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A New Kiwifruit Cultivar 'Nokong' with High Sugar and Vitamin C Content

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Kiwifruit (*Actinidia* spp.), a deciduous vine belonging to the family Actinidiaceae and the genus *Actinidia*, is cultivated primarily in New Zealand, Chile, and China (Lee et al. 2020). Globally, the genus *Actinidia* is comprised of ~60 species (Ferguson 1999), among which several species, such as *Actinidia arguta*, *Actinidia rufa*, *Actinidia polygama*, and *Actinidia kolomikta* are native to Korea. These *Actinidia* resources exhibit considerable variation among species, making them valuable genetic resources for breeding (Ferguson 1999). Leveraging this genetic diversity, kiwifruit breeding programs worldwide have developed various cultivars (Lee et al. 2020).

Kiwifruit was first introduced to Korea in 1978, which began its cultivation (Kwack et al. 2008). Until the late 1990s, cultivation centered primarily around 'Hayward' (*Actinidia chinensis* var. *deliciosa*), a green-flesh cultivar imported from New Zealand (Kwack et al. 2010). However, with the introduction of 'Hort16A' (*A. chinensis* var. *chinensis*), a yellow-flesh cultivar, to Jeju Island in the 2000s, coupled with consumer preferences for sweeter cultivars, breeding efforts shifted toward developing yellow-flesh cultivars (Kim et al. 2018; Kwack et al. 2017). As a result, the cultivation share of 'Hayward' has decreased to ~55%, whereas the cultivation of high-sugar, yellow-flesh kiwifruit cultivars such as Zesy002 (Gold3) (*A. chinensis* var. *chinensis*) from New Zealand, and 'Sweet Gold' (*A. chinensis* var. *chinensis*) and 'Garmhwang' (*A. chinensis* var. *chinensis*), developed by the Rural Development Administration of Korea, has rapidly increased (Rural Development Administration 2023). Nonetheless, yellow-flesh kiwifruit cultivars often present challenges, such as labor-intensive cultivation, high susceptibility to bacterial canker, and lower storage capacity compared with 'Hayward', leading some growers to continue to favor green-flesh kiwifruit cultivation.

Kiwifruit is widely recognized as a nutritious fruit that is rich in vitamin C and effective in alleviating constipation, which makes it beneficial for people of all ages (Kim et al. 2011; Nishiyama et al. 2004). Consequently, domestic consumer markets have increasingly highlighted its health benefits, with rising purchase rates and consistent increases in imports (Korea Customs Service 2023; Wi et al. 2019). However, 'Hayward' faces limitations, such as a relatively strong acidity and a difficulty for consumers to ripen the fruit at home, contributing to a decline in its popularity (Kwack et al. 2022; Wi et al. 2019). Against this background, there is a increasing demand among growers for new, green kiwifruit cultivars with greater sweetness and easier ripening characteristics.

In our study, we developed a new cultivar, Nokong (*Actinidia* hybrid), by interspecific hybridization using *Actinidia eriantha*. This cultivar features a greater sugar content, larger fruit size, and higher vitamin C levels than 'Hayward'. We provide a detailed account of the breeding process and the major characteristics of this new cultivar.

Origin

Nokong is a cultivar selected through the hybridization of an early-maturing, high-vitamin C maternal parent, 'JCS17', and a pollinizer resource introduced from China, 'Tomuri' (*A. chinensis* var. *deliciosa*) (Fig. 1). The maternal parent, 'JCS17' (*Actinidia* hybrid), was developed through a cross conducted in 1998. The cross was between a yellow-flesh genetic resource from China, 'Haenam' (*A. chinensis* var. *chinensis*, IT233174), and 'S20' (*A. eriantha*, IT233203). The elite line was selected in 2005. In 2006, 10 flowers were cross-pollinated, and fruit were harvested. In 2007, 3500 seeds were sown and 770 seedlings were nurtured. After growing these seedlings in a greenhouse for 3 years, 200 seedlings were transplanted in Apr 2010 to the breeding seedling plot at the Research Institute of Climate Change and Agriculture, National Institute of Horticultural and Herbal Science (NIHHS). In 2013, the line '65-WN-2.14' characterized by green flesh and a high sugar content, was initially selected. In 2014, five propagated plants were transplanted to the selection test plot at the Namhae Branch, NIHHS. From 2018 to 2020, growth characteristics and fruit traits were evaluated. In 2020, the final selection was made, and the cultivar was named 'Nokong' after approval by the New Cultivar Selection Committee for Crop Breeding in Rural Development Administration. After 2 years of cultivation review by the Korea Seed & Variety Service (KSVS), 'Nokong' was registered for plant variety protection (PVP no. 10128) on 24 Apr 2024.

Description

For the trait investigation, 4- to 6-year-old 'Nokong' plants and 10- to 12-year-old 'Hayward' plants were used. Each cultivar was managed with a T-bar training system. The planting distance for the test vines was 5 m between rows and 4 m between plants, and a

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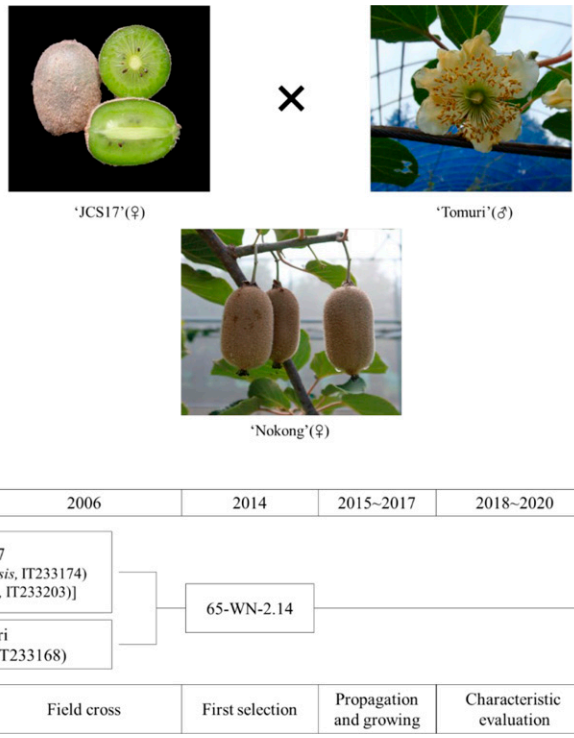

Fig. 1. Breeding pedigree diagram of 'Nokong'.

Table 1. The principal qualitative traits of the new kiwifruit cultivar Nokong.

		Flower			Fruit		
Cultivar[i]	Tree vigor	Inflorescence	No. of flowers	Main petal color	Fruit shape	Density of hairs	Fruit flesh color
Nokong	Medium	Dichasium	Many	Red pink	Elliptical	Medium	Light green
Hayward (control)	Medium	Solitary	Very few	White	Elliptical	Medium	Medium green

[i] Both cultivars were cultivated and investigated in an open field within a windbreak in Namhae Branch from 2018 to 2020.

Fig. 2. Flower and fruit set of 'Nokong' (**A** and **C**) and 'Hayward' (**B** and **D**).

fertilizer treatment was applied uniformly. Pollination was performed artificially using 'Deliwoong' (*A. chinensis* var. *deliciosa*), and the pollen was collected the previous year and stored frozen, with a germination rate of more than 80% (data not shown). The fruit set was adjusted to an average of three fruit per fruiting shoot.

Between 2018 and 2020, trait evaluations revealed that the vigor of 'Nokong' is moderate and comparable to the control cultivar Hayward. In terms of flower characteristics, 'Nokong' exhibits a dichasium inflorescence with a relatively high number of flowers. Consequently, it produces more flowers than 'Hayward'. The petals of 'Nokong' have a reddish pink color (Table 1, Fig. 2), a trait inherited from 'S20', the maternal grandparent of 'JCS17' (Huang 2016). This color differentiates it from the typical white petals of other kiwifruit cultivars and suggests potential ornamental or garden use based on its flowering period and fragrance. The fruit of 'Nokong' is elliptical, with medium-density hair on its skin. Its flesh color is bright green, appearing brighter than that of 'Hayward' (Table 1, Fig. 2).

The sprouting date of 'Nokong' is 23 Mar, with full bloom occurring on 16 May and harvest on 27 Oct, making its growth cycle earlier than that of 'Hayward' (Table 2). One of the main issues with 'Hayward' cultivation in Korea is the strong acidity caused by insufficient sugar accumulation resulting from early harvests relative to its maturation period. This is because frost occurs in the main kiwifruit-producing regions of Korea during autumn because of low temperatures, which typically occur around mid-November, the optimal harvest time for 'Hayward' (Kwack et al. 2022). In contrast, 'Nokong' flowers about a week earlier than 'Hayward' and has a shorter maturation period, allowing it to be harvested in late October, which is a significant advantage.

The fruit quality of 'Nokong' is as shown in Table 3. The average fruit weight of 'Nokong' is 117.7 g, ~1.14 times larger than the control cultivar Hayward (102.5 g). The fruit shape index is 1.59, indicating a longer elliptical shape compared with 'Hayward,' and its flatness ratio is 1.13, giving it a slightly flatter appearance. The soluble solids content is 14.4°Brix, and the titratable acidity is 1.12%. With larger fruit size and a higher sugar-to-acid ratio than 'Hayward', 'Nokong' is well suited to consumer trends favoring large, high-sugar cultivars. The vitamin C content of 'Nokong' is 253.5 mg/100 g, approximately five times higher than the control cultivar, and higher than any kiwifruit genetic resources investigated in the study by Lee et al. (2020).

This makes 'Nokong' a valuable, functional cultivar with high potential as a breeding material. The high vitamin C content is likely a result of the influence of 'S20' (*A. eriantha*), the maternal grandparent of 'JCS17'. The *A. eriantha* species is known for its high vitamin C content (Huang 2016) and has been used as breeding material to enhance vitamin C levels in kiwifruit. It has been reported that when vitamin C content in kiwifruit flesh exceeds 1700 mg/100 g, it increases tartness and reduces sweetness perception (Marsh et al. 2003). However, the vitamin C content of 'Nokong' remains less than 300 mg/100 g (Table 3), suggesting no adverse impact on its flavor. Nishiyama et al. (2008) emphasized the need to introduce new *Actinidia* cultivars with superior eating quality to invigorate the kiwifruit industry and provide excellent choices for consumers. The traits of 'Nokong' align with these requirements, showcasing its potential to

Table 2. Budbreak, full bloom, and harvest dates of 'Nokong' kiwifruit.

Cultivar[i]	Budbreak[ii]	Full bloom date[iii]	Harvest date[iv]
Nokong	23–24 Mar	15–17 May	25–30 Oct
Hayward (control)	23–28 Mar	21–23 May	15–18 Nov

[i] Both cultivars were cultivated and investigated in an open field within a windbreak in Namhae Branch from 2018 to 2020.
[ii] Budbreak is when more than 10% of the vegetative buds on the vines have begun to grow.
[iii] The full bloom date is when 70% to 80% of the flowers on the vines are fully open.
[iv] The harvest date is determined based on a soluble solids content of 7.5 to 8.5°Brix.

Table 3. Fruit characteristics of 'Nokong' kiwifruit.

Cultivar[i]	Fruit wt (g)	Fruit shape index[ii]	Flattening[iii]	Soluble solids content (°Brix)	Titratable acidity (%)	Vitamin C content (mg/100 g FW)
Nokong	117.7 ± 4.8 a[iv]	1.59 ± 0.01 a	1.13 ± 0.01 a	14.4 ± 0.1 a	1.12 ± 0.08 a	253.5 ± 17.5 a
Hayward (control)	102.5 ± 2.4 b	1.23 ± 0.01 b	1.09 ± 0.01 b	13.0 ± 0.2 b	1.47 ± 0.09 b	56.2 ± 6.2 b

[i] Both cultivars were cultivated and investigated in an open field within a windbreak in Namhae Branch from 2018 to 2020.
[ii] The ratio of fruit length to fruit diameter.
[iii] The ratio of the maximum fruit diameter to the minimum fruit diameter.
[iv] The values represent mean ± the standard deviation, with n = 20 each year. Values within a column with different letters are significantly different ($P < 0.05$) by the t test.
FW = fresh weight.

contribute to future interspecific hybridization efforts and the development of diverse, new cultivars.

Cultivation Notes

Like other kiwifruit cultivars, Nokong is not self-fertile, so pollination is required for fruit set. Its flowering period occurs in mid-May, which is earlier than that of 'Pohwa' and 'Chieftain', two pollenizer cultivars commonly used in Korea. Because of this difference, pollen from these cultivars must be collected in the previous year and stored frozen for use. Because 'Nokong' exhibits dichasium inflorescences, thinning of lateral flowers is necessary to ensure proper fruit enlargement. The cultivar is susceptible to fruit rot, so careful management during the growing season is required to minimize decay during storage or ripening. In 2024, the soluble solids content of 'Nokong' fruit was ~12°Brix after ripening, which was relatively low. This was likely a result of poor starch accumulation caused by heat stress during the summer and late-autumn heat waves. To resolve this issue, further evaluation of its heat tolerance is recommended.

Availability

'Nokong' is registered for Plant Variety Protection (PVP no. 10128) with the KSVS and is being distributed through nonexclusive licensing agreements. For inquiries regarding the cultivation or research of 'Nokong', please contact the author Mockhee Lee at the Research Institute of Climate Change and Agriculture, NIHHS (1285, Aejo-ro, Jeju-si, Juju-do, 63240, Republic of Korea; e-mail: mockey92@korea.kr).

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