

# Breeding of New Ever-bearing Strawberry “Doha” Variety

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**Abstract** - “Doha” is a new strawberry (*Fragaria x ananassa* Duch.) variety, which was released by the Highland Agriculture Research Institute in 2021. The “Doha” variety originates from a 2014 cross between “Saebong No. 3” and “Yeolha,” both of which exhibited excellent ever-bearing characteristics, including continuous flowering and large fruits under long-day and high temperature conditions. This new cultivar was initially named “Saebong No. 13” after examining its characteristics and productivity during summer cultivation between 2015 and 2018. After regional adaptability tests, “Doha” was selected from “Saebong No. 13” as an elite cultivar. The general characteristics of “Doha” include spreading, elliptic leaves, and strong growth. The fruits are long and conical and of a red color. The plant height of “Doha” was similar to that of “Goha,” but the number of leaves was lower. The number of flower clusters of “Doha” was 8.6, which was 2.8 fewer than that of the control variety, “Goha,” with 11.4. The average fruit weight of “Doha” was 13.9 g, which was 4.9 g heavier than that of “Goha.” The fruit hardness of “Doha” was 35.5 g·mm<sup>-2</sup>, which was 9.4 g·mm<sup>-2</sup> harder than that of “Goha.” The marketable yield of “Doha” was 26,971 kg·ha<sup>-1</sup>, 125% more than that of “Goha” with 21,479 kg·ha<sup>-1</sup>. The findings of this study suggest that “Doha” is a hard fruit and high-yielding variety of ever-bearing strawberries that could increase farming income when distributing to farmers.

**Key words** – Cultivar, Hard fruit, High temperature, Long day, Saebong No. 13

## Introduction

Worldwide, strawberries are produced mostly in winter and spring. During this period, June-bearing, which is flower differentiated under low temperature and short day, is mainly cultivated (Lee *et al.*, 2019). Recently, numerous strawberry farmers have expressed the hope to be able to produce strawberries even during summer and autumn.

The market for fresh strawberries, which caters to bakeries and dessert cafes mainly during summer and autumn, is rapidly growing. The unit price per kilogram has increased because supply does not keep up with demand. In Korea, summer strawberries are produced at altitudes of 500 m above sea level. Recently, the production of malformed and small fruits has increased due to abnormal temperatures. In addition, as a result of low product quantity, farm income has stagnated for all summer strawberry varieties that are

currently cultivated (Lee *et al.*, 2014).

Summer strawberries are planted from March to April and harvested between May and June, up to early August. Then, then harvest is interrupted for more than a month before reproduction begins again in mid to late September, and harvest occurs in November and December. These idle periods between harvesting occur for more than a month because the roots of the strawberries die off due to consuming more in respiration than can be equaled by photosynthetic transmission to the fruit. Strawberries exhibit the highest photosynthesis rate at 15°C~20°C (Yoon and You, 1992). During July to August, summer strawberries are exposed to 30°C, which is higher than their photosynthesis limit of 25°C. For most summer strawberries, developing varieties that can be harvested continuously without any interruption is crucial. The objective of this study was to breed a variety of ever-bearing strawberries that yields large fruits and produces favorable flower clusters as well as good fruit fat even at the high temperatures that are common in summer.

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## Materials and Methods

This study was conducted in Daegwallyeong’s greenhouse, situated at an elevation of 800 m. During the 2016 characteristic test period, Daegwallyeong’s outdoor average high temperature range was 13.7°C~32.4°C; the average low temperature range was 2.0°C~20.3°C; and the daily average temperature range was 7.3°C~25.1°C. The test seedlings were planted in late April with a spacing of 110 × 30 cm in two rows). For high bed hydroponic cultivation, an elevated platform was constructed using a pentite pipe with a diameter of 22 mm at a height of 100 cm above the ground. On top of it, a plastic bed with a width of 20 cm, length of 100 cm, and depth of 10 cm was installed. For bedding, a Chamgro strawberry medium 50 (Chamgro) was used, with a mixing ratio of 50% coco-peat and 50% perlite, with 2.5 L per plant. The strawberry culture solution was supplied with a Netherland PBG (N-P-K-Ca-Mg-S = 12.5-3.0-5.5-6.5-2.5-3.0 me/L) solution using a timer and managed in a spilled manner. The EC of supplying the culture solution was in the range 0.6~1.5 dS·m<sup>-1</sup>, the supply pH was in the range 5.5~6.5, and the amount of liquid supplied once was in the range 60 cc, 3~7 times per day. The planted cultivar was “Doha,” which is an ever-bearing strawberry that continuously blooms even at high temperatures. In this study, “Doha” was compared with “Goha” (Lee *et al.*, 2008). The yield investigation was conducted from mid-June to October 31, with a range of more than 15 g for the big size and 7~14 g for the middle size. Other investigations were conducted in accordance with the Rural Development Administration’s Agricultural Testing Research

Standards (RDA, 2003). Statistical processing was conducted using SAS Version 9.4 (SAS Institute Inc, Cary, NC, USA).

### Breeding process

When cultivated under high temperature, flower buds occurred, large fruits were produced, and a large number of four-season strawberries with small deformities were developed (Fig. 1). It was artificially bred in 2014 as a cross between “Saebong No. 3,” an ever-bearing cultivar with large fruits, and “Yeolha,” another ever-bearing variety with high water content even at high temperatures. In January 2015, 1,000 grains of botanical seeds were sown, which subsequently yielded 100 seedlings. In April 2015, these seedlings were planted, and one ever-bearing cultivar with large fruits and high quantity was selected. According to the Daegwallyeong summer cropping system, in 2016, excellent cultivars were selected; in 2017, productivity tests were conducted; in 2018, characteristic tests were conducted; and in 2019 local adaptability test was conducted (Fig. 2). Subsequently, the strain that was most consistent with the breeding goals was named “Saebong No. 13 (15-24-64).” This cultivar was named “Doha” after deliberation by the Rural Development Administration’s New Variety Selection Committee in 2021 because it was judged to be suitable as an ever-bearing strawberry variety due to its large fruit, high yield, and continued flowering even at high temperatures.

### Distinctness of variety

The plant type of “Doha” was characterized by spreading, and the plant vigor was strong (Table 1). The leaf was

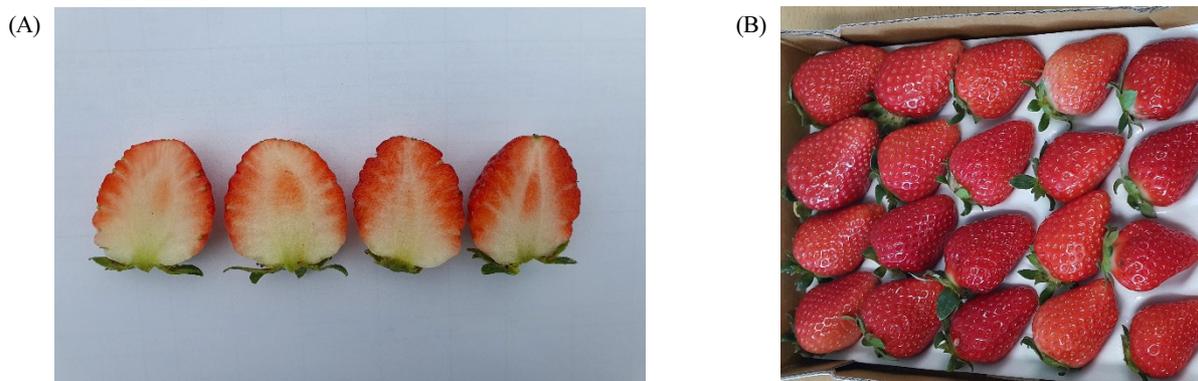


Fig. 1. Internal structure of fruits (A) and package condition (B) of the ever-bearing strawberry cultivar, “Doha.”

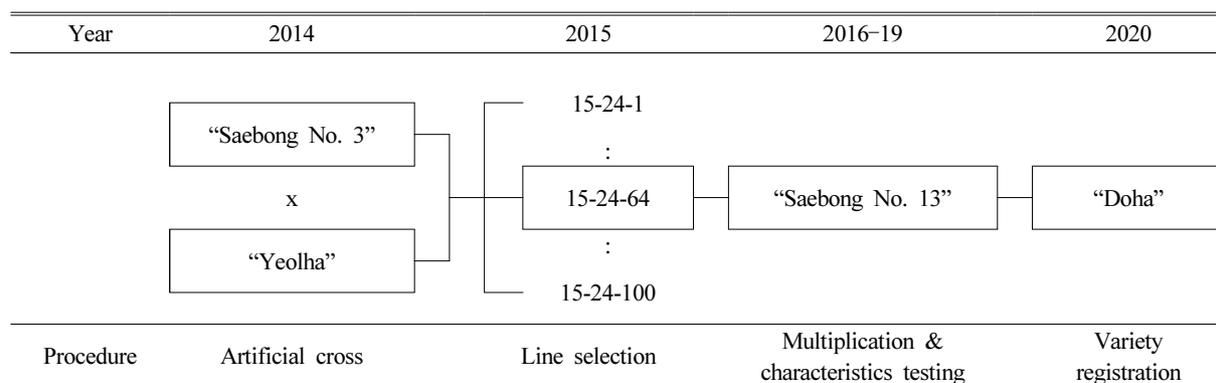


Fig. 2. Pedigree of the strawberry cultivar, “Doha.”

Table 1. Plant characteristics of the ever-bearing strawberry cultivars, “Doha” and “Goha,” during summer cultivation

Cultivar	Growth	Plant vigor	Leaflet shape	Fruit shape	Fruit color	Cycle of cluster appearance
Doha	Spreading	Strong	Elliptic	Long-conical	Red	Continuity
Goha <sup>z</sup>	Intermediate	Medium	Elliptic	Conical	Red	Continuity

<sup>z</sup>Control.

elliptical, and the fruit was long and conical. The color of the fruit was red, and the continuous budding of the flower cluster was favorable even at high temperatures and considering the long days in August and September. The plant height of “Doha” was 30.4 cm, comparable to that of “Goha,” 30.8 cm, and the number of leaves was 24.5, which was 3.6 fewer than of “Goha” with 28.1 (Table 2). The leaflet length of “Doha” was longer than that of “Goha,” and the flower cluster length was 48.8 cm, 8.2 cm longer than that of “Goha” with 40.6 cm. The number of flower clusters occurring during the cultivation period was 8.6 in “Doha,” 2.8 less than that of “Goha” with 11.4. Winter strawberries are cultivated with one crown and the removal of buds in the early stages of cultivation. By contrast, ever-bearing varieties are not interfered with, therefore ever-bearing cultivars have numerous buds, and the flower clusters are differentiated (Lee *et al.*, 2021). Among the ever-bearing varieties cultivated in Korea, 18.7 and 21.6 flower clusters were generated by “Muha” (Lee *et al.*, 2019) and “Yeolha” (Lee *et al.*, 2014), respectively. By contrast, “Flamenco” (Lee *et al.*, 2014; Lee *et al.*, 2019) generated only 10.0, which is the lowest number among the ever-bearing strawberry varieties. “Doha” also exhibited a moderate amount of occurrence among other ever-bearing varieties, although blooming occurred favorably under high

temperature and long-day conditions. The flowering period began on May 17, 26 days after planting. The onset of the first harvest period was similar to that of the control variety, “Goha.” The average soluble solid content of fruits harvested from June to October was 10.3 °Brix in “Doha,” which is 1.8 °Brix higher than that of “Goha” with 8.5 °Brix (Table 3). The average soluble solid content of “Doha” was also higher than that of other summer strawberry varieties such as “Muha” (8.6 °Brix; Lee *et al.*, 2019) and “Bokha” (9.2 °Brix; Lee *et al.*, 2018). The acidity of “Doha” was 0.67%, which was higher than that of “Goha” with 0.63%, and the soluble solid content/acidity ratio was 15.4, which was 1.7 points higher than that of “Goha” with 13.7. This translates into favorable taste. Strawberries exhibit a higher soluble solid content at low temperatures and higher acidity at higher temperatures, and most summer strawberry varieties have a high acidity. In addition, the hardness of “Doha” was 35.5 g·mm<sup>-2</sup>, 10.1 g·mm<sup>-2</sup> harder than that of “Goha” with 26.1 g·mm<sup>-2</sup>. Considering the incidence of powdery mildew, “Doha” had an incidence index of 1, which was lower than that of “Goha,” which had an index of 3 (Table 4). The index for gray mold disease in “Doha” was 2, which was slightly higher than that of “Goha.” The occurrence of other pests exhibited no significant difference. In previous studies, winter strawberry

Table 2. Growth characteristics of the ever-bearing strawberry cultivars, “Doha” and “Goha,” during summer cultivation

Cultivar	Plant height (cm)	Number of leaves	Leaflet length (cm)	Leaflet width (cm)	Cluster length (cm)	Number of flower clusters	Flowering date
Doha	30.4 ± 0.4 <sup>z</sup>	24.5 ± 1.0	8.2 ± 0.3	7.2 ± 0.3	48.8 ± 3.8	8.6 ± 1.1	May 17
Goha <sup>y</sup>	30.3 ± 0.6	28.1 ± 1.9	7.7 ± 0.3	7.2 ± 0.4	40.6 ± 4.6	11.4 ± 1.2	May 17

Planting date: April 21.

<sup>z</sup>Mean ± standard deviation of 20 plants.<sup>y</sup>Control.

Table 3. Fruit quality characteristics of the ever-bearing strawberry cultivars, “Doha” and “Goha,” during summer cultivation

Cultivar	Soluble solid content (A) (°Brix)	Acidity (B) (%)	A / B	Fruit hardness (g·mm <sup>-2</sup> )
Doha	10.3 ± 0.4 <sup>z</sup>	0.67 ± 0.01	15.4	35.5 ± 2.1
Goha <sup>y</sup>	8.5 ± 0.3	0.63 ± 0.02	13.7	26.1 ± 1.5

<sup>z</sup>Mean ± standard deviation of 20 plants.<sup>y</sup>Control.

Table 4. Disease and pest incidences of the ever-bearing strawberry cultivars, “Doha” and “Goha,” during summer cultivation

Cultivar	Diseases (0-9) <sup>z</sup>			Pests <sup>y</sup>		
	Powdery mildew	Gray mold	Fusarium wilt	Aphids	Thrips	Two-spotted spider mite
Doha	1	2	1	+	+	++
Goha <sup>x</sup>	3	1	1	+	+	++

<sup>z</sup>0, healthy; 9, severe.<sup>y</sup>+, slight; ++, moderate; +++, very severe.<sup>x</sup>Control.

Table 5. Yield characteristics of the ever-bearing strawberry cultivars, “Doha” and “Goha,” during summer cultivation

Cultivar	Average fruit weight (g) <sup>z</sup>	Top number of fruits	Marketable fruits	Marketable weight (g/plant)	Marketable fruit (%)	Yield (kg·ha <sup>-1</sup> )
Doha	13.9 ± 0.7 <sup>y</sup>	61.1 ± 16.6	32.7 ± 3.9	449.5 ± 28.1	53.5	26,971 ± 301
Goha <sup>x</sup>	9.0 ± 0.4	88.9 ± 14.2	40.0 ± 4.1	358.0 ± 30.3	45.0	21,479 ± 255

<sup>z</sup>Marketable fruit: >7 g.<sup>y</sup>Mean ± standard deviation of 20 plants.<sup>x</sup>Control.

varieties exhibited substantial damage from powdery mildew and anthracnose (An *et al.*, 2012; Yoon *et al.*, 2020). By contrast, summer strawberries are cultivated at high temperatures, therefore insect pests commonly occur throughout the year (Lee *et al.*, 2018), which requires periodic pest control. When fruits with a product weight of 7 g or more were harvested, the average weight of “Doha” was 13.9 g, which was 4.9 g heavier than that of “Goha” with 9.0 g (Table 5). In general, the product weight of winter strawberries is 26.0 g for “Okamae,”

21.6 g for “Maehyang,” and 23.6 g for “Akihime” (An *et al.*, 2012), which is more than 10 g heavier than that of the summer strawberry, “Doha.” The total number of fruits harvested in “Doha” was 32.7, 7.3 less than the amount of “Goha” with 40.0. However, “Doha’s” product rate was 53.5%, which was 8.5% higher than that of “Goha” with 45%. Therefore, the product yield of “Doha” was 26,971 kg·ha<sup>-1</sup>, which is more than that of “Goha” with 21,481 kg·ha<sup>-1</sup>. During the cultivation period of “Doha,” the production of flower clusters was

small, but fertilization was carried out consistently, even during the high temperature period. Therefore, big fruits were produced, and the yield was high. Based on these findings, the cultivation of “Doha” is likely to increase farm household incomes. Most summer strawberries are used for confectionery, but because the unit price per kg is constant from June to November, high yields are directly related to high profits.

### **Agricultural characteristic of “Doha”**

For the cultivation of the “Doha” variety, seedlings were selected after breeding, and the cultivation characteristics were investigated for 5 years. As a result, numerous fruits were produced and the product yield ratio was high, leading to a large marketable yield. Strawberry is a crop that requires a balance between vegetative and reproductive growth. When cultivated at temperatures above 30°C, vegetative growth is more vigorous than reproductive growth, and fertility is poor, resulting in numerous malformations. Because of the high sugar content of “Doha,” controlling the humidity of the greenhouse is crucial for preventing damage caused by gray mold (Table 4) and diseases that are common during the rainy season and in late fall, which is a humid season.

### **Key points on the cultivation and propagation of the new variety**

“Doha” has a high yield from June to August, which is the early harvest period of the summer crop. The yield decreases in September. Because ever-bearing strawberries are cultivated in summer, balancing vegetative and reproductive growth is crucial. For example, through the absorption of nitrogen after planting, the vegetative growth of “Muha” increases. Concomitantly, the generation of flower clusters and runner generation are delayed compared with that of other ever-bearing varieties (Lee *et al.*, 2019). By contrast, “Doha” exhibits strong reproductive growth and fewer runners. As an ever-bearing variety, it is characterized by deep dormancy. This must be interrupted by providing a sufficiently low temperature for propagation. An accumulation time of approximately 2,000 h or more is required at temperatures of 5°C or less. Nevertheless, “Doha” exhibits less runner generation, so it is necessary to spray GA<sub>3</sub> and apply nitrogen to promote vegetative growth and runner generation.

### **Registration and usage information of the new variety**

On December 2, 2021, the new ever-bearing strawberry variety, “Doha,” was submitted to the Rural Development Administration’s New Variety Selection Committee and passed. On December 22, 2021, an application for protection status for this variety was submitted to the Korea Seed & Variety Service (Application number 2021-558) under the New Varieties Protection Act. Currently, it is produced in the context of demonstrative cultivation in the highlands of Muju-gun and Jeollabuk-do.

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## **Conflicts of Interest**

The authors declare that they have no conflict of interest.

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