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A New Self-Compatible Asian Pear: 'Sweet Cost'

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Abstract

'Sweet Cost', a new self-compatible Asian pear cultivar carrying the S_4^{sm} (SM, stylar-part mutant) allele, was developed from a cross between 'Wonwhang' (S_3S_5), the main early-maturing pear cultivar with high fruit quality in Korea and the self-incompatible '92-18-31' ($S_4^{sm}S_4^{sm}$) obtained from self-crossing of 'Osa-Nijisseiki' ($S_2S_4^{sm}$), a self-compatible bud mutant that originated from self-incompatible 'Nijisseiki' (S_2S_4). The cross was made in 2000 at the National Institute of Horticultural and Herbal Science, Rural Development Administration in Korea. It was first selected as '2000-10-22' in 2006 for its attractive eating quality, good appearance and self-compatibility. After regional adaptability tests at 10 sites for 5 years from 2008 to 2012 as 'Wonkyo Na-61', it was selected and named in 2012. It bloomed 1 day earlier than 'Osa-Nijisseiki' and 1 day later than 'Wonwhang' in 2007 - 2012. It is medium in tree vigor and has an upright-spreading tree habit. 'Sweet Cost' is classified as susceptible to pear scab (*Venturia nashicola*), similar to 'Osa-Nijisseiki'. Its S-genotype, determined using PCR-RFLP, is $S_3S_4^{sm}$. 'Sweet Cost' had a 49.5% fruiting rate by self-pollination. The average optimum harvest time of 'Sweet Cost' was 138 days after full bloom and it matured around one week earlier than 'Osa-Nijisseiki' and one week later than 'Wonwhang'. The fruit is roundish oblate in shape and yellowish brown in skin color. Average fruit weight was 464 g and soluble solids concentration was 12.2°Brix. The flesh had abundant juice and negligible grit.

Asian pears belong to the *Rosaceae* family and exhibit an S-RNase-mediated gametophytic self-incompatibility (SI) system where its SI reaction is controlled by a single multi-allelic S-locus (Kikuchi, 1929). Pear accounts for 69.2% of fresh fruit exports and is the most important fruit crop in Korea ranking first in both amount (20,120 tonnes) and value (US$54,869,211) (2013 figures). The crop is sent to 31 countries including the USA, Taiwan and Indonesia. Commercial pear cultivars growing in Korea, such as 'Niitaka', 'Wonwhang' (Kim et al., 1995), 'Whangkeum Bae' (Kim et al., 1985), and 'Whasan' (Kim et al., 1994), need artificial pollination using pollen of another cultivar having a different S-genotype to reliably bear fruit due to lack of pollinizers and a reduction of flower visits by insects due to unfavorable temperatures and/or strong winds during the flowering season.

Hence breeding self-compatible cultivars in order to cut down labor and artificial pollination costs has been one of the important pear breeding goals at the RDA (RDA, 2013). The breeding program for self-compatibility started in 1992 at the National Institute of Horticultural and Herbal Science. So far five promising selections resulting from crosses with a self-compatible parent have been released: 'Wonkyo Na-Jasoojung 1' (Shin et al., 2008) was selected in 2007, 'Wonkyo Na-Jasoojung 2' (Shin et al., 2009) in 2008, 'Wonkyo Na-Jasoojung 3' in 2010, and both 'Wonkyo Na-Jasoojung 4' and 'Wonkyo Na-Jasoojung 5 ' in 2011. 'Sweet Cost' (Fig. 1), an early-mid season variety with good appearance and high fruit quality, was selected to meet the needs both of producers aiming to reduce labor costs and of consumers seeking high fruit quality.

Materials and Methods

A total of 222 seedlings from 298 seeds were obtained from a cross made in 2000 at the National Institute of Horticultural

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and Herbal Science (NIHHS), Rural Development Administration in Korea between 'Wonwhang', the main early maturing, high quality pear cultivar, with self-incompatible '92-18-31' ($S_4^{sm}S_4^{sm}$) which had been obtained from self-crossing of 'Osa-Nijisseiki' ($S_2S_4^{sm}$; sm = stylar-part mutant). 'Osa-Nijisseiki' is a self-compatible cultivar that originated as a bud mutant from self-incompatible 'Nijisseiki' (S_2S_4), in which the S_4-allele exhibits style-specific inactivation, but behaves as a functional S_4 allele in pollen. Seedlings from the cross more than 1.5 m in height were planted in a breeding field at the NIHHS in Hwaseong (37.23N, 126.95E) in 2003. It was first selected as '2000-10-22' in 2006 for its attractive eating quality, good appearance and self-compatibility. Eight trees each of '2000-10-22' and of the control cultivar 'Wonwhang', were propagated on *P. betulaefolia* seedling rootstock, and planted in the same row with a 2 m (in row) × 6 m (between rows) spacing in 2007. All trees were trained to a central leader growth habit. After regional adaptability tests at 10 sites, spanning the far northern (Chuncheon-si, 37.52N, 127.53E), far southern (Jinju-si, 35.11N, 128.09E), far western (Naju-si, 35.01N, 126.71E), and far eastern (Daegu-si, 35.87N, 128.57E) regions in latitude and longitude, for 5 years from 2008 to 2012 as 'Wonkyo Na-61', it was selected and named in 2012. Trees were evaluated for flower, tree and fruit characteristics including fruit set ratio. The latter was determined by covering flower clusters with paper bags at the balloon stage to ensure self-pollination according to the manual for Agricultural Investigation (RDA, 2003) and related guidelines (UPOV, 1994). During the flowering period (Fig. 1), 100 flowers at the balloon stage in the second or third position of a flower cluster were picked and anthers were collected. After dehiscence of anthers for 24 hours at 20°C, pollen was collected using the 100% acetone dipping method (Niimi and Yu, 1992), and total quantity was determined.

Pollen tube elongation in pistils of 'Sweet Cost' was observed at 48 h after self-pollination with confocal laser scanning microscope (Carl Zeiss LSM 510, Jena, Germany) according to the method of Kho and Baer (1968). S-genotype was analyzed by a PCR-based method using HS prime tag DNA polymerase (Genetbio, Korea) following the method of Ishimizu et al. (1999) for S_3 and Wu et al. (2007) for S_2, S_4, and S_5.

Cross compatibility with 'Sweet Cost' was evaluated using a total of 100 flowers of each of five cultivars in 2012. Two flowers per flower cluster at the balloon stage were retained and each flower was emasculated by hand and covered with a paper bag until pollination. Fruit set was determined 30 days after the full bloom stage.

Each spring, flower and fruit thinning were carried out to prevent biennial fruiting. Final distance between fruits at harvest was main-

Fig 1. Fruit and flowers of 'Sweet Cost'.

Table 1. Tree characteristics and scab resistance of 'Sweet Cost' pear at Suwon, Korea, 2012.

Cultivar	Full flower date	Tree habit	Tree vigor	No. of spurs	Pollen quantity (mg•100 flowers^{-1})	Scab resistance[z]
Sweet Cost	Apr. 28	Upright spreading	Moderately high	Many	Abundant (292)	HS
Wonwhang	Apr. 27	Upright spreading	High	Many	Abundant (113)	S

[z] HR (highly resistant), no visible symptoms on all leaves; R (resistant), yellow or necrotic lesions with no sporulation on a few leaves; S (susceptible), sparsely sporulating lesions on a few leaves or petioles; HS (highly susceptible), abundant sporulating lesions on several leaves or petioles.

tained at a minimum of 20-30 cm. However, total yield was not determined.

As trees came into bearing, five fruits were taken from each of eight trees at three times to ascertain the optimal ripening date. After the fruits were weighed, they were cut in half longitudinally. Flesh firmness was measured on each side of the fruit with a penetrometer (QA Supplies, FT 327, USA) equipped with an 8 mm diameter plunger. Soluble solids were measured on each fruit by expressing juice from each side onto a digital refractometer (Atago PR-101, Japan). Titratable acidity of each fruit was measured from 10 mL samples of squeezed juice plus 40 mL distilled water and reported as a percentage in terms of malic acid equivalents. The solution was titrated to an endpoint of pH 8.1 using 0.1 N NaOH. Titrations were performed using an auto-titrator (Schott TitroLine Alpha, Mainz, Germany). Sensory evaluation for grit, flesh juiciness, appearance and overall taste were conducted by three trained personnel. Storability of 'Sweet Cost' and 'Wonwhang' at 2°C was investigated by losses of fruit weight and fruit firmness every 20 days until 120 days after storage in 2013. Each treatment was comprised of three replications with three fruits per replication. Fruit weight loss and fruit firmness loss were calculated as the difference between values at harvest time and those determined every 20 days. Fruit which had decreased by more than 10% of the harvest time values were considered unacceptable.

Degree of scab caused by *V. nashicola* (Fig. 2) was estimated according to the methods of Abe and Kurihara (1992), Langford and Keitt (1942) and Shin et al. (2004, 2007).

The experiments were designed as randomized complete block designs with year as the designated block. Statistical significance was calculated by Tukey's studentized range (HSD) test of GLM using SAS statistical software (V 9.1, SAS Institute Inc., North Carolina, USA).

Description

'Sweet Cost' has medium tree vigor and an upright-spreading tree habit (Table 1). It blooms one day later than 'Wonwhang', the main early-maturing pear cultivar that has high fruit quality in Korea. Fruiting spurs are abundant and the number of axillary flower

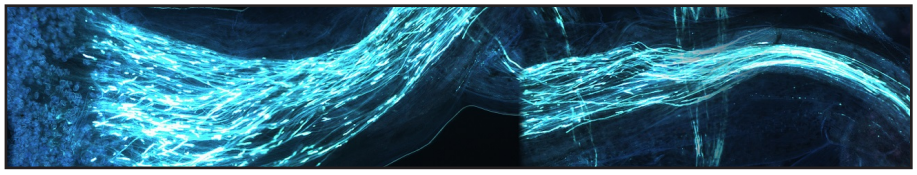

Fig 2. Pollen tube elongation in pistil at 48 hours after self-pollination of 'Sweet Cost'.

Table 2. Cross compatibility of 'Sweet Cost' pear at Suwon, Korea, 2012.

Cross combination	Fruit-set (%)
Niitaka × Sweet Cost	65.9
Wonwhang × Sweet Cost	65.0
Whasan × Sweet Cost	57.8
Chuwhangbae × Sweet Cost	57.7
Whangkeum Bae × Sweet Cost	78.3
Sweet Cost × Sweet Cost	49.5

buds on 1-year-old shoots is moderate. Precocity is similar to 'Wonwhang' on *P. betulaefolia* rootstock, with the onset of fruiting in the third year. Flowers have 26 stamens per flower (a moderate number) compared to 20 stamens of 'Wonwhang' and the pollen amount is two-times higher than 'Wonwhang' (292 mg•100 flowers^{-1}). In pollination compatibility tests, 'Sweet Cost' was compatible with all test cultivars, such as 'Niitaka' (a leading mid-late season cultivar), 'Wonwhang', 'Whasan' and 'Whankeum Bae' (Table 2). It was also confirmed that 'Sweet Cost' is self-compatible through self-pollination (Table 2, Fig. 2). Thus it may be used both for fruit production and as a pollinizer variety.

In order to assign the S-alleles of 'Sweet Cost', two endonucleases, *Ppu*MI which digested both S_3- and S_5-allelles and *Alw*NI, which digested S_5 but not the S_3-allele, were used because seedlings released from crossing between S_3S_5 ('Wonwhang') and $S_4^{sm}S_4^{sm}$ ('92-18-31') are assigned just two SI genotypes as either $S_3S_4^{sm}$ or $S_5S_4^{sm}$. Only 'Sweet Cost' but not 'Wonwhang' was digested by *Alw*NI endonuclease and consequently it was confirmed as having the $S_3S_4^{sm}$ genotype (Fig. 3).

'Sweet Cost' requires optimal chemical control of scab, since it shows the same high degree of susceptibility to this disease as 'Niitaka', and is more susceptible than 'Wonwhang'.

The average optimum harvest time for 'Sweet Cost' was 138 days after full bloom and it matured around one week earlier than 'Osa-Nijisseiki' and one week later than 'Wonwhang' over the 2007-2012 period (Table 3). The fruit is oblate in shape and yellowish brown in skin color. Average fruit weight was 464 g (smaller than 'Wonwhang' at 549 g), total soluble solids concentration averaged 12.2°Brix and titratable acidity was 0.161%. Fruit flesh was similar to that of 'Wonwhang', being very juicy and having

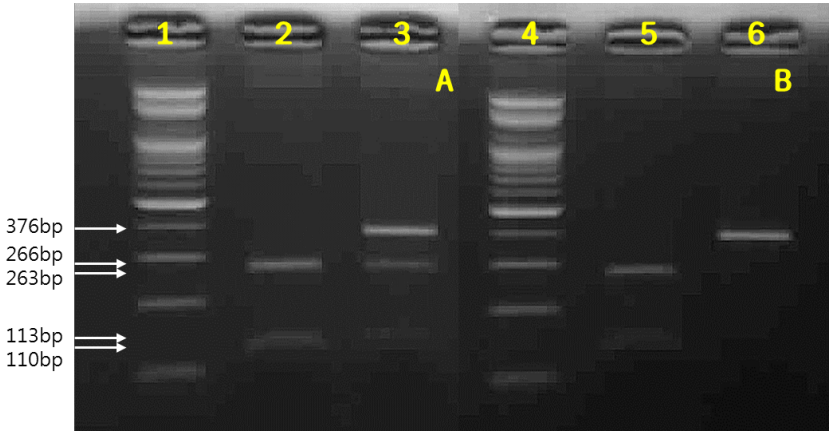

Fig. 3. Analysis of the PCR fragment digested with restriction endonucleases. The endonucleases employed were A, *Ppu*MI (lanes 2 and 3); B, *Alw*N1 (lanes 5 and 6). The lanes in each gel show the molecular size marker (lanes 1 and 4), 'Wonwhang' (lanes 2 and 5) and 'Sweet Cost' (lanes 3 and 6) on the left and the right. The band sizes are 376, 266 and 100 bp in the left gel and 376, 263 and 113 bp in the right gel, from the top.

Table 3. Fruit characteristics and ripening time of 'Sweet Cost' at Suwon, Korea from 2007 to 2012.

Cultivar	Maturity[z]	Fruit weight (g)	SSC (°Brix)	Flesh firmness[x] (kg)	Flesh firmness/ texture	Acidity (%)	Storability (days at 2°C)
Sweet Cost	138 a[w]	464 b	12.2 a	2.4 a	Soft/medium	0.161 a	80 a
Wonwhang	133 a	549 a	12.1 a	2.5 a	Soft/fine	0.140 a	80 a

[z] Days after full bloom.
[y] Soluble solids concentration.
[x] Flesh firmness evaluated with a 8 mmØ plunger.
[w] Means followed by different letters are significantly different at the 5% level according to Turkey's studentized range (HSD) test.

negligible grit. The fruit does not store for more than 30 days at ambient temperature or for more than 3 months after harvest at cold temperatures of approximately 1-2°C.

Availability

Protection for 'Sweet Cost' was applied for in Dec. 2012 for registration in 2014 after two years of records on distinctness, uniformity and stability as required by Korean seed industry law. Propagation material of 'Sweet Cost' will be available after cultivar registration.

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