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Review

Pecan production in China

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ABSTRACT

China is the world's largest market for pecans and imports more than a third of the U.S. pecan crop to meet its needs. Since 2008, pecan cultivation in China has been a rapidly growing industry. This paper summarizes the history of pecan importation and cultivation in China, the suitability of various cultivars for different regions, propagation techniques, major pests and diseases, pecan processing, and relevant research conducted in China. We also discuss current issues with pecan production in China and possible solutions to these challenges.

Contents

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1. Introduction

Pecan (*Carya illinoinensis*), a member of the hickory genus (*Carya* spp., Juglandaceae), is the most valuable nut tree native to North America. It is widely distributed and tolerates varied environmental conditions (ranging between 30°N and 42°N), and it is commercially produced in New Mexico, Georgia, Louisiana, and Texas, as well as Mexico (Sagaram et al., 2007; Sparks, 2005). The United States is the world leader in pecan nut production, accounting for about 50% of total production. In past decades, pecan has been introduced to many other countries, including South Africa, Brazil, Australia, Argentina, and China (McEachern, 2014).

Consumption of pecan in China has skyrocketed since 2008, due to a global walnut shortage and record pecan harvests. However, the supply of China-grown pecan is low and unpredictable, so China must import 50,000 t of U.S.-grown pecan annually to satisfy its market, which accounts for over one third of the total U.S. production (Wessel, 2011). The low production of pecan in China may be attributed to limited land available for pecan growing and low yield of aging pecan orchards (Li et al., 2009).

Many Chinese researchers and growers have become involved in the pecan industry since 2008. They are devoted to developing a pecan culture system that best suits the actual conditions of China. The objective of this review is to provide an overview of pecan culture in China and highlight the research efforts of Chinese researchers over the past decades.

2. History of pecan introductions to China

Pecan was first introduced to China over 100 years ago, but the entire history of its introduction may be divided into four stages: unintentional introduction (1900s); first intentional introduction (1910s); second intentional introduction (1950s), and third intentional introduction (1970s) (Li et al., 2009; Liu et al., 2011; Zhang et al., 2003).

A missionary, M. Shao, first brought pecan to China in 1900 and again in 1901, planting a few pecan seeds at the Shucheng Christian Church in Anhui (Li et al., 2009; Yu, 2010). In 1907, Dr. E.H. Wilson brought a few two-year-old seedlings and planted them in Nanjing, Jiangsu (Zhang et al., 2003). A few Chinese silviculturists, such as Huanguang Fu, became interested in introducing pecan species for silviculture. Pecan seeds from Georgia and South Carolina (in the United States) were introduced to China in 1916, 1928, and 1944, and were planted at Nanjing, Jiangsu (Zhang et al., 2003). In the 1950s, the Nanjing Forestry Bureau introduced approximately 100 kg pecan seeds from the United States for propagation. These seedlings were mostly planted alongside streets to serve as landscape and crop plants (Li et al., 2009).

However, all these early introductions were in the form of seeds or seedling plants, not vegetatively propagated cultivars. It was not until 1965 that a French pathologist (name unknown) presented China with two pecan cultivars ('Mahan' and 'Elliott') as gifts, which were planted in Guangdong, Fujian, and Zhejiang (Li et al., 2009; Zhang et al., 2003). Pecan was only planted on a small scale before the 1970s. In 1974, the Yunnan Academy of Forestry established the first commercially pecan orchard at Yunnan Province. A few more introductions were made by Baipo Wang (in 1978), Zuijun Sun (in 1983), Shengke Xi (in 1991), Riqing Zhang (in 1998 and 1999), and Jianqing Huang (in 2011). These cultivars were widely, experimentally planted in southern, eastern, and northern China (Fig. 1, Table 1) (Grauke, 2000; Han, 1995; Li et al., 2009; Shi et al., 2013; Zhang and Lv, 1998).

3. Pecan cultivars in China

3.1. Cultivars imported from the United States

Over 100 U.S. pecan cultivars have been introduced to China through Zhejiang A&F University, the Chinese Academy of Forestry, and South Central Forestry University. Of these, 67 have been preserved (Table 1) (Grauke, 2000; Li et al., 2009; Zhang et al., 2001a). These cultivars were established by grafting onto seedling rootstocks in the nursery and observing the resulting plants for growth, phenology, disease and insect resistance, nut production, and nut quality. Several cultivars, including 'Mahan,' 'Western,' 'Tejas,' 'Shoshoni,' 'Wichita,' and 'Pawnee,' were recommended for Jiangsu, Anhui, Zhejiang, Jiangxi, and Henan Provinces after years of evaluation, whereas 'Mahan,' 'Pawnee,' 'Caddo,' and 'Shawnee' were strongly recommended for Yunnan Province. Among these, 'Mahan' and 'Pawnee,' which are very well received by growers, are the main cultivars that have been propagated in the past decade (Fang et al., 2010; He et al., 2013; Li et al., 2009; Liu et al., 2010, 2013; Sheng et al., 2011; Xi et al., 2006c; Xiong et al., 2006, 2008; Yao et al., 2004; Zou et al., 2010a).

3.2. Selection and breeding

The early introduction of pecan seeds has resulted in approximately 70,000 30-year-old pecan trees growing in China, distributed in 22 provinces (Fig. 1) (Zhang et al., 2003). A few individual trees that have good nut quality and disease resistance were selected and later named after the towns or provinces in which they were located. The first selection was conducted in 1957 by Hongyu Sun, a horticulturist at Zhejiang A&F University, who selected two superior individuals, 'Gulou' and 'Mochou,' due to their high yield and large nut size, out of 202 adult pecan trees in Gulou District and around Mochou Lake in Nanjing (Table 2) (Dong, 2003; Li et al., 2009; Zhang et al., 2001a).

Zuijun Sun and Yong Tan preliminarily selected 10 individuals with large nut size for nut production and 8 individuals that showed vigor for use as timber and in afforestation. They chose after evaluating 4366 15–22-year-old bearing pecan trees in terms of tree vigor, yield, nut size, percent kernel, kernel thickness, and oil content, in Nanjing, Jiangsu Province, from 1972 to 1974 (Table 2) (Dong, 2003; Li et al., 2009).

A nationwide investigation of adult pecan trees was carried out by Zhejiang A&F University, in collaboration with the Research Institute of Subtropical Forestry, from 1982 to 1986, after which they released four varieties: 'Changlin 13,' 'Shaoxing 1,' 'Shanzhan 2,' and 'Jinhua 1,' and partially tested them in southeast China. 'Shaoxing 1′ and 'Jinhua 1′ were later renamed 'Shaoxing' and 'Jinhua,' respectively, and were widely planted across China. 'Jinhua' has a large nut, a high percent kernel, golden kernel color, and fancy flavor, whereas 'Shaoxing' has a small nut, high yield, and low alternate bearing tendency (Table 2) (Dong, 2003; Zang et al., 2011; Zhang and Duan, 2011; Zhang et al., 2001a).

Anhui, Jiangxi, and Yunnan Provinces also selected several seedling varieties from their own region (Table 2). However, most of these varieties were only partially tested and were not widely accepted by growers (Zhang and Duan, 2011).

In addition to performing seedling selection, researchers conducted interspecific hybridization between selected clones of pecan and other Chinese Juglandaceae species. Ye and Wu (1965) suggested that a reciprocal cross between pecan and Chinese hickory (*Carya cathayensis*) could fertilize both, producing more vigorous seedlings with larger leaves and superior disease resistance, but pecan pollinated by English walnut (*Juglans regia*) or Chinese wingnut (*Pterocarya stenoptera*) failed to bear, probably due to incompatibility. Hong (2009) proved that when *C. cathayen-*