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High-yield Cultivation Techniques of *Stevia rebaudiana* (Bertoni) Hemsl. in Gannan Area of Jiangxi Province

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Abstract In order to expand the production of *Stevia rebaudiana* (Bertoni) Hemsl., the main points of high-yield cultivation techniques of a two-year-old stevia cultivar Shoutian No.3 in Gannan area of Jiangxi Province were summarized: cutting and transplanting in early spring; fine management, applying more basic and additional fertilizers and retaining stubbles two times in summer, retaining roots for seeding in late autumn, and mulching membrane for safe overwintering in winter. This study will provide practical guidance for the planting of *S. rebaudiana* in Ganzhou, Jiangxi Province.

Key words Gannan area, *Stevia rebaudiana* (Bertoni) Hemsl., Shoutian No.3, High-yield cultivation

1 Introduction

Stevia rebaudiana (Bertoni) Hemsl. was introduced into China in 1977 as a valuable sugar crop. It has been widely planted in China[1]. The Gannan area of Jiangxi Province is a traditional planting area of *S. rebaudiana*. It has obvious cultivation advantages: feasibility for 12 h short sunlight duration treatment to reproduce seeds and enabling overwintering for perennial production. The disadvantage is that the duration of sunshine is short, so that the vegetative growth period is not as long as in the north[2]. Based on the planting experience of a stevia cultivar Shoutian No.3 in 2016 and 2017, the high-yielding cultivation techniques of *S. rebaudiana* in Gannan area were summarized in this article to expand its planting production.

2 Planting ecological conditions

2.1 Soil *S. rebaudiana* is suitable for loose soil with convenient irrigation and drainage and rich humus. Neutral pH is preferred. Too acidic (<5.5) or alkaline (>7.9) condition is not suitable. In the acidic soil in Gannan area of Jiangxi Province, the use of lime should be increased properly. For the former crop, green manure legume plants (peanut, soybean, mung bean) are preferred. There are continuous cropping obstacles.

2.2 Sunlight and temperature *S. rebaudiana* is a strong photoperiodic short-day plant with a critical daylength of ≤ 12 h. In the Gannan area with low latitude, *S. rebaudiana* blooms earlier, and the early blooming period is in early June. It grows well in warm and humid environment with critical low temperature of ≥ -5℃. The suitable temperature for seed germination of *S. rebaudiana* is 20 - 25℃, and the suitable growth temperature for stems and leaves is 20 - 30℃.

2.3 Moisture and nutrient *S. rebaudiana* is a shallow rooted plant, resistant to dampness but sensitive to drought. During the cultivation and management, more attention should be paid to the drainage of water in the field, the ventilation of the ridges and the cultivation and banking. *S. rebaudiana* has high requirements for fertilization, and it demands enough nitrogen, phosphorus and potassium to support its growth. In general fields with medium fertility level, 45% N, P, and K compound fertilizers (450 kg/ha) and composted manure (1 500 kg/ha) are applied, supplemented with two times of topdressing. The general transplanting density is 120 000 - 135 000 plants/ha. Under the condition of compact planting, the density is 150 000 - 165 000 plants/ha. There is only one plant transplanted in each hole[3].

3 Cutting seedling technique

S. rebaudiana seedlings can be nursed through three ways: seed, cutting and division propagation. For regular hybrid breeds, seed seedling was ever the most commonly used way. However, it has flaws of low germination rate and easiness to be mixed, and has now been eliminated in production. At present, new stevia cultivars containing high-content stevioside A, represented by Shoutian No.3 are widely promoted in production. However, the phenomenon of self-incompatibility exists. In order to maintain the excellent characteristics of the cultivars, cutting and division propagation emerged.

3.1 Cutting seedling Cutting seedlings can be nursed using bare land, film cover and plastic greenhouse. According to the climatic conditions in Gannan area, the combination of film mulching and shade net covering is used for cutting seedlings. Cutting is usually carried out from early September to mid-late November to provide spring cutting seedlings for the following year.

Cutting seedling beds should be arranged in the fields with abundant sunlight and convenient drainage and irrigation. Considering soil texture, loose fertile sandy soil is preferred. Before cut-

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ting is carried out, the beds should be deeply plowed several times to make the soil loose. Usually, the seedling beds have a length of 10 – 13 m, a width of 1.2 m and a seedbed groove width of 0.6 m. During the cutting, rooting powder is used to promote rooting, and shade net is used for dimming, temperature adjustment and moisture retention. Stem segments with robust branches and lateral buds, in length of 15 – 20 cm are generally selected for cutting seedling. The lower one third of the stem segments are inserted into the beds, at a row and plant spacing of 5 cm × 2 cm.

3.2 Cutting seedling management After cutting seedling, irrigation should be carried out timely according to the climatic conditions and the soil moisture to maintain seedling beds moist and cutting seedlings non-wilted. Plastic film and shade net are covered to adjust the light and temperature conditions of the seedling beds. At day, moisture is maintained; and at night, temperature is maintained to create the conditions suitable for rooting and sprouting of the stem segments. After the emergence of new shoots, more attention should be paid to ventilation and hardening of cutting seedlings to enhance their adaptability. As a result, cutting seedlings with robust stems and leaves and developed roots are nursed.

During the nursery, topdressing should be carried out properly according to the principle of shallow water fertilizer and more fertilization times but small amount for each time. In Gannan area, topdressing is usually carried out two times, one after the emergence of new leaves (0.1% urea + potassium dihydrogen phosphate, root topdressing) and the other 20 d after the cutting (0.2% urea). Then, topdressing is carried out according to the growth of cutting seedlings, and more attention is paid to weed removal and ripping between rows. The growth period of autumn cutting seedlings is longer. Before the temperature drops to 10℃, cutting seedlings may bloom. Therefore, the aboveground part of the seedlings should be cut off before wintering, and the retaining part should be covered with thin fine soil and plastic film to keep warm. When the air temperature rises to >10℃, the seedlings will grow unearthed. In order to prevent the degradation of cultivars, seedlings should be removed in a timely manner. When the seedlings enter the three-leaf stage, they can be cut off and subjected to cutting. In Gannan, one autumn mother plant can grow 2 – 4 spring cutting plants. After seedlings are collected, irrigation and fertilization are conducted timely to promote the emergence of new seedlings. In the first half of March, the autumn mother plants can be transplanted to fields.

3.3 Division propagation Division propagation is one of the main methods for the breeding of *S. rebaudiana*, characterized with conservation of the excellent traits of the female parent, simple operation, high reproductive survival rate and high annual output. The roots and stems of *S. rebaudiana* can be safely overwintered at ≥ −5℃. After the temperature rises around the spring equinox of the next year, new shoots can be regenerated and sprouted, reaching a number of 20 – 60. The new shoots, along roots can be transplanted separately, followed by irrigation and fertilization.

4 Field transplanting

4.1 Land selection and ridging It is better to choose sandy loam with convenient drainage and irrigation, which is ploughed deeply and exposed to sunlight before the end of December. Soil preparation is conducted 15 d before the transplanting next year. During soil preparation, basic fertilizers are applied composed of organic fertilizers (dominant) and compound fertilizers (auxiliary). Usually, composted cattle dung (5 000 kg/ha) and 45% compound fertilizers (750 kg/ha) are applied as basic fertilizer. After soil preparation, south-north ridges with a ridge width of 1 m and a trench width of 0.4 m are made. The ridges are sprayed with herbicides and covered with black mulch to reduce weed damage.

4.2 Transplanting The cutting seedlings of *S. rebaudiana* with 5 – 6 pairs of true leaves and height of 10 cm are suitable for transplanting. In Ganzhou, when the daily average temperature in early-mid March is stable at more than 12℃, transplanting can be carried out. The transplanting density of Shoutian No. 3 is around 150 000 plants/ha, at a row and plant spacing of 27 cm × 17 cm, with 6 plants per row. After transplanting, sufficient irrigation is carried out to keep the field moist for first 7 d. The transplanted seedlings should be inspected within 10 d after transplanting to prevent seedling missing. After 8 – 9 pairs of true leaves grow out and seedling height reaches 10 – 15 cm, the seedlings are topped timely to promote branching, ensure the production of this crop and prevent the early flowering of the next crop. For Shoutian No. 3, topping should be carried out two times to promote branching. In combination with cultivating and weeding, 2 – 3 times of topping are carried out for the first crop and 1 – 2 times of topping is carried out for the second crop according to the principle without hurting the roots. Horse running water is irrigated timely to prevent the death of seedlings.

4.3 Water and fertilizer management According to the conditions of the seedlings, soil and climate, drainage and irrigation and fertilization are carried out reasonably. In the rainy season, the trenches are cleared and stagnant water is discharged to reduce the moisture of the field. When the soil is white in high-temperature dry season, horse running water is irrigated timely. After the intertillage or harvest, irrigation is also carried out timely to make the soil moist. During fertilization, the principles of little amount of fertilizers in the early period, big amount of fertilizers in the middle period, supplementation in the late period and more fertilization times are complied with small amount for each time. For the first crop, topdressing can be carried out 2 – 3 times in the form of root fertilizer or water fertilizer. After 15 d of transplanting, 30 kg/ha of urea and 45 kg/ha of 45% compound fertilizer are dissolved in 22 500 kg/ha of water and poured to the seedlings. For the second time, 225 kg/ha of 45% compound fertilizer is dissolved in 22 500 kg/ha of water and poured to the seedlings at the exuberant branching stage. At the later stage, foliar fertilizer is

applied according to the growth of seedlings. After the harvest of the first crop, the mulch is peeled off in time and bought out the field. During the nursery of the second crop of cutting seedlings, the roots are kept moist to promote germination, accompanied by intertillage and weeding. The first time of topdressing (450 kg/ha of 45% compound fertilizer) is carried out after the germination of the second crop, accompanied by intertillage and weeding to prevent lodging, and the second time (150 kg/ha of urea + 300 kg/ha of 45% compound fertilizer) is carried out before the seedlings grow to trenches, combined with intertillage and weeding.

5 Ratoon cultivation and field management

5.1 Advantages of ratoon cultivation *S. rebaudiana* is a cross-pollination crop that is highly heterozygous and its seed seedlings are severely degenerated, so optimization, purification and rejuvenation are required. During seed selection after the harvest of the second crop, the plants with thick stems, dense nodes, compact plant type, thick dark green leaves and disease and pest resistance are selected, while miscellaneous plants, especially early flowering plants are eliminated. Ratoon cultivation is characterized with prevention from variety degradation, early germination, rapid germination, without topping, more branches, late blooming, longer vegetative growth period, simple management and high dry leaf yield throughout the year, and is conducive to saving nursery costs and improving yield and quality[4]. In Gannan area, under the condition of ratoon cultivation, *S. rebaudiana* can be cultivated in the same fields for three consecutive years, and it can be planted in open field or covered for overwintering. Ratoon cultivation is the main cultivation method for *S. rebaudiana* in Gannan area.

5.2 Perennial root management Under the condition of open field ratoon cultivation, the wintering rate is generally 70% – 75%. Under the condition of mulching (dry straw or plastic film) ratoon cultivation, it can be divided into field protective wintering and concentrated protective wintering. Usually, the cutting seedlings are covered after initial frost but before freezing, and the soil is kept moist. Before sprouting next spring, the cover is cleared. Thus, the wintering rate is above 95%. Field protective wintering refers to cutting off the perennial roots near the ground, removing weeds, and mulching the remaining roots for wintering. Concentrated protective wintering refers to planting cutting seedlings, at a density of 17 cm × 3 cm, in sandy loam beds (width of 1.2 m) with excellent soil quality, convenient drainage and irrigation, abundant sunlight and shelter from wind. For perennial roots with multiple seedlings, the seedlings can be transplanted separately along roots, and then covered with straw for overwintering. Under the condition of dense planting, water management should be strengthened. If seedbed is dry, irrigation is carried out; and if seedbed is wet, drainage is carried out.

Under the condition of ratoon cultivation, for cutting seedlings nursed in spring, their transplanting is early. In Gannan area, the transplanting is usually carried out in March, that is, between Rain Water and waking of Insects. As long as the temperature is stable and suitable, the covering is removed in time, and the cutting seedlings are transplanted after the emergence of new shoots. Under the condition of open field cultivation, when the perennial roots begin to sprout, water and fertilizer management is strengthened, and seedlings are inspected timely. Under concentrated protective wintering, the ratoon cultivation fields are ploughed deeply and exposed to sunlight before December. Before middle February, sufficient basic fertilizer is applied, followed by harrowing and ridging (width of 1 m). Herbicides are sprayed 5 d before transplanting. Planting ditches are dug according to the row and plant spacing of 27 cm × 17 cm, *i. e.*, six plants per row. The transplanting density is 120 000 – 150 000 plants/ha. After the transplanting, irrigation is conducted, and straw or plastic film is covered in a timely manner to prevent weeds.

When most of the new seedlings of perennial roots emerge, field management is carried out. First, when the sprouts are unearthed, the covered film is broken in a timely manner to help new seedlings emerge. Second, emerged seedlings are inspected timely to prevent seedling missing. Third, topdressing (more emphasis is put on potassium fertilizer) is carried out properly to promote growth and development, and the field is kept moist. Under the condition of plastic film mulching, application of sufficient basic fertilizer, and two times of topdressing are carried for the ratoon cultivation fields. The first time of topdressing (75 kg/ha of urea + 45 kg/ha of 45% compound fertilizer) is carried out 15 d after the transplanting, and the second time (225 kg/ha of 45% compound fertilizer) is carried out in the early stage of budding and branching. In the later period, foliar fertilizer is applied according to the growth of the seedlings to prevent premature aging and keep the field ventilated.

6 Disease and pest control

The prevention and control of pests and diseases in *S. rebaudiana* should be based on the plant protection principle of prevention first and comprehensive prevention and control. At the same time, attention should be paid to avoid continuous cropping, and paddy-upland rotation can be adopted to reduce soil-borne pathogens. During the rainy season, attention is paid to clearing trenches for drainage and reducing the moisture in the field. More manure is applied to improve the structure of the soil and promote healthy growth and increase the resistance of the plants.

6.1 Main diseases In the seedling stage, seedling rot, caused by low temperature, high moisture and poor soil permeability is the main disease, causing the base of young shoots to become watery, yellow-brown and wilted. When the disease is severe, all the plants will die. Spraying of 40% carbendazim suspension (500 ×) can be used to control this disease. In February-April, stalk break is prone to occur, due to high moisture in the field. When it occurs, the base or the middle leaves of individual plants of the seedbed are water-stained, resulting in wilting and dark browning of plants. Then, the lesions rapidly expand, and the

plants quickly rot and are covered with mycelia, forming brown sclerotia. For the control of this disease, 70% thiophanate-methyl wettable powder (1 000 ×) can be sprayed.

During the growing season, high soil moisture, due to the rainy season is prone to southern blight, which can damage the roots and cause plant death. Southern blight can be controlled with 50% chlorobromoisocyanuric acid (1 000 ×). In the later period of growth, high plant density, excessive rain and insufficient sunlight are easy to cause spot disease, and black mold is formed at the lesion. Under severe condition, the top bud of *S. rebaudiana* plants will shrink. Spot disease can be controlled with 10% difenoconazole (1 000 ×).

6.2 Main pests Aphids, whiteflies, red spiders, mirids, leaf rollers, cutworms and *Spodoptera litura* are the main pests that occur in *S. rebaudiana*, and avermectin plus imidacloprid can be sprayed to control them comprehensively.

7 Timely harvest and storage

7.1 Timely harvest In Gannan area, the mature stage of the first crop of *S. rebaudiana* is 105 – 110 d, and that of the second crop is 50 – 60 d, that is, the first harvest period is in the early-mid June, and the second harvest period is in August. In general, *S. rebaudiana* leaves can be harvested when the 5% of the field plants sprout. At this time, the stevioside content is the highest. When *S. rebaudiana* is cut, 10 – 15 cm of the base, along with 1 – 2 pairs of leaves are retained to maintain photosynthesis and plant vitality.

7.2 Storage The harvested leaves of *S. rebaudiana* are air-dried, placed in woven bags and placed in a dry place in a timely manner. After air-drying, the water content of *S. rebaudiana* leaves is better to be maintained within 10% – 11%, and they better maintain the natural color (green). At this time, the storage effect of *S. rebaudiana* leaves is best as they have high sugar content and strong water absorption.

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