High-yielding Fertilization Technology for *Citrus grandis*

Derong YANG\(^1\)\(^2\), Ming SHEN\(^3\), Zhiwei ZENG\(^4\), Long ZHOU\(^1\)\(^4\)*

1. Yunnan Yuntianhu Co., Ltd., Kunming 650228, China; 2. Yunnan Chemical Research Institute, Kunming 650228, China; 3. Yunnan Hengguan Taida Agricultural Development Co., Ltd., Kunming 650034, China; 4. Yunnan Agricultural University, Kunming 650201, China

**Abstract** As of April 2017, the planting area of *Citrus grandis* in Ruili City was 594.3 ha. Among it, the area of fruiting trees was 267.2 ha, and they were mainly owned by small growers. In view of the serious fragmentation of pomelos, the large investment in fertilizers, and the unsatisfactory production efficiency of *C. grandis* in Ruili, the fertilization technology for *C. grandis* was discussed. The problems in the fertilization process, as well as the principles and modes of fertilization were analyzed briefly. The fertilization methods for saplings and fruiting trees were introduced, in order to promote the improvement of the fertilization and management level of local pomelo growers.

**Key words** *Citrus grandis*, Cultivation technique, Fertilization

1 Introduction

Ruili belongs to the south subtropical monsoon climate. It is divided into dry and rainy seasons throughout the year and is basically frost-free. The dam region is 736 – 780 m above sea level, with an annual average temperature of 21°C, an annual rainfall of 1 394.8 mm, and average annual sunshine hours of 2 330 h. The winter is not cold, and the summer is not hot, with plenty of heat and plenty of rainfall, so it is ideal for growing pomelo and a variety of tropical crops. Compared with the Pinghe Guangxi Honey Pomelo in Fujian Province, Ruili Crystal Pomelo can be put on the market 10 d earlier\(^1\). According to statistics, as of April 2017, *Citrus grandis* had a planting area of 594.3 ha in Ruili City. Among it, the area of fruiting trees was 267.2 ha, and they were mainly owned by small growers and mainly concentrated in Nongdao and Jiexiang townships. Crystal pomelo was originally named Dong Shi Zao. It was introduced from Xishuangbanna in the 1980s. Affected by local climatic conditions, its traits have been improved, and its fruit taste quality has become better after artificial domestication. For more than 20 years, as a fruit of Ruili, it is highly valued by the local government. The government has increased the support for growers through the form of seedling subsidies. At the same time, the government has guided farmers to plant large area of crystal pomelos. However, problems still exist, such as severe fragmentation of fruit, backward science and technology, lack of cultivation and management measures, poor quality of fruit, fluctuation of yield, uniform fruit size, large fertilizer cost, and unsatisfactory production efficiency\(^2\). This paper focuses on fertilization techniques, in order to promote the improvement of the fertilization and management level of local pomelo growers.

2 Existing problems

2.1 Unreasonable use of organic fertilizer During the fertili-

zation process of *C. grandis*, most of the organic fertilizers used by the growers are organic wastes left by their own farming (pig, cattle and sheep). They are not fully fermented and contain more harmful pathogens, which cause pollution to the soil and affect the tree potential. Commercial organic fertilizers and refined organic fertilizers are scarcely used by local growers due to their high prices and unsatisfactory efficiency in short term. At the same time, long-term application of large amounts of chemical fertilizers has led to acidification and serious compaction of the soil. More importantly, the lack of trace elements in the soil has caused poor quality of pomelo fruit.

2.2 Not scientific fertilization Pomelo tree is a perennial fruit tree. The entire growth cycle needs to go through several periods, such as sapling, early fruiting, full fruiting and aging. Different periods have different requirements for the type, amount and application time of fertilizers. The traditional smallholder thinking has led some pomelo growers to reluctantly apply fertilizers during vegetative growth period but fertilize indiscriminately during reproductive growth period, resulting in low yield, poor quality and premature aging. Especially in the first three years of planting, there is no output. Coupled with unreasonable management, *C. grandis* becomes poorer and poorer, with serious problems of flower falling and fruit drop, and the yield is unstable or not high.

2.3 Not fully understanding soil properties Soil properties determine soil fertilizer retention and supply capacities. Different soils have different physical and chemical properties and different fertilization methods. Most of the soil in Ruili is alluvial yellow sandy soil. Pomelo orchards are mostly transformed from rice and maize fields. Although the soil has good air permeability, it is severely sandy, which not conducive to water retention and fertilizer conservation. The groundwater level is high, and the organic matter and potassium, zinc, boron and other nutrient contents are low. If fertilizers are not applied combined with the soil properties, the effect of the fertilizers will not be fully exerted. Even worse, they may pollute groundwater.
3 Fertilization principles

3.1 Combination of organic and inorganic fertilizer Although chemical fertilizers have high nutrient content and can significantly increase the yield of crops, the nutrition content is single. Long-term application of chemical fertilizers is highly destructive to the soil. Organic fertilizers have comprehensive nutrients, stable efficiency and long release time. They have the ability to improve the physical and chemical properties of the soil, and play an important role in improving crop yield and quality. The combination of organic fertilizers and chemical fertilizers can combine the advantages of both, and complement each other, satisfying crops’ need for rapid and long-term release of nutrients, especially for many medium and trace elements. Thus, during the fertilization process, attention should be paid to the perfect combination of organic and inorganic fertilizers. In addition, organic fertilizers are required to be fully fermented farmyard manure or qualified commercial organic fertilizers and refined organic fertilizers\(^5\).

3.2 Fertilizing according to tree potential and fertilizer requirement Fruit trees of different ages have different nutrient requirements. Therefore, the fertilization type and fertilization amount of pomelo saplings, early fruiting C. grandis, full fruiting C. grandis and aging C. grandis, especially the C. grandis around fruiting bearing, are quite different. Fertilization is also different for different developmental stages of trees of the same age. In particular, for fruiting trees, fertilization type and fertilization amount should be determined according to tippling, flowering, fruit bearing, fruit growth and tree growth\(^4\).

Usually, saplings mainly focus on expanding the crown and increasing the root system to ensure that an ideal tree form and a developed root system can be formed in the sapling period, thereby promoting the absorption of nutrients by the tree body and preparing for the subsequent fruit bearing. On the basis of applying organic fertilizers, in the sampling period, the fertilization mode of "less but more times" can be adopted. More nitrogen fertilizer can be applied, accompanied by phosphorus and potassium fertilizers, to make the saplings grow more branches and leaves and form a high-yielding canopy as soon as possible. After entering the fruiting period, C. grandis is transformed from vegetative growth to reproductive growth, and fertilization should ensure tree growth and fruit bearing. In the sprouting period of spring shoots, summer shoots and autumn shoots, the flowering period and the fruit expansion period, the absorption of nitrogen and potassium is the most. During the flowering, young fruit and flower bud differentiation period, the absorption of phosphorus is the highest. If the tree growth is robust, it is necessary to appropriately reduce the fertilization amount of nitrogen fertilizer.

3.3 Fertilizing depending on soil conditions For some mountain red soil, neutral or alkaline fertilizers should be the mainstay. The application of acid fertilizers should be reduced and the application of organic fertilizers can be increased to improve soil structure and adjust soil acidity. In addition, because clay has slow release of nutrients, the number of fertilization times can be appropriately reduced during fertilizing. Deep application or re-application can be adopted. For most alkaline alluvial sandy soil, the combination of organic and inorganic fertilizers or single application of slow-release fertilizers can be adopted. For quick-acting fertilizers, the number of fertilization times should be reduced to reduce nutrient loss and improve fertilizer utilization\(^5\). For the soil with different fertility, the nutrient content of the soil can be determined conditionally. According to the nutrition level of the soil, fertilization plan is determined.

4 Fertilization modes

4.1 Rhizosphere fertilization Rhizosphere fertilization refers to the fertilization mode which applies fertilizers directly to the soil, and crops absorb the nutrients through roots. Fertilization should be based on fertilizer mobility and tree size. Fertilizers should be applied to the soil layer of the root system to increase the absorption of nutrients by the root system. Using the fertilizer-tropism of the root system, saplings mainly promote horizontal root growth. As the tree grows, fertilizers are applied deeper year by year to promote rooting and lateral expansion, increase the ability of the tree to absorb and utilize the fertilizers in the soil and improve the resistance of the tree\(^6\).

The modes of rhizosphere fertilization mainly include sprinkling, furrow application, and hole application.

In the sprinkling mode, organic fertilizers and chemical fertilizers are first sprinkled evenly within the drip line. Then, the soil is plowed at a depth of 20 cm to turn the fertilizers and weeds into the soil to facilitate the absorption of fertilizers by new roots. This method is suitable for being used once every 2 – 3 years, accompanied by deep tillage to improve soil permeability, promote horizontal root renewal and rejuvenation, and improve root vitality. It must be noted that fertilizers cannot be applied to the trunk or too far from the roots. Big roots should be avoided when plowing.

In the furrow application mode, furrow is dug around or at both sides of the drip line, with a width of 15 – 25 cm. Its depth is determined by the vertical range (30 – 40 cm) of the fine root distribution. The furrow is expanded and deepened year by year, until the furrows between adjacent plants is connected. A few radicalized furrows can be dug with the trunk as the center. The inside is shallow, while the outside is deep. Fertilizers are evenly applied in the furrows. After mixed evenly with the soil, the fertilizers are covered with soil. This method is suitable for applying the winter fertilizer or fruit fertilizer of C. grandis. The position needs to be changed every time of fertilization, so that fertilizers can be evenly distributed across the orchard.

In the hole burying mode, holes are dug evenly around the tree plate, with a depth of 20 – 50 cm. When digging, the big roots should be prevented from damage. The holes are shallow inside and deep outside. Fertilizes are applied to the holes, mixed with soil, and covered with soil. As root system is developed during fruiting period and digging may damage the roots, this method is most suitable for the fruiting period of older trees. In addition, the position of the holes should be changed time after time so that fertilizers can be evenly distributed throughout the orchard.

4.2 Foliage spray Foliage spray is also called foliar fertiliza-
tion. It is a fertilization method of spraying a low-concentration solution of a water-soluble fertilizer or a biological substance on leaves of growing crops. The method has the characteristics of fast absorption and convenient implementation. It can make for the rapid and timely supplementation of nutrients when the root system is difficult to absorb. Deficient elements can be supplemented timely, improving the winter resistance of plants. However, it cannot completely replace the rhizosphere fertilization. Foliage spray is usually applied to some medium and trace elements that are difficult to be absorbed by some crops or foliar fertilizers for improving crop resistance. It can be applied at any time and can be implemented together with pest control. Usually, it is frequently used in the new leaf stage, flower bud differentiation stage, flower and fruit protection stage, young fruit stage and fruit coloring stage.

5 Fertilization methods

5.1 Young tree fertilization Young tree refers to C. grandis that has not been fruited for 1–3 years (the fruit is to be removed during the period). The main purpose of fertilization for young trees at the vegetative-growth period is to promote root growth and crown enlargement, to form a good tree shape, and to prepare for the later fruiting. Since the sapling roots are few and weak, with poor absorption ability and weak fertility tolerance, the principle of "less but more times" is adopted for the fertilization of saplings to cultivate a strong root system and promote the generation of new shoots to form a canopy as soon as possible[7]. In this period, fertilization is dominated by nitrogen fertilizer, supplemented by phosphorus and potassium fertilizers. Fertilization is carrier once before, during and after each generation of new shoots, and 8–12 times of fertilization is carried out throughout the year. Urea (50–100 g/plant) and balanced compound fertilizer (50–80 g/plant) are used alternately. The fertilizer is usually dissolved in water and poured to plants or buried around the plants. In winter, 5–10 kg of organic fertilizer can be applied through furrow application, and the amount of fertilizer is increased year by year.

5.2 Fruiting tree fertilization Fruiting trees are both vegetative and reproductive. In fertilization, it is necessary to consider both to meet the nutrition needs by various phonological stages, such as new shoots and new roots growth, flower bud differentiation, flowering and fruit development, thereby increasing the number and quality of shoots and new roots, improving the fruiting rate and quality, and ensuring the flowering, fruiting and canopy regrowth of current year and next year. The fertilization of fruiting C. grandis can be roughly divided into shoot and flower fertilizer, fruit fertilizer, harvest fertilizer and winter fertilizer.

Shoot and flower fertilizer (from the end of February to the beginning of March). Spring shoots of C. grandis are usually used as the fruiting mother branches. Fertilization before spring germination can promote sprouting, robustness and uniformness. After the spring shoots turn green, there is enough nutrient supply to strengthen the photosynthesis ability of spring shoots and meet the nutrient needs by flowering and the second physiological drop to prevent falling flowers and fruit. Shoot fertilizer is usually applied 2–3 weeks before shoot generation. The fertilization is mainly based on high-content quick-acting compound fertilizer, accounting for 10% of the annual fertilization amount. The amount of fertilizer applied to each plant is 0.5–1.0 kg. If the application amount of winter fertilizer is too large, the soil is too fertile or the pomelo tree grows better, it may be applied less or not. The fertilization mode is dominated by pouring. For the pomelo tree that fruits early and grows vigorously, before and after the germination of spring shoots, the application of quick-acting nitrogen fertilizer should be controlled, and the fertilization plan of high potassium, medium phosphorus and low nitrogen is optimum. Excessive nitrogen fertilizer will cause excessive vegetative growth of spring shoots and early generation of a large amount of summer shoots, which compete with young fruit for nutrients and lead to low fruit bearing rate.

Fruit fertilizer (from the end of April to the beginning of May). After completing the second physiological fruit drop, the fruit of C. grandis rapidly expands, and the demand for water and fertilizer is large. In addition, in this period, summer shoots sprout, and spring shoots are in the stage of flower bud differentiation. Summer shoots compete for nutrients with C. grandis, so a large amount of nutrient supply is needed to meet the needs of fruit enlargement and new shoots. Fruit enlargement is usually completed before the end of May. Fruit fertilizer is dominated by nitrogen and potassium fertilizers, accounting for 35% of the annual fertilization amount. It is applied together with organic fertilizer. The fertilization amount is 1.5–2.0 kg/plant of high nitrogen-high potassium compound fertilizer (15-5-25 or 20-5-20) and 5–10 kg/plant of refined organic fertilizer. The fertilization mode is dominated by circling fertilization or hole application.

Harvest fertilizer (from late September to mid-October). Harvest fertilizer is mainly to meet the nutrient consumption of fruit harvesting to restore the tree potential and promote root growth. Fertilization is carried out 1–2 weeks after fruit picking, accounting for 15% of the fertilization amount in the whole growth period. Harvest fertilizer is dominated by phosphorus and potassium fertilizers or balanced fertilizer. The fertilization amount is 0.5–1.0 kg/plant. The fertilization mode is mainly circling fertilization or loose soil application.

Winter fertilizer (late mid-December). Winter fertilizer is the most important and commonly used fertilizer throughout the year. Organic and inorganic fertilizers are applied synchronously. Fertilization is carry out along with soil improvement and expansion of holes. Winter fertilizer is mainly applied through furrow application. Application of winter fertilizer can promote root rejuvenation, protect roots, improve cold resistance, promote tree potential recovery, and increase the nutrient accumulation of various organs of trees. At the same time, application of winter fertilizer can promote second flower bud differentiation of C. grandis and stores nutrients for the germination and flowering of the spring of the next year. Winter fertilizer is usually applied around the winter solstice, and its application amount accounts for about 40% of the fertilization amount of the whole growth period. High phosphorus-high potassium compound fertilizer or balanced compound fertiliz-
er, accompanied by organic fertilizer, is usually used as winter fertilizer. At the same time, medium and trace elements are supplemented. The fertilization amount of compound fertilizer is 1.5 – 2.0 kg/plant, and that of commercial organic fertilizer is 15 – 30 kg/plant (composted farmyard manure 50 – 80 kg/plant). In addition, medium, and trace element fertilizer is applied according to the amount of 100 g/plant. For acidic soil, quicklime can be mixed with the soil according to the amount of 0.5 – 1.0 kg/plant.

References