Biological Characteristics and Vegetative Propagation of a New *Camellia* Cultivar Maozi

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Abstract. *Camellia* flowers are highly prized for their beauty worldwide and are strongly symbolic in many cultures. A new interspecific hybrid cultivar, *Camellia* ‘Maozi’, generated by crossing *Camellia pubipetala* with *C. japonica* ‘Dahong Mudan’, exhibits strong hybrid vigor and has small flowers with a rare light tone of purple. In southwest China with a subtropical monsoon climate, young *Camellia* ‘Maozi’ trees flush shoots three times in spring, summer, and autumn, with an average annual growth of 12.9 cm. Adult trees flush once a year. Floral bud formation occurs in late April and early May. *Camellia* ‘Maozi’ flowers are sterile with no fruits and seeds produced. While an individual flower wilts 4–8 days after opening, the blossom can last 1–3 months. Frost damage can be found in young leaves when temperature drops to 4–7 °C. Under direct sunlight with temperatures of 37–39 °C lasting for more than 2 days, young leaves can turn yellow on their edges. Its primary diseases include sooty mold, shoot tip blight, and peony leaf tip blight. Its primary insect pests are tea green leafhopper (*Jacobiasca formosana*) and tea aphid (*Toxoptera aurantii*). Rooting of stem cuttings occurs directly from stems, mostly without callus development. Two hours of treatment with 500 mg·L⁻¹ indole-3-butyric acid and rooting in a mix of latosolic red soil and vermiculite (2:1 v/v) resulted in high rooting rate and quality of aboveground growth. Grafting can be carried out from May to September, while survival rate and new shoot length are highest in July. The most compatible rootstock is *C. oleifera*, followed by *C. polyodonta*. The results of this study are of value for understanding the reproductive biology of *Camellia* ‘Maozi’ and further disseminating it as a new cultivar for camellia collection.

Camellia flowers are highly prized for their beauty and are strongly symbolic in many cultures, particularly in Chinese culture. China is the origin of many cultivated *Camellia* species that now are grown throughout the world, including *C. japonica* (common camellia), *C. chrysantha*, and *C. yuhsienensis*. Seventy six of the 97 species in the genus are endemic to the country (Min and Bartholomew, 2007; Ming, 2000). The ornamental trees of the genus and their flowers are commonly referred to as *cha-hua* in Chinese (Ming, 2000; Zhu et al., 2007). According to Cothran (2004), Chinese camellias made their way to the Western world in the 18th century after being cultivated

and treasured in the Orient for thousands of years. Camellias are evergreen shrubs or trees with broad, shiny, dark green leaves, and have primarily a subtropical and warm-temperate distribution. Their flowers bloom from winter to spring in a remarkable range of colors, forms, fragrance, and sizes. Besides being cherished and collected in botanical gardens and home greenhouses, camellias have long been planted as a hedge or shelter belt, or for firewood. Currently, there are more than 22,000 varieties or cultivars cataloged in the International Camellia Society (<http://www.camellia-international.org/>). In the United States, there are more than 2300 named cultivars registered with the American Camellia Society (<https://www.americancamellias.com/>).

Due to its great economic and cultural value as a living symbol of elegance and aristocracy, novel cultivars with variations in flower colors, shapes and fragrance, bloom sizes and timing, growth habits, and disease resistance are constantly sought after by amateur and commercial camellia growers throughout the world. While most *Camellia* species flower in winter or spring, *C. azalea*, a newly discovered species, blooms during

midsummer and has been introduced into the breeding systems of camellia for generating new and more summer-flowering varieties (Fan et al., 2015). As the most widely grown ornamental species of the genus, *C. japonica* has a long history of being used in breeding for different flower shapes and colors (Shibata et al., 2004). However, *C. japonica* is poorly fragrant. Therefore, scented camellias, such as *C. lutchuensis*, have been crossed with *C. japonica* to produce various fragrant camellia plants (Oyama-Okubo et al., 2009). Camellia ‘Julius Nuccio’ (Nuccio et al., 2015), ‘Green 99–016’ (Green, 2014), and ‘Pink Cascade’ (Fei et al., 2013) are a few examples of new and distinct cultivars that were recently patented.

We obtained a novel interspecific hybrid cultivar, *Camellia* ‘Maozi’, by crossing *C. japonica* ‘Dahong Mudan’ (Fig. 1A) with *C. pubipetala* (Fig. 1B) (Wei et al., 2013). This new cultivar blooms during January–March, coinciding with three major Chinese holidays, New Year’s Day, Lunar New Year, and Lantern Festival. This timing is an important considering that *cha-hua* is not only an ornamental flower but also has been endowed with rich spiritual connotation in Chinese culture. *Camellia* ‘Maozi’ flowers are small in size and have a rare light tone of purple (Fig. 1C–E). In addition, *Camellia* ‘Maozi’ shows strong hybrid vigor. It grows faster than its parents (Supplemental Table 1). It has a strong root system and is resistant to partial shade. The size of its dark green foliage is similar to the male parent, smaller than the female parent. As a new addition to the camellia collection, *Camellia* ‘Maozi’ has the potential to be developed as both a landscaping and a high-end indoor potted plant. However, as an interspecific hybrid, *Camellia* ‘Maozi’ is sterile. As a result, vegetative propagation is a major approach for the cultivation of this new cultivar. In this study, we investigated floral biology, flowering phenology, and grafting and cutting propagation techniques. The results of this study are of value for understanding the reproductive biology of *Camellia* ‘Maozi’ and its further dissemination as a new cultivar for camellia collection.

Materials and Methods

Plant materials and study site. The studies were conducted in the Camellia Nursery of Guangxi Academy of Forestry (lat. 22°56’ N, long. 108°21’ E, 95 m above sea level), China. With a subtropical monsoon climate, the area has distinct dry and wet seasons. The average annual temperature is 21.8 °C, while the average in January is 11.8 °C and 27.6 °C in July. The rainy season occurs from May to September, with an annual rainfall of over 1300 mm. Rootstocks used in the experiments included *C. osmantha*, *C. japonica* ‘Dahong Mudan’, *C. polyodonta*, *C. oleifera*, *C. japonica* ‘Hei Mudan’, and *Camellia* ‘Maozi’. Only healthy plants that were free of diseases and had vigorous growth and straight stems with at least 0.3 cm in diameter

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at the base were chosen. All rootstock cuttings and scions were from the camellia germplasm bank collected and maintained by Guangxi Academy of Forestry, China.

Observations of biological characteristics. In 2013, twenty 12-year-old adult *Camellia* ‘Maozi’ trees and thirty 1-year-old cuttings were selected and observed for phenological stages of plant growth and characteristics for three consecutive years. For an individual adult tree, observation was conducted on five branches located in the south, north, east, and west side of the tree.

Cutting propagation. Healthy and partially lignified branches from adult *Camellia* ‘Maozi’ trees were cut into 8- to 10-cm-long sections containing one to two buds and one to two leaves. Cutting propagation was tested in eight different soil matrices and conducted on 1 June 2015. The soil matrices consisted of latosolic red soil, coconut husk, perlite vermiculite, or peat in various combinations: H₁ (latosolic red soil: coconut husk = 2:1 (v/v)), H₂ (latosolic red soil: perlite = 2:1), H₃ (latosolic red soil: vermiculite = 2:1), H₄ (latosolic red soil: vermiculite = 1:1), H₅ (latosolic red soil: peat = 2:1), H₆ (vermiculite: perlite = 1:1), H₇ (vermiculite: coconut husk = 1:1, control (CK₁) (100% latosolic red soil) (Table 1). To measure pH, 10 g of each soil substrate were mixed in 50 mL carbon dioxide-free distilled water separately in a shaker for 30 min. pH values were measured with a Mettler Toledo FE20 FiveEasy Benchtop pH Meter

(Greisensee, Switzerland) after filterlization. The base (3–4 cm) of each cutting was soaked in 500 mg·L⁻¹ indole-3-butyric acid (IBA) for 1.5 h before being buried in soil media.

To study the effects of different plant growth regulators on cutting propagation, the base of *Camellia* ‘Maozi’ cuttings was treated in eight experimental designs: N₁-2 h in 500 mg·L⁻¹ 1-naphthaleneacetic acid (NAA), N₂-0.5 h in 2000 mg·L⁻¹ NAA, M₁-2 h in 500 mg·L⁻¹ IBA, M₂-1 h in 1000 mg·L⁻¹ IBA, M₃-quickly dipped in a mix of 2000 mg·L⁻¹ IBA and talc, L₁-2 h in 500 mg·L⁻¹ indole-3-acetic acid (IAA), L₂-0.5 h in 2000 mg·L⁻¹ IAA, and control (CK₂)-2 h in tap water (Table 2). After the treatments, the cuttings were inserted into latosolic red soil. This experiment was conducted in June 2015.

Grafting propagation. To identify the optimal time of the year for conducting grafting of *Camellia* ‘Maozi’, five dates were tested: May 11, June 1, July 3, Aug. 6 and 10 Sept. 2015. *C. osmantha* were used as rootstock. Five rootstocks (*C. japonica* ‘Dahong Mudan’, *C. polyodonta*, *C. oleifera*, *C. japonica* ‘Hei Mudan’ and *Camellia* ‘Maozi’) were compared for their impacts on grafting survival rate and performance of scions. This study was conducted in May 2015.

Propagation conditions. Both cutting and grafting propagations were conducted under a shade canopy that was ≈2.25 m in height and blocked 70% to 80% sunlight. Initially, the plants were covered with plastic to ensure

high humidity (80% to 90%) until new shoots flushed. Fungicide carbendazim or zineb (0.3% to 0.5%) was sprayed on the plants every 10–15 d for disease control.

Experimental design and data processing. Complete random block design was used in all experiments, with three replicates for each treatment. There were 100 cuttings for each replicate in cutting propagation and 60 plants for each replicate in grafting propagation. Rooting and budbreak were recorded 100 d after cutting propagation. Fresh roots were weighed after being rinsed with tap water and blot dried on paper towels. The diameter of new shoots was measured at the base 5 months after grafting, and the survival rate, budbreak, diameter of new shoots, and number of new leaves were recorded. Data were processed and analyzed by Excel and SPSS 17.0.

Results

Phenology. *Camellia* ‘Maozi’ started to produce new shoots in early December and the flushing period lasted into January. Leafing and shooting occurred simultaneously. Young trees produced new shoots three times in a year, in spring, summer, and autumn, with each shooting lasting 25–30 d. The adult trees (12 years old) flushed only once yearly and shooting lasted for 15–20 d. Floral buds formed in late April and early May. Among the 20 adult trees surveyed, flowering mostly

Fig. 1. Illustrations of *Camellia japonica* ‘Dahong Mudan’, *C. pubipetala*, and *Camellia* ‘Maozi’. Flower of (A) male parent *C. japonica* ‘Dahong Mudan’, (B) flower of female parent, *Camellia pubipetala*, (C–E) flowers of *Camellia* ‘Maozi’, (F) *Camellia* ‘Maozi’ cuttings, (G) a new *Camellia* ‘Maozi’ shoot, (H) a heavily pruned *Camellia* ‘Maozi’ plant, and (I, 2-matrix H₅ latosolic red soil: peat, 3-control latosolic red soil only) rooting of cuttings. The scale bars in A–E represent 2 cm, while 5 cm in F–I.

Table 1. Effects of different soil matrices on rooting characters and growth.^z

Name of soil matrices	Composition of soil matrices	pH	Sprouting rate (%)	New shoot length (cm)	Rooting rate (%)	Root number	The longest root length (cm)	Root fresh wt (g)
H ₁	Latosolic red soil: coconut husk = 2:1	5.49	16.67 c	1.55 c	80.17 b	11.30 b	5.38 b	0.15 b
H ₂	Latosolic red soil: perlite = 2:1	5.82	58.31 a	3.60 b	100.00 a	24.70 a	7.61 ab	0.34 a
H ₃	Latosolic red soil: vermiculite = 2:1	5.49	68.35 a	5.64 a	100.00 a	27.80 a	8.53 a	0.46 a
H ₄	Latosolic red soil: vermiculite = 1:1	5.35	56.33 a	3.73 b	91.57 ab	19.60 ab	8.12 ab	0.32 a
H ₅	Latosolic red soil: peat = 2:1	5.02	62.50 a	4.75 ab	100.00 a	19.30 ab	7.06 ab	0.37 a
H ₆	Vermiculite: perlite = 1:1	5.40	41.67 b	3.94 ab	91.67 ab	19.70 ab	8.46 a	0.37 a
H ₇	Vermiculite: coconut husk = 1:1	4.95	12.50 c	1.44 c	60.83 c	9.60 b	5.20 b	0.16 b
CK ₁	Latosolic red soil (100%)	6.07	17.09 c	1.87 c	73.36 bc	11.36 b	6.09 ab	0.19 b

^zDifferent letters in the table indicate significant difference ($P < 0.05$).

Table 2. Effects of different growth regulators on rooting characters and growth.^a

Labeling of treatments	Concn of growth regulator and exposure time	Sprouting rate (%)	New shoot length (cm)	Leaf number	Rooting rate (%)	Root number	The longest root length (cm)	Root fresh wt (g)
N ₁	2 h in 500 mg·L ⁻¹ NAA	47.83 b	3.98 a	2.80 ab	80.43 b	36.20 b	7.40 a	0.47 ab
N ₂	0.5 h in 2,000 mg·L ⁻¹ NAA	38.96 b	3.16 ab	2.40 ab	89.13 ab	46.40 a	6.01 a	0.53 a
M ₁	2 h in 500 mg·L ⁻¹ IBA	60.87 a	4.05 a	3.60 a	100.00 a	35.80 b	7.57 a	0.45 ab
M ₂	1 h in 1,000 mg·L ⁻¹ IBA	52.17 ab	3.87 a	3.30 a	99.98 a	18.90 cd	7.27 a	0.30 bcd
M ₃	Quickly dipped in a mix of 2,000 mg·L ⁻¹ IBA and talc	15.22 c	1.87 bc	1.80 bc	67.39 c	7.00 e	6.25 a	0.14 d
L ₁	2 h in 500 mg·L ⁻¹ IAA	45.65 b	3.83 a	3.40 a	97.83 a	12.90 de	5.93 a	0.21 d
L ₂	0.5 h in 2,000 mg·L ⁻¹ IAA	4.35 d	1.31 c	1.20 c	58.70 c	12.60 de	6.24 a	0.26 cd
CK ₂	2 h in tap water	17.39 c	1.97 bc	2.40 ab	78.26 bc	11.60 de	6.11 a	0.18 d

^aDifferent letters in the table indicate significant difference ($P < 0.05$).

occurred in winter and spring (January–March), lasting 3 months.

Growth characteristics. *Camellia* ‘Maozi’ can be defined as evergreen shrubs or small trees, with a mature height of 3–5 m. Cuttings grew fast in their first 2 years, with shoots flushing three times in a year (Fig. 1F and G). New shoots mainly appeared in March, May, and August, with mean increments of 3.9, 4.1, and 4.9 cm, respectively. Young cuttings gained an average annual growth of 15.9 cm in height. Adult trees only flushed once yearly. Elongation of new shoots in adult trees ended in March, while secondary growth of stem mainly occurred in summer and autumn. *Camellia* ‘Maozi’ exhibited strong capability of flushing and branching. As a result, it could be heavily pruned. Adult trees 6 or 7 years old were found to be able to spout out 5–10 branches within a year when being pruned at the main stem (Fig. 1H).

Flowering and fruiting habit. The flowers of *Camellia* ‘Maozi’ were pale violet red in color (Fig. 1C–E) (Royal Horticultural Society color code, RHS# CD69C9), located in the axil of leaves on 1- to 3-year-old branches. The flowers had six to eight petals, three styles, and numerous golden stamens. The life span of a single flower was 4–8 d. *Camellia* ‘Maozi’ cuttings started to flower in 4–5 years, 1–2 years earlier than grafted plants. Some of the trees in the Nursery were more than 10 years old. None of them have produced seeds. Therefore, *Camellia* ‘Maozi’ seems sterile.

Adaptability. *Camellia* ‘Maozi’ grows well in a warm and damp climate. Shading was needed for 1- to 2-year-old cuttings and grafted plants. Young plants also required an average annual temperature of at least 20 °C, with the coldest temperature not below 2 °C. Although young plants could survive when the lowest mean temperature reached 4–7 °C, young leaves suffered freeze injury. When the temperature reached 37–39 °C for three consecutive days, young plants could get sunburns under direct sunlight, with young leaves turning yellow on edges. *Camellia* ‘Maozi’ grew well in acidic or subacid red and yellow-red soil. A decade’s observations found that the primary diseases included sooty mold, shoot tip blight, and peony leaf tip blight. *Meliola camelliae*, *Capnodium* sp., and *Phyllosticta* sp. were the common causal agents. The diseases could be controlled by fungicides such as carbendazim (500–600 ppm) and chlorothalonil (750–900 ppm). The

primary insect pests were tea green leafhoppers (*J. formosana*) and tea aphids (*T. aurantii*). It was found that 80% dichlorvos (1:1500 dilution) was effective in killing the pests.

Cutting propagation: the effects of soil matrices on rooting and growth of *Camellia* ‘Maozi’ cuttings. The soil matrices were acidic, with pH values ranging from 4.95 to 6.07 (Table 1), as recommended by both American Camellia Society (<https://www.americancamellias.com/care-culture-resources/general-culture-requirements/planting-camellias>) and Royal Horticultural Society (<https://www.rhs.org.uk/advice/profile?pid=327>) for camellia cultivation. All cuttings grown in soil matrices of H₂ (latosolic red soil: perlite = 2:1), H₃ (latosolic red soil: vermiculite = 2:1), and H₅ (latosolic red soil: peat = 2:1) generated roots (100% rooting rate). Rooting rate of cuttings grown in H₁ (latosolic red soil: coconut husk = 2:1), H₄ (latosolic red soil: vermiculite = 1:1), and H₆ (vermiculite: perlite = 1:1) was 80.17%, 91.57%, and 91.67%, respectively. H₇ (vermiculite: coconut husk = 1:1) resulted in the lowest rooting rate (60.83%), not significantly different from the control (CK₁), which was latosolic red soil and had a rooting rate of 73.36%. Among the soil matrices tested, cuttings in the soil H₃ (latosolic red soil: vermiculite = 2:1) exhibited the best growth, having a significantly higher flushing rate (68.35%), new shoot length (5.64 cm), rooting rate (100%), root number (27.80), length of the longest root (8.53 cm), and root fresh weight (0.46 g) when compared with the control. The growth of cuttings in the soil matrices H₁ (latosolic red soil: coconut husk = 2:1) and H₇ (vermiculite: coconut husk = 1:1) was the poorest, with no significant differences with the control. Mold was found at the bases of cuttings rooted in the H₁ (latosolic red soil: coconut husk = 2:1) and H₇ (vermiculite: coconut husk = 1:1) soil matrices, resulting in low survival rates. Figure 1I shows the roots generated in matrices H₂ (latosolic red soil: peat) and control (latosolic red soil).

Cutting propagation: the effects of plant growth regulators on rooting and growth of *Camellia* ‘Maozi’ cuttings. The treatments M₁ (2 h in 500 mg·L⁻¹ IBA) and M₂ (1 h in 1000 mg·L⁻¹ IBA) resulted in the highest new shoot rates, followed by N₁ (2 h in 500 mg·L⁻¹ NAA), N₂ (0.5 h in 2000 mg·L⁻¹ NAA), and L₁ (2 h in 500 mg·L⁻¹ IAA) (Table 2). Cuttings from the M₁ (2 h in 500

mg·L⁻¹ IBA), M₂ (1 h in 1000 mg·L⁻¹ IBA), N₁ (2 h in 500 mg·L⁻¹ NAA), N₂ (0.5 h in 2000 mg·L⁻¹ NAA), and L₁ (2 h in 500 mg·L⁻¹ IAA) treatments had the longest new shoot length (an average of 3.78 ± 0.32 cm) and the largest number of new leaves (an average of 3.1 ± 0.44). Rooting rate in the M₁ (2 h in 500 mg·L⁻¹ IBA), M₂ (1 h in 1000 mg·L⁻¹ IBA), N₂ (0.5 h in 2000 mg·L⁻¹ NAA), and L₁ (2 h in 500 mg·L⁻¹ IAA) was the highest, while root number in N₂ (0.5 h in 2000 mg·L⁻¹ NAA) was largest. None of the hormone treatments had a significant effect on the length of the longest root of each rooted cuttings. Fresh root weight was the highest in the cuttings treated with N₂ (0.5 h in 2000 mg·L⁻¹ NAA), N₁ (2 h in 500 mg·L⁻¹ NAA), and M₁ (2 h in 500 mg·L⁻¹ IBA) (an average of 0.48 ± 0.04 g). It was found that lower concentrations of auxin were beneficial for rooting, shoot elongation, and leaf development. Overall, N₂ (0.5 h in 2000 mg·L⁻¹ NAA) and M₁ (2 h in 500 mg·L⁻¹ IBA) resulted in the best rooting and growth of the cuttings. Cuttings treated with M₃ (quickly dipped in a mix of 2000 mg·L⁻¹ IBA and talc) and L₂ (0.5 h in 2000 mg·L⁻¹ IAA) performed similar to or poorer than the control, which was mock treated with tap water.

Examination of 100 random cuttings per treatment found 100% rooting directly from the bark for NAA and IAA treatments, and 95% for IBA treatments, while calli were observed on some of the cuttings. Thus, rooting of cuttings derived primarily from the root primordium in the bark, not from calli. Depending on the types of treatments, the number of roots per plantlet ranged between 7 and 62, with an average of fifteen 120 d after cutting propagation, while root length ranged from 2 to 12 cm.

Grafting propagation: effect of grafting time on the survival and growth of scions. When *C. osmantha* was used as rootstock and grafting was performed between May and September, at least 90% of success rate was achieved 3 months after grafting, with July 3 being the highest (100%) followed by June 1 (97%) (Table 3). Grafting in June and July had the highest flushing rates, 95% and 94%, respectively, as well as new shoot length, 13.1 cm for July and 12.3 cm in June. However, no significant differences were found among the grafting times at the P value of 0.05.

Grafting propagation: effect of rootstocks on the survival and growth of scions. Among the five rootstocks being tested, survival rate with *C. oleifera* reached 100%. *Camellia* ‘Maozi’ scions also performed the best on *C. oleifera* considering budbreak rate, new shoot length, and number of new leaves (Table 4). Survival rate on *C. polyodonta*, *C. japonica* ‘Hei Mudan’, and *Camellia* ‘Maozi’ was 88%, 89%, and 54%, respectively, 5 months after grafting. While *C. polyodonta* resulted in budbreak rate, new shoot length, and number of new leaves comparable to those of *C. oleifera*, *Camellia* ‘Maozi’ scions grafted on *C. japonica* ‘Hei Mudan’ and *Camellia* ‘Maozi’ did not perform as well. None of the *Camellia* ‘Maozi’ scions grafted on *C. japonica* ‘Dahong Mudan’ survived, suggesting these two genotypes are incompatible. Our results indicate that rootstock genotype play an important role in the success of grafting and the growth performance of scions.

Discussion and Conclusion

Camellia is a woody perennial flower, and thus breeding of new cultivars can take a long time. Although many breeding strategies can be used to shorten the cycle in many species (van Nocker and Gardiner, 2014), classical breeding remains the main strategy in camellias. As an interspecific cultivar obtained by crossing *C. japonica* ‘Dahong Mudan’ with *C. pubipetala* (Wei et al., 2013), *Camellia* ‘Maozi’ has a strong root system, shows strong hybrid vigor (Supplemental Table 1), and has strong capability to sprout after pruning. Cuttings elongate three times yearly in the first 2 years, with an average of increment of 15.9 cm, whereas adult trees flush once a year. Its primary diseases include sooty mold, shoot tip blight, and leaf tip blight. Tea green leafhoppers (*J. formosana*)

and tea aphids (*T. aurantii*) are the primary insect pests observed. The purple flower color of *Camellia* ‘Maozi’ is unique, distinctively different from its parents, which have red (RHS# FF3030) and yellow (RHS# FFFF00) colors, respectively. Floral buds start to form in late April and early May. While an individual flower wilts 4–8 d after opening, the blossom can last 3 months, occurring during January and March. In contrast, the female parent blossoms between November and April, while the male parent blossoms during February and March (Liang and Huang, 1989). Its unique purple color in flowers, blossom timing coinciding with several major Chinese holidays, and vigorous hybrid growth make *Camellia* ‘Maozi’ an excellent addition to the camellia collection and profitable for commercial marketing.

Like its male parent, *Camellia* ‘Maozi’ is sterile with no fruits and seeds produced. However, propagation can be achieved vegetatively. Because it is asexual, vegetative propagation can help maintain desirable traits and ensure consistency of a cultivar of plant. In addition, vegetative propagation can save time and money for commercial plant production because plants bypassing the immature seedling phase reach the mature phase sooner. In our study, *Camellia* ‘Maozi’ cuttings and grafted plants flowered 2–3 and 1–2 years, respectively, earlier than their seedling parent.

Camellia ‘Maozi’ is easy to root. Without hormone treatments, a rooting rate of 78% was achieved. However, without hormone treatments, flushing rate (17%), new shoot length (1.97 cm), and root fresh weight (0.18 g) were significantly low. Our study indicated that the types of plant growth regulators and soil matrices played important roles in rooting and growth performance of *Camellia* ‘Maozi’ cuttings, similar to the findings in other cultivars in the genus (Chen and Li,

2013; Gao, 2012; Larcher and Scariot, 2009; Liao et al., 2013; Zhang et al., 2012). For instance, NAA could increase survival rate of *C. oleifera* cuttings from 67.9% (control, without NAA treatment) to 87.8–100% (Hu et al., 2013). Camellias require well-drained soil (Min and Bartholomew, 2007). It was found in our study that vermiculite, a preferred substrate for potting ornamentals and nut trees (Gao, 2012; Hu et al., 2013; Zhang et al., 2015), provided better drainage, thermal insulation, moisture holding, and good air permeability for *Camellia* ‘Maozi’ cuttings. Soaking the bottom parts of cuttings in 500 mg·L⁻¹ IBA for 2 h and then rooting them in a mix of latosolic red soil and vermiculite (2:1 v/v) resulted in optimal rooting and growth performance. In contrast, mold was found in cuttings grown in matrices containing coconut husks. These cuttings also had the lowest flushing rate. Therefore, sterilization and disinfection are recommended when using coconut husks for *Camellia* ‘Maozi’ rooting.

A success rate of at least 90% could be achieved when grafting was carried out during May to September and *C. osmantha* was used as rootstock. However, grafting conducted in July is recommended since grafting success rate was highest and new shoots had the most vigorous growth. It is worth noting that *C. osmantha*, recently registered in the Catalogue of Life: Higher Plants in China (<http://www.etaxonomy.ac.cn/node/108854?language=en>), is a species of section Paracamellia (Ma et al., 2012) and is related to *C. fluvialis*. Among the five rootstocks compared, *C. oleifera* was most compatible for *Camellia* ‘Maozi’. Commonly known as tea-oil camellia, *C. oleifera* is a native of China and its seeds are used extensively in China as cooking oil (Robards et al., 2015). Its natural geographical distribution is at latitudes ranging from 23°30′ to 31° N and longitudes ranging from 104°30′ to 121°25′ E, where the climate is one of intermediate subtropical moist monsoon types. This distribution spans 11 provinces in the south of China (He and He, 2002). It is important to evaluate growth performance of grafted *Camellia* ‘Maozi’ having *C. oleifera* as rootstock in this region in future studies for assessing distribution potential. The second most compatible rootstock for *Camellia* ‘Maozi’ is *C. polyodonta* with 89% survival rate. *Camellia* ‘Maozi’ and *C. japonica*

Table 3. Survival and growth of grafted *Camellia* ‘Maozi’ with different grafting dates during May to September.

Grafting dates	Number of individuals for grafting	3 mo. after grafting		5 mo. after grafting	
		Surviving individual	Survival rate (%)	Budbreak rate (%)	New shoot length (cm)
11 May	180	163	90.56	90.23	11.46
1 June	180	157	97.22	95.31	12.65
3 July	180	180	100	93.67	13.08
6 Aug.	180	178	93.89	86.43	10.92
10 Sept.	180	171	95.00	83.72	11.16

Table 4. Survival and growth of grafted *Camellia* ‘Maozi’ with different rootstocks.^a

Rootstocks	3 mo. after grafting		5 mo. after grafting				
	Survival rate (%)	Budbreak rate (%)	Survival rate (%)	Budbreak rate (%)	New shoot length (cm)	New shoot diam (cm)	Number of leaves on new shoots
<i>C. japonica</i> ‘Dahong Mudan’	12.82 c	0.26 d	7.78	0 d	0 c	0c	0c
<i>C. polyodonta</i>	96.97 a	69.70 ab	88.33 b	84.67 b	6.35 b	3.27 a	6.10 ab
<i>C. oleifera</i>	100.00 a	82.05 a	100.00 a	96.10 a	11.65 a	3.47 a	7.30 a
<i>C. japonica</i> ‘Hei Mudan’	95.17 a	20.51 c	89.44 b	41.03 c	2.73 b	1.80 b	3.30 b
<i>Camellia</i> ‘Maozi’	72.73 b	24.24 c	54.44 b	36.36 c	4.35 b	1.57 b	3.70 b

^aDifferent letters in the table indicate significant difference ($P < 0.05$).

‘Dahong Mudan’ had low compatibility with a grafting success rate lower than 7.8% five months after grafting.

This is the first report on the biological characteristics of *Camellia* ‘Maozi’ and its propagation techniques. Knowledge obtained through the study is valuable for the cultivation and dissemination of the new cultivar.

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Supplemental Table 1. Comparison of stem growth of *Camellia* 'Maozi' and its parental species.^z

Genotype	Height of cuttings (cm)				Stem diam of cuttings (mm)			
	February	April	June	August	October	December	February	April
<i>Camellia</i> 'Maozi'	18.17 ± 0.84 a	25.45 ± 1.23 a	29.75 ± 1.84 a	35.65 ± 0.68 a	36.26 ± 0.67 a	37.52 ± 0.58 a	43.26 ± 0.69 a	58.04 ± 1.05 a
<i>C. pubipetala</i>	10.21 ± 0.70 b	11.16 ± 0.26 b	14.39 ± 0.60 b	17.19 ± 0.87 b	18.13 ± 0.48 b	19.34 ± 0.48 b	36.03 ± 0.24 b	46.81 ± 0.70 b
<i>C. japonica</i> 'Dahong Mudan'	9.51 ± 0.96 b	10.62 ± 0.65 b	11.45 ± 0.63 c	16.18 ± 0.31 c	17.32 ± 0.36 c	17.63 ± 0.30 c	33.54 ± 0.63 c	43.27 ± 0.55 c
							50.71 ± 0.79 c	60.53 ± 0.65 c
							62.42 ± 0.54 b	68.32 ± 0.49 b
							70.17 ± 0.45 b	80.31 ± 0.64 a
							76.92 ± 1.04 a	82.13 ± 0.41 a

^zCuttings that were 9 cm long and had a diameter of 3 mm at the base were treated with 1500 ppm IBA for 45 min and then rooted in latosolic red soil in June 2012. Thirty healthy cuttings were randomly selected for each genotype. Measurements of stem height and diameter at the base were taken every 2 months in 2013. Data were processed and analyzed by Excel and SPSS 17.0. Different letters in the table indicate significant difference ($P < 0.05$). The results indicated that *Camellia* 'Maozi' cuttings grew faster than its parental species in both stem height and diameter.