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Huaiqi: A New Cultivar of Chinese Chestnut with Staminate Catkins Abortion

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Chestnut is an important tree species valued for its ecological and economic importance. The chestnut is well known for its nutritional properties—namely, its high starch and low fat contents. Because of its health-promoting nutritional qualities, the chestnut is recommended at various levels (Santos et al. 2022). With a long history of cultivation, Chinese chestnut is geographically widespread and is commercially grown for nut production in 26 Chinese provinces (Zhang et al. 2005). The species thrives in infertile soils and is widely cultivated in mountainous areas of China. In 2023, the annual nut yield of Chinese chestnut reached 1,521,017 tons, accounting for 72.58% of the total world production of chestnut (Food and Agriculture Organization of the United Nations 2023). Despite this substantial production, the average yield remains low at only 0.98 tons/ha. The low productivity of the land is a major challenge for the development of the industry. This limitation is mainly due to the lack of high-yielding cultivars with high female ratio and insufficient techniques to regulate the ratio.

Chinese chestnut is monoecious, producing both staminate and unisexual catkins. The unisexual catkins contain functional male and female flowers. The ratio of female to male flowers on each shoot is ~1:2000 to 3000 (Liu et al. 2021). Overproduction of male flowers takes up a large portion of the nutrients in the tree, limiting the growth of plant. Therefore, breeding cultivars with a higher proportion of female flowers is critical for improving nut yields in Chinese chestnut. Some Chinese chestnut cultivars, such as Duanhuayunfeng (Feng et al. 2011) and Heishanzai7 (Huang et al. 2009), are characterized by a higher proportion of female flowers. These cultivars have short staminate catkins with aborted distal flowers at the staminate flower differentiation stage. In this study, we introduce a new cultivar, Huaiqi, which has been identified as having aborted staminate catkins. This cultivar has a ratio of female flowers to male catkins of 1.48:1. Compared with 'Duanhuayunfeng' and 'Heishanzai7', 'Huaiqi' exhibits complete male catkin abortion, which represents a novel type of staminate abortion. The cultivar also has higher yield potential and improved drought resistance, making it an excellent breeding cultivar for chestnut industry.

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Origin

'Huaiqi' originated from a seedling selection with an unknown pedigree. In 2010, open-pollinated seeds of Chinese chestnut from a chestnut orchard were planted in the orchard of Liulimiao Town, Huairou District, Beijing City, China. In 2015, an exceptional individual exhibiting male catkins abortion was identified among the progeny and was designated as 'WH1'. The male flower clusters of 'WH1' ceased development, withered from the top before blooming, and eventually fell off at the base (Fig. 1A). Both bisexual catkins and female flowers on the same fruiting branch developed normally, and fruit development was unaffected, yielding 2.5 kg of nut in 2015.

From 2016 to 2019, a regional experiment was conducted in three orchards located in Liulimiao, Bohai, and Qiaozhi Towns, Huairou District, Beijing. During this period, the unique plant was propagated asexually through grafting. The specific trait of male catkins abortion was stably inherited. According to "The National Standard of the People's Republic of China: Guidelines for the conduct of tests for distinctness, uniformity and stability—Chestnut (*Castanea mollissima* Bl.)" (LY/T 1851-2009; National Forestry and Grassland Administration of China 2009), the characteristics of 'WH1' were continuously measured and analyzed for 3 years (2019–21). No significant difference was observed in the number, length, and abortive biological traits of male catkins. In 2022, 'Huaiqi' was officially recognized as a new cultivar by the National Forestry and Grassland Administration of China (Accession No. 20220456).

Description

'Huaiqi' trees present strong vigor, a spreading growth habit, and a naturally open shape. The fruiting branches are classified as the long-shoot type, with gray-brown bark. They have abundant trichomes, large lenticels, and moderate lenticel density. Dormant buds

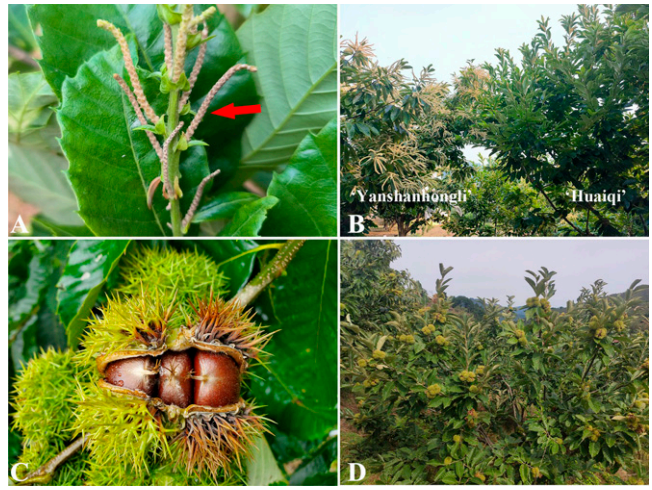

Fig. 1. A view of 'Huaiqi' tree, staminate catkins, and nut taken at the chestnut orchard base in 2022. (**A**) Abortion of staminate catkins (red arrow); (**B**) tree during the male flowering of 'Huaiqi' and 'Yanshanhongli'; (**C**) bur; (**D**) tree during the fruit maturity.

Table 1. Characteristics of Chinese chestnut cultivars Huaiqi and Yanshanhongli.

Characteristics	'Huaiqi'	'Yanshanhongli'
Abortion time of staminate catkins	11 May	—
Time of male flowering	—	5 Jun
Time of female flowering	6 Jun	1 Jun
Time of maturity for consumption	20 Sep	15 Sep
Length of final developmental stage of staminate catkins (cm)	4.24 ± 0.69	24.56 ± 1.32**
No. of staminate catkins per bearing branch	8.32 ± 0.26	10.25 ± 1.23**
No. of staminate catkins per male flower branch	7.56 ± 0.23	9.54 ± 0.87**
No. of female flowers per the bearing shoots	2.89 ± 0.15**	2.26 ± 0.21
Single nut weight (g)	9.15 ± 0.21*	8.30 ± 0.37
Total bur weight (g)	51.40 ± 4.35*	43.26 ± 4.57
Nuts number per bur	2.62 ± 0.26*	2.18 ± 0.38
Kernel yield (%)	46.28 ± 3.23*	40.29 ± 3.75
No. of fruiting branch per bearing mother branch	2.51 ± 0.26**	1.93 ± 0.34
No. of burs per bearing branch	2.85 ± 0.53**	2.26 ± 0.25
Yield (kg/tree)	6.62 ± 0.16**	5.71 ± 0.16
Moisture (%)	56.79 ± 1.21	54.89 ± 0.71
Soluble sugar (%, DW)	13.83 ± 0.32	12.63 ± 4.82
Amylose (%, DW)	11.93 ± 1.05	14.70 ± 1.24*
Amylopectin (%, DW)	46.09 ± 1.82**	39.42 ± 1.87
Total starch (%, DW)	58.02 ± 0.77*	54.13 ± 2.32
Protein (%, DW)	5.22 ± 0.32	4.94 ± 0.41
Fat (%, DW)	0.71 ± 0.23	0.70 ± 0.24

Values are presented as mean ± *SD* and were analyzed using a *t* test, based on 10 plants per cultivar (n = 30). DW = dry weight.
*, **$P < 0.05$ and < 0.01, respectively.

are rounded and plump, and yellow-brown, breaking dormancy relatively early. The leaves are dark green and broadly elliptical in shape, with a narrow acuminate apex and an obtuse base. The leaf margins are acute, straight, and shallowly serrated. The leaves are densely covered with trichomes. The average leaf length is 16.23 cm, the width is 7.28 cm, the petiole length is 1.48 cm, the petiole thickness is 0.22 cm, and the petiole color is yellow.

The staminate catkins of Chinese chestnut 'Huaiqi' undergo abortion, starting to turn yellow approximately 11 May and completely falling off by approximately 20 May in a chestnut orchard of Bohai Town, Huairou District, Beijing. Compared with the control Chinese chestnut 'Yanshanhongli', 'Huaiqi' has only unisexual catkins and female flowers present on the bearing branch during the full bloom stage (Fig. 1B). The average length of the staminate catkins of 'Huaiqi' at the time of abortion is 4.24 cm, which is significantly shorter than the average length of normal staminate catkins of 'Yanshanhongli'. The number of staminate catkins per bearing branch and male flower branch of 'Huaiqi' is significantly lower than of that of 'Yanshanhongli'. However, the number of female flowers per the bearing shoots of 'Huaiqi' is 2.89, which is significantly higher than that of 'Yanshanhongli' (Table 1). In the Beijing region, leafing occurs in late April and leaf shedding occurs in early November. The female flowering period is from early to mid-June, and the fruit is usually harvested in mid-September.

The bur is elliptical in shape, with an average total weight of 51.40 g and an average of 2.62 nuts per bur. The dimensions of the bur are 7.3 × 6.19 × 5.71 cm, with a husk thickness of ∼0.36 cm. Dehiscence occurs initially through longitudinal splitting. The prickles are sparsely distributed, long, hard, and widely angled, with a yellow coloration. The nuts are elliptical, with an average weight of 9.15 g per nut and dimensions of 3.04 × 1.88 × 2.56 cm. The nut color is dark brown with a bright glossiness. The apex and shoulders of the nut are rounded. The hilum is small, with a straight-bordered outline. The kernel has yellow flesh, and the seedcoat adheres weakly to the kernel. The kernel yield rate is as high as 46.28%, which is significantly higher than that of 'Yanshanhongli'. The number of burs per bearing branch and fruiting branch per bearing mother branch of 'Huaiqi' are 2.85 and 2.51, respectively, both significantly higher than those of the control cultivar Yanshanhongli. The average yield of 5-year-old grafted 'Huaiqi' Chinese chestnut trees is 6.62 kg, significantly higher than that of the main cultivar Yanshanhongli. The main quality analysis revealed that the nut of Chinese chestnut 'Huaiqi' have the following composition: moisture content of 56.79%, soluble sugar content of 13.83%, total starch content of 58.02%, amylose content of 11.93%, amylopectin content of 46.09%, protein content of 5.22%, and fat content of 50.71%.

Cultivation

Chinese chestnut 'Huaiqi' is well suited for cultivation in the northern chestnut-growing regions of China. Its propagation is primarily achieved through grafting. For effective pollination, 'Yanshanhongli' and 'Jingshuhong' are recommended as compatible pollinizers. The preferred tree forms are the natural open-center shape and the sparse-layer shape, pruning should focus on timely crown control by shortening branches to ensure adequate ventilation and light penetration, thereby facilitating fruit production. Additionally, fertilization and irrigation should be appropriately increased, with base fertilizer applied after fruit harvest. During the growing season, careful pest control measures should be implemented, particularly against pests such as *Tetranychidae* and *Lachnus tropicalis*.

Availability

A limited quantity of 'Huaiqi' scions is available for trial, research, and commercial propagation. For research purposes, requests for cuttings can be directed to Yang Liu (bualiuyang@163.com).

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