The breeding and the performance of ‘Liaoning 4’ walnut cultivar

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Walnut is an important cultivated tree with high economic value and wide distribution across China. The objective was to breed a new walnut cultivar with high yield and desirable nut and tree qualities that could meet the demands of the walnut industry in China. ‘Liaoning 4’ walnut cultivar is lateral bearing which originated from a controlled cross between the Persian walnut (J. regia) selections ‘Liaoning Chaoyang big and rough walnut’ and ‘11001’. During long term assessment and research, ‘Liaoning 4’ walnut performed well and it was released as a new cultivar in China on 15 Oct. 2018. It has a high yield and excellent nut traits and has thus been widely planted in North China.

Key Words: blight resistance, breeding, Juglans regia, lateral bearing, persian walnut.

Introduction

Walnuts are widely distributed in China where they have a long history of cultivation (Gao et al. 2010). Walnut germplasms have been collected and utilized in various countries, including China, allowing for the discovery of promising genotypes (Chen et al. 2014). Selected or crossbred cultivars have been used in established orchards since the 1980s in China (Zhao et al. 2010). China has 440,300 hectares in walnut cultivation area with an annual nut production of 1.6 million metric tons and is ranked first among the walnut-producing countries of the world (Yi 2017). The Liaoning Institute of Economic Forestry (LIEF) was one of the pioneers of walnut research in China and initiated its walnut breeding program in 1959. International walnut cultivars, including ‘Payne’, ‘Franquette’, ‘Sunland’, and ‘Chico’, were introduced into China during 1992–1995, but they were unable to survive the cold winter in Liaoning province. ‘Liaoning 4’ was released as a new Persian walnut (Juglans regia L.) cultivar in China on 15 Oct. 2018. This new cultivar was bred and evaluated at LIEF. It has a high yield and excellent nut traits and has thus been widely planted in North China.

Materials and Methods

‘Liaoning 4’ originated from a controlled cross between the Persian walnut selections ‘Liaoning Chaoyang big and rough walnut’ and ‘11001’ in 1971 (Liu et al. 1990). ‘Liaoning Chaoyang big and rough walnut’, an unreleased selection with a terminal bearing habit, was used as the female parent because of its cold hardiness, robust growth, and large nut size. The selection ‘11001’ has a lateral branching habit and was used as the male parent due to its smooth nut surface and thin nutshell. Seventy-three seeds were obtained in the fall of 1971 and 40 seedlings were obtained in 1972. Of these, 4 seedlings flowered and 2 of 4 produced fruit in 1973.

In 1974, ‘Liaoning 4’ was preliminarily selected as a desirable genotype based on its lateral bearing habit, moderate growth, walnut blight (Xanthomonas campestris pv. juglandis) resistance, attractive nut appearance, and thin nutshell. It was identified as ‘7109’. After six years of evaluation, ‘7109’ was assessed as the most promising walnut selection by the Department of Science & Technology of Liaoning Province in 1979. In 1986, ‘7109’ was evaluated in national regional experiments and was renamed ‘Liagong 4’ in 1990. In 1999, it was certified by the Liaoning Provincial Forest Tree Certification Committee (LPFTCC) as a cultivar with the registration number LC96044 and a three-year validation planting period. After the validation dates, the right of the cultivar is lapsed according to Chinese regulations, the evaluation was re-performed during 2015–2018. In Oct. 2018, it was approved by LPFTCC. The cultivar number was assigned as Liao S-SV-JR-003-2018.

We conducted field trials for ‘Liaoning 4’ at three locations in Liaoning Province (Table 1). One-year-old grafted trees of ‘Liaoning 4’ were arranged in a randomized
complete block design, with each location containing three blocks and a given number of trees for each block (Table 1).

We evaluated the nut traits of ‘Liaoning 4’ according to “The national standard of the People’s Republic of China: Guidelines for the conduct of tests for distinctness, uniformity and stability—Juglans (Juglans L.)” (Pei et al. 2011). We randomly selected 30 nuts for nut characteristic analysis and measured the total tree yield as well as tree growth characteristics.

Means were separated using Duncan’s multiple range test at $P \leq 0.05$.

### Results

The vigor of ‘Liaoning 4’ tree is moderate with upright or half-open growth and the branching ability is high (Fig. 1). The annual shoot is thin with slightly long internodes. The first female flower appears in the 2nd year, while the male flower occurs in the 3rd year after planting. The abundant fruiting period occurs in the 8th year after planting. This is a laterally fruitful cultivar made up of 90–100% lateral buds. The fruiting shoot produces 2–3 female flowers. The flowering is protandrous, with male and female flowers overlapping for 2–3 days. In the region of Dalian in Northeast China, leafing is in the middle of April, while leaf shedding occurs in early November (Fig. 2). The pollen shedding period is at the beginning of May, and the female flower blooming period is in mid-May (Fig. 2). The harvest date is usually in the middle of September. A comparison of the pollen shedding and female flower blooming dates for ‘Liaoning 4’ with ‘Liaoning 1’, ‘Liaoning 5’, and ‘Liaoning 7’ is shown in Fig. 2. All these cultivars were certified by LPFTCC in 1999.

The nut shape of ‘Liaoning 4’ is round and smooth with a light color (Fig. 3). The apex is round and slightly sharp, the bottom is round. The longitudinal, transverse, and lateral diameters are 3.4, 3.4, and 3.3 cm, respectively, on average. The suture is flat and tight in combination. The nutshell is 0.9 mm on average and the inner fold is vestigial, and thus the whole kernel is easy to remove out. The average weight is 11.4 g, with the kernel contributing 59.7% of the nut weight. The color of the kernel is classified as yellow-white. In 2017, the nutrient content of the ‘Liaoning 4’ kernel were measured and evaluated. The kernel contained 60.2%, 23.9%, and 61.0% oil, protein, and fat, respectively.

The growth characteristics were investigated in the year

![Fig. 1. ‘Liaoning 4’ walnut tree at the end of the 18th year of growth in Paotai town, Jinpu new district, Dalian city (4.9 m tall, 11.94 m² canopy area on average).](image)

![Fig. 2. The leafing dates, pollen-shedding period, pistillate bloom times, and harvest dates for the walnut cultivars ‘Liaoning 1’, ‘Liaoning 4’, ‘Liaoning 7’, and ‘Liaoning 5’. The straight lines indicate the male flower, the dashed lines indicate the female flower, and the stars are the peak bloom dates.](image)
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Fig. 3. Nuts of ‘Liaoning 4’ (nuttshell is 0.9 mm, the average weight is 11.4 g with the 59.7% kernel).

of 2018 (Table 2). For example, at the end of the 18th year of growth in Paotai town, the average trunk diameter, height, and canopy area values were 13.97 cm, 4.9 m, and 11.94 m², respectively (Table 2). The yield of ‘Liaoning 4’ and ‘Liaoning 1’ in the field trials in the three locations from 2015 to 2017 were superior to the other cultivars tested (Tables 3–5). In 2018, the yields of ‘Liaoning 4’ were suppressed due to excessive trimming.

Discussion

‘Liaoning 4’ has performed very well in walnut-producing areas in northern China, such as Shaaxi, Hebei, Shanxi, and Liaoning provinces. It requires fertile soil and standard management practices. The advantages of ‘Liaoning 4’ include its smooth nut surface, high kernel percentage, thin nutshell, high nut yield and low susceptibility to walnut blight. The disadvantages of ‘Liaoning 4’ include that it does not adapt to poor soil conditions and has strict cultivation requirements, for example, fertile and well-drained soil, and a well-designed drainage and irrigation system. We recommend 4 m × 6 m spacing for ‘Liaoning 4’ plantations with pollination by ‘Liaoning 5’.

‘Liaoning 4’ is a dwarf cultivar suitable for high-density plantations (Liu et al. 1990) that exhibits good cold tolerance during the leaf expansion period (Wang et al. 2019). Wang and Guo (2005) reported that ‘Liaoning 4’ has the lowest susceptibility to walnut blight compared to standard cultivars ‘Xiang ling’, ‘Liaoning 1’, ‘Zhonglin 5’, and ‘Zhonglin 1’. Therefore, ‘Liaoning 4’ will play an important role in expanding walnut production in north China.

Table 2. Growth profiles of ‘Liaoning 4’ in three locations in China recorded during the fall of 2018

| Location       | Tree age (years) | Avg tree trunk diameter (cm) | Avg tree ht (m) | Avg canopy area (m²) |
|----------------|------------------|------------------------------|-----------------|----------------------|
| Leijiadian town | 33               | 32.15                        | 7.9             | no measurement       |
| Gaotai town    | 19               | 13.78                        | 4.1             | no measurement       |
| Paotai town    | 18               | 13.97                        | 4.9             | 11.94                |

* Leijiadian town, Jianchang county, Huludao city; Gaotai town, Shuizhong county, Huludao city; Paotai town, Jinpu new district, Dalian city.

Table 3. In-shell nut yield of ‘Liaoning 4’ walnut in comparison with ‘Liaoning 1’, ‘Liaoning 5’, and ‘Liaoning 7’ from the 30th to 33th leaf after planting in Leijiadian town

| Cultivar | Yield (kg·ha⁻¹)² | 2015 | 2016 | 2017 | 2018 |
|----------|------------------|------|------|------|------|
| Liaoning 4 | 3550.8 ± 223.5 ab | 3722.4 ± 102.0 a | 3610.2 ± 194.0 a | 2778.6 ± 163.9 b |
| Liaoning 1 | 3669.6 ± 89.3 a   | 3537.6 ± 58.7 ab | 3616.8 ± 216.2 a | 3399.0 ± 109.5 a |
| Liaoning 5 | 2343.0 ± 125.0 c  | 2362.8 ± 126.3 c | 2772.0 ± 233.2 b | 2428.8 ± 125.5 b |
| Liaoning 7 | 3022.8 ± 227.2 b  | 3273.6 ± 182.6 b | 3003.0 ± 121.1 ab | 3227.4 ± 123.5 a |

² Based on 660 trees/ha. The data shown are the mean value ± standard error (SE).

Table 4. In-shell nut yield of ‘Liaoning 4’ walnut in comparison with ‘Liaoning 1’, ‘Liaoning 5’, and ‘Liaoning 7’ from the 16th to 19th leaf after planting in Gaotai town

| Cultivar | Yield (kg·ha⁻¹)² | 2015 | 2016 | 2017 | 2018 |
|----------|------------------|------|------|------|------|
| Liaoning 4 | 3770.3 ± 68.4 a  | 3456.8 ± 49.2 a | 3597.0 ± 62.4 b | 4108.5 ± 199.5 a |
| Liaoning 1 | 3646.5 ± 54.0 ab | 3531.0 ± 117.5 a | 3918.8 ± 50.5 a | 3778.5 ± 59.8 ab |
| Liaoning 5 | 1311.8 ± 54.3 c  | 1320.0 ± 53.2 b | 1278.8 ± 57.3 c | 1287.0 ± 53.1 c |
| Liaoning 7 | 3382.5 ± 175.2 b | 3349.5 ± 104.6 a | 3869.3 ± 28.7 a | 3522.8 ± 207.4 b |

² Based on 825 trees/ha. The data shown are the mean value ± SE.

Mean separation in columns by Duncan’s multiple range test at P≤0.05.
Author Contribution Statement

BZ designed the experiment, evaluated trait and wrote the manuscript; FL investigated data and conducted data aggregation; YG carried out statistic analysis; XZ, XW, YW investigated data.

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