Spatiotemporal Coupling of Water and Fertilizer for Double-cropping Grape in Guangxi

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Abstract This paper summarizes the research progress and major achievements of the coupling effect of water and fertilizer on grape cultivation in China and abroad in recent years, emphatically analyzes the application status and some problems of the coupling effect of water and fertilizer on double-cropping grape cultivation mode in Guangxi Zhuang Autonomous Region, discusses the key problems to be further resolved, and finally makes the relevant recommendations.

Key words Grape, Double cropping, Water and fertilizer coupling, Research status

1 Introduction

Guangxi has creatively developed double-cropping grape cultivation technique to create a "winter grape" brand in Guangxi, and make grape become the fruit with the best economic benefits in Guangxi. Water and fertilizer are extremely important two factors in agricultural production, and also two important technical measures that can be regulated in production. The effect of water and nutrients on crop growth is not a simple single-factor effect, but an interacting effect[1]. With the rapid increase of grape acreage in China[2], some problems are ubiquitous in grape cultivation such as irrational fertilization, blind fertilization and experience-based fertilization[3-7]. Currently, the water and fertilizer use efficiency in China's grape production is lower than the international level; the irrigation water use efficiency is only 40% and the fertilizer utilization rate is only 30%[8]. In this case, the water and fertilizer coupling has emerged as a new type of fertilization technique, and it can significantly improve grape's water and nutrient use efficiency, promote grape quality, reduce production costs, and reduce non-point source pollution[9-11].

2 Research status of water and fertilizer coupling effect on grape

2.1 Effect of water and fertilizer coupling on physiology of grape The study found that different degrees of water and fertilizer coupling and the dynamic change mode, can directly or indirectly affect the nutrient content and composition. The growth and development of crop root is directly related to the growth of aboveground part and yield[12], and the differences in water and nutrient will affect other physiological and ecological effects of crops[13]. Studies of Shen Qirong *et al.*[14] have shown that potassium deficiency or excess will reduce chlorophyll and ATP content, and block the photosynthetic electron transport and photophosphorylation, so that the photosynthesis-related enzyme activity decreases, thus affecting the plant's assimilation of carbon. The studies of Guo Xiuwu *et al.* indicate that under moderate water stress, increasing the proportion of phosphorus and potassium can promote the grape's absorption of nitrogen[15]. The studies of Yu Na *et al.*[16] show that proper water stress and increase of fertilizer can increase yield and improve the water and fertilizer use efficiency. One of the reasons for the synergistic coupling role of water and fertilizer in increasing yield is that proper coupling of water and fertilizer improves crop's biological properties[8]. Obviously, water and fertilizer can complement each other under certain conditions.

2.2 Coupling effect of water and fertilizer on grape yield At different water levels, the proportion of grape's demand for nutrients is different. Taking Centennial Seedless Grape for example, at budding and fruiting stages, the water and fertilizer treatment (water accounting for 55% to 60% of field moisture capacity; fertilizer ratio of N: P: K = 2: 5: 3) is an efficient water and fertilizer utilization mode; after veraison and harvest, the water and fertilizer treatment (water accounting for 75% to 80% of field moisture capacity; fertilizer ratio of N: P: K =2: 1: 5) has high photosynthetic rate and the highest yield[15]. Yan Qiaodi finds that when the soil moisture conditions are good, the grape's photosynthetic rate rises, and when the soil moisture conditions are poor, the grape's photosynthetic rate falls[17]. Huang Ying *et al.* study the impact of three fertilizer levels (high, medium and low) and 4 irrigation levels (abundance of water, mild stress, moderate stress and severe stress) on the yield of Red Globe Grape. The results show that the impact of irrigation amount on the grape's vertical and horizontal diameter and weight reaches a highly significant

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level, and grape yield is highest under treatment (fertilizer: 161.92 kg/ha of N, 53.97 kg/ha of P and 44.98 kg/ha of K; moderate stress: 55%-60% of field moisture capacity), suggesting that the coupling effect of water and fertilizer is best[18].

2.3 Coupling effect of water and fertilizer on grape quality Different irrigation methods not only affect the content of titratable acid in fruit, but also affect the content of total fruit sugar, peel anthocyanin and mineral elements in fruit[19]. At different growth stages, grape has different demand for fertilizer and water and different sensitivity to fertilizer and water. The fruit swelling period is a key period of water control in the whole growth period of grape, and the water consumption during this period accounts for 37%-40% of water consumption in the whole growth period[20]. Liu Hongguang *et al.*[21] find that the regulated deficit irrigation at the budding and heading stages of grape can play the compensatory growth effect; at the flowering stage, the regulated deficit irrigation can strengthen flower thinning, increase weight, and optimize spatial distribution effect of fruit ear. Hagin *et al.*[22] (1996) find that in the case of combination of irrigation and fertilization, the use rate of nitrogen fertilizer reaches more than 90%, and it can also reduce the fruit acidity, increase soluble solids to acidity ratio, and improve fruit quality. Huang Ying *et al.*[18] report that in terms of Red Globe Grape, the grape soluble solids shows parabola development with increasing fertilizer, titratable acid content increases with increasing fertilizer, and moderate fertilization and water shortage can increase the anthocyanin content. Obviously, the precise adjustment of fertilizer and water supply in the growth period is the key to ensuring the quality of the grapes. However, it is still difficult to transport the water and fertilizer in sync to grape roots precisely according to the water and fertilizer needs in the growth period of grapes.

2.4 Coupling effect of water and fertilizer on soil and environment of vineyard In the actual production, excessive irrigation will not only cause underdevelopment of crop roots and affect roots' absorption of nutrients, but also cause loss of nutrients, which is not conducive to increasing fertilizer use efficiency[8]. Similarly, drought can also cause difficult dissolution of nutrients and make them difficult to be adsorbed by soil colloids, thus polluting the environment. Xing Weiqin *et al.*[23] study the environmental effects of nitrogen under coupling conditions of water and fertilizer, and the results show that the content of available N is highest in the soil of less than 40-60 cm under conventional irrigation and fertilization, which is not conducive to crop roots' absorption of N, and will pollute groundwater through leaching; under the water and fertilizer coupling with the same amount of irrigation, N is mainly distributed in 20-80 cm soil, which is conducive to crop roots' absorption of N, improves fertilizer use efficiency, and reduces the risk of fertilizer contamination. The study of Du Taisheng shows that the application of alternate partial root-zone drip irrigation in grape can help to regulate vegetative growth, reduce nutrient loss, and lower the fertilizer contamination risk[24].

3 Application of water and fertilizer coupling in Guangxi's double-cropping grape

3.1 Late start of water and fertilizer application in Guangxi's grape production Guangxi has the natural advantages of sufficient temperature and light for the development of grape, double cropping technical advantages, as well as the market advantages of nearing Pearl River Delta and Southeast Asia[25]. However, the hot, wet and rainy climate in Guangxi is an important factor limiting the production of grapes. Therefore, the development of double-cropping technology in Guangxi is the key to stabilizing grape production and giving full play to the advantages of climate and technology. The rainfall is abundant but unevenly distributed in Guangxi, and it is mainly concentrated in May to August. There is often spring drought in spring. The drought is more serious in Guangxi's northwestern main producing areas of grape. Grapes are drought-resistant crops, but excessive drought will affect survival rate, sprouting, yield and quality. In Guangxi's main producing areas of grape, the water and fertilizer integration technology started to be used in 2009; Xing'an County and Lingchuan County started to adopt the simple water and fertilizer integration technology in 2012[26]. The study on water and fertilizer for Guangxi's grape is rarely reported, indicating that most of Guangxi's grape producers and researchers only focus on the grape variety breeding, pruning and other cultivation problems, but ignore water and fertilizer problem in grape production.

3.2 Low level of water and fertilizer application in Guangxi's grape production Currently, the fully automated computer-controlled modern drip irrigation system is rarely adopted in Guangxi's vineyard. The vast majority of local farmers still use the simplest drip irrigation equipment, with low level of automation, so the advantage of water and fertilizer integration in Guangxi has not yet been fully exerted. The water and fertilizer application in Guangxi's vineyard is mainly based on experience, and there are no unified technical parameters. For the same variety, different growers have different application amount and time of water and fertilizer, and there is the phenomenon of blind fertilization. Because of poor understanding of grape's fertilizer absorption law, the growers often increase amount of fertilizer and irrigation to meet the tree's growth needs, but ignore the nutritional balance. There are messy varieties of fertilizer for irrigation, and some varieties of fertilizer have low solubility and can easily cause blockage, thereby affecting production.

4 Problems in the study and use of water and fertilizer coupling for Guangxi's grape production

4.1 Lack of basic research Currently, there are few studies on root irrigation, fertilization levels and coordination effects of combining different growth stages of double-cropping grape. There are no in-depth studies on water and fertilizer demand at different growth stages and in annual cycle of double-cropping grape, and the amount of fertilizer and irrigation can not be accurately grasped. At different growth stages of double-cropping grape,

there is a shortage of studies on the spatio-temporal water-fertilizer coordination effect of local spatial irrigation mode for root zone on the double-cropping grape under different fertility levels. It also lacks the studies on the issues concerning efficient use of fertilizers in vineyards and environmental problems.

4.2 Low standard for water and fertilizer management technology The water and fertilizer facility input standard is low for Guangxi's grape, and the equipments are not complete, with low operating efficiency. The organic fertilizer is rarely applied in the production, and farmers often blindly increase fertilizer and irrigation based on experience, leading to diminishing returns. Many farmers do not pay attention to nutritional balance, but only focus on the application of N and neglect the combined application of N, P, K, resulting in unbalanced tree nutrition. They often use poorly water-soluble fertilizers in irrigation, and place great emphasis on the effect of single factor of water and fertilizer on grape growth, but neglect the coupling effect of water and fertilizer on grape yield and quality.

5 Recommendations

(i) It is necessary to strengthen the basic research on the coupling of water and fertilizer for grape, clarify the grape's water and fertilizer absorption law, and enhance the accurate management of water and fertilizer for double-cropping grape in accordance with the water and fertilizer demand of Guangxi's double-cropping grape at different growth stages. It is also necessary to strengthen the study of water and fertilizer coupling effect on grape yield and quality, clarify the effect of water and fertilizer as well as interaction between some elements in water and nutrient on grape yield, quality and utilization rate of water and fertilizer during the cultivation of Guangxi's double-cropping grape, and propose constructive fertilization program for the double-cropping grape cultivation in Guangxi. (ii) It is necessary to perfect the technical standards for the management of water and fertilizer coupling, and improve water and fertilizer equipments, to improve operation efficiency, optimize management and form unified technical parameters for the water and fertilizer application. There is a need to strengthen the supporting water and fertilizer project in the vineyard based on local conditions, and enhance scientific supply of water and fertilizer, so that water and fertilizer create synergies, to increase production. (iii) Guangxi's hot and rainy weather conditions drive the development of water and fertilizer coupling technology for grape in Guangxi. In recent years, the water and fertilizer integration technology in Guangxi continues to get the attention of farmers, so the water and fertilizer coupling technology for Guangxi's double-cropping grape needs to be combined with different disciplines to develop, especially computer technology. The coordinated management of crop, soil, water and fertilizer and efficient farm water and fertilizer management system, is of great significance to promoting the high-yield, high-quality and high-efficiency grape production.

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(ii) Most of 15 districts and counties of Xi'an City, Baoji City, Weinan City, and Shangluo City in Guanzhong - Tianshui Economic Zone are situated in area of Qinling Mountains, southern Shaanxi directly radiated by Guanzhong - Tianshui Economic Zone has 25 counties and districts in area of Qinling Mountains. In accordance with policies and measures in *Development Plan for Guanzhong - Tianshui Economic Zone* approved by the State Council, it is required to make efforts to explore application approaches and methods for ecological protection of Qinling Mountains from financial and tax policies, land policies, environmental protection policies, and urban and rural integration policies. It can be considered that the area of Qinling Mountains is difficult and weak point of development of Guanzhong Economic Zone and area directly radiated by Guanzhong Economic Zone. If not treated properly, it may hinder the development, thus it is recommended that relevant departments energetically support Guanzhong Economic Zone to develop cases suitable for *Ecological and Environmental Protection Regulations on Qinling Mountains in Shaanxi Province*, to realize synchronous growth of development of Guanzhong Economic Zone and ecological protection of Qinling Mountains[11-12].

(iii) Qinling Mountains provide a natural boundary between North and South China and an essential watershed of Yellow River and Changjiang River. According to great significance and ecological value of ecological and environmental protection in Qinling Mountains, as well as great significance in the world, it is recommended that the National People's Congress should lift *Ecological and Environmental Protection Regulations on Qinling Mountains in Shaanxi Province* to the national level, *i. e. Ecological and Environmental Protection Law on Qinling Mountains*, to cover Gansu, Shaanxi, and Henan provinces[13-15].

(iv) There is no tracing and monitoring and evaluation of ecological environment in Qinling Mountains in *Ecological and Environmental Protection Regulations on Qinling Mountains in Shaanxi Province*. This is a defect in legislation of ecological and environmental protection. In view of long-term, complex, arduous, and slow ecological and environmental protection, it is recommended to establish ecological and environmental protection tracing and evaluation method and system for Qinling Mountains. Besides, it is recommended to protect biological diversity in accordance with water conservation ability, develop and build green, clean, and sustainable monitoring means and system according to changes in carbon sink of vegetation, and scientifically monitor and evaluate improvement of ecology and environment of Qinling Mountains, to promote implementation of the Twelfth Five-Year ecological and environmental protection objectives[16-17].

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