases in crop yield and output. These improvements contribute to significant economic benefit for growers. In addition, the technology of transplanting in well cellar greatly reduced the labor force necessary for transplanting and is promised to ease the pressure on agricultural production and development caused by shortage of rural laborers.

A few shortcomings of the technology of transplanting in well cellar in its current form are worth noting. For example, the standard necessary to build proper well cellars for different crops remains to be studied. The tools used to make well cellars also require further research and development. A standard needs to be set for the seedlings used for transplanting in well cellars, and management of plants after transplanting needs to be regulated. Addressing these issues in future research should open the door to widespread adoption of this technology, which can help alleviate the problem of lack of labor and technology for agricultural development in China, particularly in rural areas.

References