Factors Influencing Technological Progress in Citrus-Producing China

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Technological progress is the use of a certain amount of input to produce more output, or, conversely, the use of less input to produce a certain amount of output. With the continuous progress in agricultural technology, productivity has greatly improved, and a large number of scholars have emerged in the field of agricultural technological progress research.

Keywords: citrus ; technological progress ; spatial correlation network structure ; transcendental logarithmic cost function ; social network analysis

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1. **Introduction**

Citrus is one of the most important cash crops in the world and the largest category of fruits in the world [1]; it is the largest category in China in terms of planted area and production [2]. China's citrus industry ranks first in the world, and production accounts for about one-third of the world's production [3]. According to the China Rural Statistical Yearbook, in 2021, China's citrus planting area was 2.922 million ha and the production was 55.956 million tons, accounting for 22.82% of China's fruit planting area and 25.81% of the production. China's citrus industry has been developing rapidly, especially in the past 45 years, since the reform and opening up. In China, citrus varieties have been enriched, the spatial layout of citrus production has been optimized, citrus quality has been improved, farmers' enthusiasm for planting is high [4], and the promotion of the healthy development of the citrus industry has become one of the most important methods for boosting industrial prosperity and realizing the revitalization of the countryside [5]. According to the UN Comtrade Database, China's citrus export was 917,700 tons in 2021, accounting for only 5.96% of the world's total citrus exports. So, some scholars say that though China is the world's major citrus producer, it is not a powerhouse of citrus production and trade [6,7]. Compared with developed countries, China's citrus-production efficiency is low [8], and citrus production per unit area is lower than the world average [2]. According to FAO data, China's citrus production per unit area in 2021 was 15.37 t/ha, which is much lower than Indonesia's production per unit area, which is the highest in the world, with a production rate of 38.53 t/ha. China's citrus industry urgently needs to accelerate the innovation-driven transformation of the development mode from "extensive" to "intensive" [1] to improve citrus production per unit area, and the improvement of production per unit area is driven by technological progress [9]. Under the role of factor flow and market and government support mechanisms, technological progress among major citrus-producing provinces does not exist independently but shows a certain spatial correlation [10]. At the same time, in plant taxonomy, mandarins and tangerines belong to the same family and the same genus but are different species of woody plants. Mandarins and tangerines are often collectively referred to as "citrus." There are differences in the mandarin and tangerine planting areas in China, and mandarins and tangerines differ in terms of scientific and technological strength [11]. So, the rates of technological progress [12] and the characteristics of the spatial network structure are also different. Therefore, what is the level of citrus-production technology progress in China? What kind of changing trends exist in mandarin- and tangerine-production technology progress? What are the differences in the technological advances related to mandarins and tangerines? Are they spatially correlated? What are the characteristics of the spatial association network structure? What are the factors affecting the structural formation of citrus spatial association networks? Answering these questions is of great practical significance for optimizing the allocation of resource factors, promoting the technological progress in mandarin and tangerine production, improving production efficiency, and promoting the high-quality development of the citrus industry.

2. **Literature Review**

Technological progress is the use of a certain amount of input to produce more output, or, conversely, the use of less input to produce a certain amount of output [13]. Theoretical research on technological progress began in the early 19th century. In 1957, Solow created an economic growth accounting model to clarify the contribution of technological progress to economic growth [14]. Scholars at home and abroad began research on economic development and technological progress. Arrow put forward the concept of "learning by doing" and believed that the skills of workers would be continuously improved in production, which led to technological progress, and tried to endogenize technological progress for the first time [15]. Based on the neoclassical investment theory, through the selection of the transcendental logarithmic production function, Christensen et al. concluded that technological progress is the main reason for productivity change [16].

With the continuous progress in agricultural technology, productivity has greatly improved, and a large number of scholars have emerged in the field of agricultural technological progress research. The methods of measuring agricultural technological progress are mainly divided into two categories: the parametric method and the non-parametric method. Tan believes that the overall technological progress in agriculture can be divided into spontaneous technological progress and induced technological progress, and many scholars have followed suit to conduct separate research on spontaneous technological progress and induced technological progress [17]. Mao et al. used data envelopment analysis (DEA) to analyze the total factor productivity of Chinese agriculture in the period 1984–1993 and found it to be the main reason for the change in productivity [18]. Da Silva et al. measured the technological progress in Brazilian agriculture in 1976–2016 and analyzed the efficiency of factor input use in different periods [19]. Tan et al. investigated the relationship between agricultural technological progress, agricultural insurance, and factor input use and concluded that both agricultural technology progress and agricultural insurance have a positive impact on farmers' income [20]. Chen et al. measured different types of environmentally friendly technological progress in Chinese agriculture from 2000 to 2010 and analyzed the spatial spillover effect [21].

In the study of citrus-production technology progress, He et al. measured citrus technical efficiency and technological progress index in 20 cities in Sichuan, China, from 2009 to 2020 and concluded that it was on the low side, which led to low productivity [22]. Gu et al. measured and decomposed the total factor productivity of citrus in China from 2006 to 2020 using the DEA-Malmquist index method and concluded that technological progress is the main factor affecting the total factor productivity of citrus [2]. Xiang et al. analyzed the technical efficiency of citrus cultivation, the time series development law, and the influencing factors from 2007 to 2015 by using the beyond logarithmic production function and concluded that the overall average technical efficiency of tangerine production is higher than that of citrus, and there are regional differences in the technical efficiency of citrus production and cultivation [23].

As spatial analysis methods have improved, many scholars have used social network analysis to study the spatial correlation network structure and the factors influencing it, i.e., agricultural total factor productivity [24], agricultural green total factor productivity [25], agro-ecological efficiency [26], and green science and technology innovation efficiency [27]. In the study of the spatial correlation network structure of technological progress, Wang et al. concluded that there are obvious spatial correlation and spillover effects in the development of agricultural science and technology innovation in China and presented the shape of the spatial correlation network structure [28]. He et al. concluded that agricultural location centrality and intermediary centrality have a significant positive moderating effect on technological progress [29].