Parthenocarpy and Self- and Cross-incompatibility in Ten European Pear Cultivars

Yuki Moriya¹, Yoshihiro Takai¹, Kazuma Okada¹, Daiyu Ito², Yunosuke Shiozaki²,
Tetsu Nakanishi^{1,3} and Takeshi Takasaki^{3*}

¹Graduate School of Science and Technology, Kobe University, Rokkodai, Nada, Kobe 657–8501

²Fujisaki Farm, Faculty of Agriculture and Life Science, Hirosaki University, Fujisakimachi, Aomori 038–3802

³Faculty of Agriculture, Kobe University, Rokkodai, Nada, Kobe 657–8501

Summary

Self- and cross-incompatibility in European pear (*Pyrus communis* L.), which is estimated by the fruit set and seed formation, is yet unclear. We carried out self-, cross- and non-pollinations with one flower per cluster on 10 European pear cultivars, and estimated their parthenocarpic potential, and self- and cross-incompatibility. Most cultivars exhibited parthenocarpy, which suggests that the fruit set is not a suitable criterion for distinguishing incompatibility from compatibility. However, clear judgment could be provided by using the self-incompatibility (SI) index, (the number of viable seeds per flower obtained from test pollination / the number of viable seeds per flower resulting from compatible cross-pollination) $\times$ 100, as a new criterion. Based on this index, 'Grand Champion' has proven to be partially self-compatible, whereas others were classified as self-incompatible. Traits of the seeded fruits, such as weight, size, and soluble solids content, were superior to those of the parthenocarpic fruits. Thus, cross-compatible pollination is necessary for a stable fruit set and production of large, good quality fruits in cultivars with a high parthenocarpic potential. Two cross-incompatible combinations were found between 'Flemish Beauty' and 'Starkrimson', and 'Bartlett' and 'Seigneur d'Espéren', respectively.

Key Words: European pear, parthenocarpy, *Pyrus communis*, self-compatibility, self-incompatibility.

Introduction

Self- and cross-incompatibility in European pear (*Pyrus communis* L.) has been judged by fruit and seed set experiments (Crane and Lewis, 1942; Lewis and Modlibowska, 1942; Rawes, 1933). Most European pear cultivars are self-incompatible, although a diploid cultivar, 'Fertility', and some tetraploid cultivars are partially and completely self-compatible, respectively (Crane and Thomas, 1939). Hence, it is necessary to inter-plant pollinizers in orchards to produce stable economic crop. Most European pear cultivars are cross-compatible, except for some triploid and diploid cultivars (Crane and Lewis, 1942; Griggs and Iwakiri, 1954; Modlibowska, 1945).

However, early studies did not describe the number of pollinated flower per cluster. They have been uncertain with regard to the following points: (1) the parthenocarpic effect on fruit set; (2) low fruit sets in some compatible pollinations. European pear cultivars exhibit

different degrees of parthenocarpy (Nyéki et al., 1994). Considerable fruit sets are induced by incompatible pollinations in the cultivars that exhibit strong parthenocarpic potential, which may mislead investigators to categorize them as compatible. Compatible pollinations must provide a stable fruit set, but a fruit set less than 30% was reported in some cultivars because of the physiological fruit drop (Crane and Lewis, 1942; Lewis and Modlibowska, 1942; Nyéki et al., 1994; Rawes, 1933).

Recently, an evaluation of pollen tube penetration into the ovule has made it possible to distinguish incompatibility from compatibility (Sanzol and Herrero, 2002). This method indicates that three types of progenies from 'Bartlett' and 'Coscia' are cross-compatible with each other; it suggests that the European pear exhibits gametophytic self-incompatibility (GSI), controlled by a single *S*-locus with multi-alleles, and that 'Bartlett' and 'Coscia' harbor 4 *S*-alleles. However, fruit and seed sets as criteria are generally accepted in other Rosaceae fruit trees that exhibit GSI, such as Japanese pear, apple, sweet cherry and almond (Kester et al., 1994; Kobel et al., 1939; Komori et al., 1998; Tehrani and Brown, 1992; Terami et al., 1946). Therefore, more accurate methods and criteria based on fruit and seed set experiments should be established to judge incompatibility or

Received; August 2, 2004. Accepted; May 30, 2005.

This work was supported in part by a Grant-in-Aid for Young Scientists (B) (15780025) from the Ministry of Education, Science, Culture, Sports, and Technology, Japan.

* Corresponding author (E-mail: taka@kobe-u.ac.jp).

compatibility in European pear.

In this paper, we conducted self-, cross- and non-pollinations in 10 European pear cultivars to establish a pollination method and a reliable criterion. Based on our results, a partially self-compatible cultivar and two cross-incompatible combinations were discovered.

Materials and Methods

Plant material

Ten European pear cultivars were tested in two experimental orchards; 'Bartlett' ('Williams'), 'Flemish Beauty', 'Grand Champion', 'La France' and 'Précoce' ('Docteur Jules Guyot') at Fujisaki farm, Teaching and Research Center for Bio-coexistence, Hirosaki University, Fujisakimachi, Aomori Prefecture, and 'Conference', 'La France', 'Le lectier', 'Passe Crassane', 'Seigneur d'Espéren', and 'Starkrimson' at Nagano Fruit Tree Experiment Station, Suzaka, Nagano Prefecture. 'La France' was tested at the both orchards.

Pollination experiments

Using one tree of each cultivar, self-, cross- and non-pollinations were conducted by gathering anthers from pollen parents and drying them to collect the pollen. One or two flowers that were selected from the second to fourth flowers in a nonadjacent flower cluster were emasculated 1–2 days before anthesis. Self- and cross-pollinations with one or two flowers per cluster, and non-pollinations with one flower per cluster were conducted at Fujisaki farm on May 7 to 12, 2000, May 1 to 7, 2001, and April 21 to 26, 2002, and at Nagano Fruit Tree Experiment Station, on April 21 to 26, 2001 and April 13 to 17, 2002. All treated flowers were covered with paper bags to avoid pollen contamination. Initial fruit sets were recorded 4 weeks after pollination (before June drop). Fruit set and the number of viable seeds were counted 10–11 weeks after pollination (after June drop). The large viable seeds were distinguished from aborted seeds. The number of viable seeds per fruit (the number of viable seeds/the number of fruit set), the number of viable seeds per flower (the number of viable seeds/the number of pollinated flowers), and the SI index ((the number of viable seeds per flower obtained from test pollination/the number of viable seeds per flower resulting from compatible cross-pollination) $\times$ 100) were calculated.

Fruit traits

The parthenocarpic and seeded fruits that were formed by non- and compatible cross-pollinations in 2002, respectively, were harvested at commercial maturation; 'Bartlett' on September 4, 'Conference' on September 9, 'Flemish Beauty' on October 1, 'La France' on October 16, and 'Le lectier' on October 19. 'La France' was harvested in Nagano. Fruit weight, length, and diameter were measured. After exposing to 4°C for 7–10 days, the

harvested fruits ripened at room temperature. The soluble solids content was measured.

Results and Discussion

Effect of the number of pollinated flowers per cluster on fruit set

Incompatibility was investigated by the pollinations with two or three flowers per cluster and the fruit sets before and after June drop; low fruit sets were observed in some compatible combinations between European pear cultivars (Kubo et al., 1989; Onoda and Ito, 1987). Cross-pollinations with two flowers per cluster in Aomori in 2000 gave a high initial fruit set on each cultivar (Table 1). A physiological fruit drop occurred from June to July in 'Flemish Beauty', 'Grand Champion', and 'La France' that resulted in fruit sets below 73.3%. The physiological fruit drop was probably due to nutrient competition between two fruits on the same cluster.

In Aomori and Nagano in 2001, therefore, cross-pollinations with one flower per cluster were conducted for 'Flemish Beauty', 'Grand Champion', and 'La France', and those with two flowers per cluster for 7 cultivars (Table 1 and 2). Cross-pollinations with two flowers per cluster also caused a drastic physiological fruit drop in 'Conference', 'Le lectier', 'Passe Crassane', and 'Seigneur d'Espéren'. However, cross-pollinations with one flower per cluster provided fruit sets of more than 80% in 'Flemish Beauty', 'Grand Champion', and 'La France'.

Fruit sets between cross-pollinations with one and two flowers per cluster for 10 cultivars in Aomori and Nagano in 2002 (Table 1 and 2) revealed that cross-pollinations with one flower per cluster prevented the physiological fruit drop and resulted in 86.2–100% fruit sets. Thus, the method is highly suitable for evaluating the parthenocarpic potential and judging the incompatibility or compatibility in European pear. However, fruit sets of more than 80% were obtained by cross-pollinations with two flowers per cluster on 'Bartlett' and 'Précoce' for three years and on 'Conference', 'La France', 'Le lectier', and 'Seigneur d'Espéren' in 2002 (Table 1 and 2). Therefore, a fruit set of more than 80% by cross-pollinations with two flowers per cluster should provide a reliable basis for establishing incompatibility.

Parthenocarpy

Self-pollinations of 'Grand Champion' in Aomori in 2000 resulted in seeded fruits, but parthenocarpic fruits in other cultivars. Parthenocarpy of 10 cultivars was evaluated in Aomori and Nagano in 2001 and 2002 by covering emasculated flowers with paper bags (Table 3). The unpollinated treatments (non-pollination) produced no fruit set in 'Starkrimson', but many or some parthenocarpic fruits in the other 9 cultivars. Self-

Table 1. SI index, fruit set and number of seeds formed by self- and cross-pollination with one or two flowers per cluster at the Fujisaki farm in Aomori Prefecture.

Seed parent	Year	Pollen parent	No. of flowers per cluster	No. of flowers pollinated	Initial fruit set (%)	Fruit set (%)	No. of seeds/fruit	No. of seeds/flower	SI index
Bartlett	2000	Flemish Beauty	2	58	93.3	91.4	6.2	5.7 ^z	0.1
		Bartlett	2	30	10.0	3.3	1.0	0.1	
	2001	Flemish Beauty	2	30	96.7	96.7	4.1	4.0 ^z	0.0
		Bartlett	2	30	36.7	36.7	0.0	0.0	
	2002	Grand Champion	2	30	100.0	83.3	8.1	6.8	3.1
		Bartlett	1	30	100.0	100.0	6.5	6.5 ^z	
		Seigneur d'Espéren	1	30	46.7	40.0	0.4	0.2	
Flemish Beauty	2000	Starkrimson	1	10	33.3	26.7	0.0	0.0	0.0
		La France	2	60	100.0	100.0	6.3	6.3	
		Flemish Beauty	2	30	71.7	61.7	3.5	2.2	
	2001	La France	2	30	66.7	50.0	0.0	0.0	0.0
		Flemish Beauty	1	28	100.0	96.4	7.4	6.9 ^z	
	2002	Flemish Beauty	1	29	93.3	93.1	0.0	0.0	0.0
		La France	2	28	100.0	75.0	7.2	5.4	
		Starkrimson	1	28	100.0	96.4	7.4	6.9 ^z	
		Flemish Beauty	1	27	93.3	88.9	0.0	0.0	
		Seigneur d'Espéren	1	30	73.3	65.5	0.0	0.0	
Grand Champion	2000	Bartlett	1	10	100.0	100.0	9.1	9.1	59.4
		Grand Champion	2	30	90.0	73.3	4.4	3.2	
	2001	Bartlett	2	28	85.7	78.6	2.7	2.1	16.4
		Grand Champion	1	15	100.0	100.0	6.9	6.9 ^z	
	2002	Bartlett	1	30	96.7	96.7	4.1	4.1	
		Grand Champion	1	58	100.0	96.6	6.3	6.1 ^z	
La France	2000	Grand Champion	1	69	94.3	85.5	1.2	1.0	0.0
		Flemish Beauty	2	60	86.7	75.0	4.2	3.1	
	2001	La France	2	28	64.3	25.0	0.0	0.0	0.0
		Flemish Beauty	1	29	100.0	82.8	4.6	3.8 ^z	
	2002	La France	1	28	100.0	57.1	0.0	0.0	0.0
		Grand Champion	1	28	100.0	80.0	8.3	6.6 ^z	
Précoce	2000	La France	1	29	100.0	58.6	0.0	0.0	0.0
		Flemish Beauty	2	60	98.3	95.0	5.7	5.4 ^z	
	2001	Précoce	2	30	36.7	26.7	0.4	0.1	1.9
		Grand Champion	2	30	100.0	100.0	7.5	7.5 ^z	
	2002	Précoce	2	28	43.3	25.0	0.0	0.0	0.0
		Flemish Beauty	2	30	100.0	80.0	3.8	3.0	
		Précoce	1	30	100.0	86.7	4.8	4.0 ^z	
		Précoce	1	40	82.5	27.5	0.3	0.1	2.5

^z Number of viable seeds per flower of compatible pollination used for calculation of SI index.

pollination in some cultivars produced parthenocarpic fruits more than non-pollination (Table 1 and 2). These results revealed that European pear cultivars possess autonomic and/or stimulative parthenocarpy.

From June to July, the young parthenocarpic fruits shed in 'Grand Champion', 'Précoce', 'Conference', 'Le lectier', and 'Passe Crassane', but not in 'Bartlett', 'Flemish Beauty', and 'Seigneur d'Espéren'. Hence, parthenocarpy that was expressed differently among cultivars is affected by physiological and environmental conditions (location and year) within the same cultivar (Table 1, 2, and 3). These results suggest that a criterion

eliminating the factor of parthenocarpy is required for judging incompatibility or compatibility in European pear.

Criterion for self-incompatibility and compatibility

Fruit sets below 30% are considered to be an expression of incompatibility in Japanese pear (*P. pyrifolia* Nakai) (Sato et al., 1992). Our data from self- and cross-pollinations with one flower per cluster in 2002 gave almost the same fruit set in 'La France', 'Flemish Beauty', 'Grand Champion', 'Seigneur d'Espéren', and 'Passe Crassane' (Table 1 and 2), which indicated that

Table 2. SI index, fruit set and number of seeds formed by self- and cross-pollination with one or two flowers per cluster at the Nagano Fruit Tree Experiment Station in Nagano Prefecture.

Seed parent	Year	Pollen parent	No. of flowers per cluster	No. of flowers pollinated	Initial fruit set (%)	Fruit set (%)	No. of seeds/fruit	No. of seeds/flower	SI index
Conference	2001	Passe Crassane	2	30	76.7	36.7	1.5	0.6	
		Conference	2	30	90.0	10.0	0.0	0.0	
	2002	Starkrimson	2	30	93.3	83.3	3.4	2.6	
			1	49	98.0	93.9	3.2	3.0 ^z	
La France	2001	Conference	1	28	82.1	35.7	0.0	0.0	0.0
		Passe Crassane	1	30	93.3	93.3	4.0	3.8 ^z	
		La France	1	30	96.7	86.7	0.0	0.0	
	2002	Passe Crassane	2	30	100.0	100.0	8.0	8.0	0.0
			1	58	98.3	98.3	7.9	8.1 ^z	
		La France	1	27	100.0	92.6	0.0	0.0	
Le Lectier	2001	Passe Crassane	2	30	83.3	56.7	2.1	0.8	
		Le Lectier	2	30	50.0	33.3	0.0	0.0	
			1	59	98.3	93.2	6.8	6.6 ^z	
	2002	Passe Crassane	2	30	90.0	83.3	7.3	6.1	0.0
		Le Lectier	1	28	71.4	64.3	0.0	0.0	
			1	28	71.4	64.3	0.0	0.0	
Passe Crassane	2001	La France	2	30	66.7	26.7	0.6	0.2	
		Passe Crassane	2	30	40.0	20.0	0.0	0.0	
			1	58	98.3	86.2	7.6	6.5 ^z	
	2002	La France	2	26	100.0	69.2	7.3	5.1	0.0
		Passe Crassane	1	29	89.7	79.3	0.0	0.0	
			1	29	89.7	79.3	0.0	0.0	
Seigneur d'Espéren	2001	La France	2	28	92.9	39.3	0.7	0.3	
		Seigneur d'Espéren	2	30	93.3	26.7	0.0	0.0	
			1	31	100.0	100.0	7.7	7.7 ^z	
	2002	La France	2	30	100.0	96.7	4.2	4.1	0.0
		Seigneur d'Espéren	1	30	73.3	70.0	0.0	0.0	
			1	30	73.3	70.0	0.0	0.0	
Starkrimson	2001	La France	2	30	46.7	46.7	2.1	1.0	
		Starkrimson	2	30	3.3	3.3	0.0	0.0	
			1	29	96.7	96.6	8.8	8.5 ^z	
	2002	La France	2	30	93.3	93.3	7.5	7.0	0.0
		Starkrimson	1	30	43.3	40.0	0.0	0.0	
			1	30	43.3	40.0	0.0	0.0	

^z Number of viable seeds per flower of compatible pollination used for calculation of SI index.

incompatibility and compatibility cannot be distinguished by the fruit set alone in cultivars with high parthenocarpic potential.

Pollen tubes from incompatible pollen are arrested at the base of the style, whereas those from compatible pollen would reach the ovule and result in fertilization and viable seeds (Sanzol and Herrero, 2002). Therefore, the difference in the number of viable seeds between the self- and cross-pollinated fruits should distinguish incompatible from compatible cultivars. We compared the number of viable seeds per fruit between the self- and cross-pollinated fruits on the cultivars that cross-pollination provided with a more than 80% fruit set. All self-pollinated fruits of 'Grand Champion' had some viable seeds, whereas 'Bartlett' and 'Précoce' had very few. In every cultivar, except 'Grand Champion', self- and cross-pollinations produced 0–1.0 and 3.2–8.8 viable seeds per fruit, respectively. Therefore, the number of viable seeds per fruit is a reliable criterion to

judge incompatibility or compatibility among European pear cultivars. However, this method still has the following problems: (1) it overestimates the number of seeds on the cultivars having a low fruit set with viable seeds such as the self-pollinated 'Bartlett' in 2000, because physiological drop of fruits was not counted; (2) it underestimates the number of seeds on the cultivars expressing parthenocarpy, because seedless fruits were counted.

Instead of the number of viable seeds per fruit, we introduced the concept of counting the number of viable seeds per flower to resolve the above problems. In every cultivar, except 'Grand Champion', the number of viable seeds per flower on self- and cross-pollination was calculated to be 0–0.2 and 3.0–8.5, respectively. Thus, the comparison of viable seeds per flower between self- and cross-pollination provides a better basis for judging self-incompatibility or compatibility.

Self-pollinated 'Grand Champion', 'Bartlett', and

'Précoce' in 2002 contained 1.0, 0.2, and 0.1 viable seeds per flower, respectively. The number of viable seeds per flower in compatible cross-pollinations differed among these cultivars (Table 1 and 2). Our comparison of viable seeds per flower from self-pollination could not distinguish partial self-compatible cultivars from self-incompatible ones. Therefore, the SI index was introduced as the new criterion. The SI index was calculated as a percentage by dividing the number of viable seeds per flower obtained by self-pollination into that resulted from compatible cross-pollination. Because fruit and seed sets are affected by environmental conditions, location, and year, the SI index is calculated from the data at the same location and year. 'Conference', 'Flemish Beauty', 'La France', 'Le lectier', 'Passe Crassane', and 'Seigneur d'Espéren' were self-incompatible because their SI indexes were found to be 0. The SI indexes of 'Grand Champion' were calculated to be 59.4 and 16.4 in 2001 and 2002, whereas those of 'Bartlett' and 'Précoce' were 0 and less than 3.1 in 2001 and 2002, respectively. Consequently 'Grand Champion' is categorized as being partially self-compatible, 'Bartlett' and 'Précoce' as self-incompatible. As SI index can distinguish partial self-compatibility from self-incompatibility, 'Grand Champion' is classified as being partially self-compatible as was 'Fertility' by Crane and Thomas (1939). Using SI index as a criterion, more cultivars will probably fall into this category.

Comparison of the fruit traits between parthenocarpic and seeded fruits

Fruit traits of the parthenocarpic fruits that were compared to those of the seeded fruits showed no significant difference in fruit size of 'La France'. However, the seedless fruits of 'Bartlett', 'Flemish Beauty', 'Conference', and 'Le lectier' tend to be smaller and have a lower soluble solid content than the

seeded ones. Furthermore, most of them were misshapen with a high length/diameter ratio (Table 4). These results indicate that seed formation is necessary for a stable fruit set and good-quality fruit production in European pear cultivars that have parthenocarpic potential.

Cross-incompatibility

Cross-incompatible combinations among the 10 cultivars were investigated preliminarily by cross-pollinations that used 5 flowers for each combination in 2001 (data not shown). Based on these data, when we re-examined some combinations by using one flower per cluster in 2002 (Table 1), we found that 'Bartlett' pollinated with 'Seigneur d'Espéren' pollen, and 'Flemish Beauty' with 'Starkrimson' pollen, yielded a SI index of 0, whereas the pollen of 'Seigneur d'Espéren' and 'Starkrimson' resulted in many viable seeds with 'Flemish Beauty' and 'Bartlett', respectively (Table 1). These results reveal two cross-incompatible combinations between 'Flemish Beauty' and 'Starkrimson', and 'Bartlett' and 'Seigneur d'Espéren'.

With new cultivars being released, paterclinal-incompatibility between cultivars has been increasing (Abe et al., 1996; Sanzol and Herrero, 2002). 'Flemish Beauty' and 'Starkrimson', and 'Bartlett' and 'Seigneur d'Espéren', however, have no parent-offspring relationships. In previous studies, most European pear cultivars have been cross-compatible (Crane and Lewis, 1942; Griggs and Iwakiri, 1954; Modlibowska, 1945), but cross-incompatible relationships seem to exist among other cultivars without parent-offspring relationships.

'Bartlett' and 'Flemish Beauty', assigned as the same *S*-genotype (S_5S_6) by protein analysis (Tomimoto et al., 1996), were cross-compatible in this experiment (Table 1), an indication that these cultivars possessed different *S*-genotypes. This misassignment was probably due to confusion of two different *S*-RNases, S_5 - and S_6 -RNase.

Table 3. Fruit set of parthenocarpic fruit formed by non-pollination with one flower per flower cluster in 10 European pear cultivars.

Location (Prefecture)	Cultivars	Year	No. of flowers treated	Initial fruit set (%)	Fruit set (%)
Aomori	Bartlett	2002	30	46.7	40.0
		2001	30	43.3	43.3
	Flemish Beauty	2002	30	90.0	90.0
		2001	15	13.3	6.7
	Grand Champion	2002	56	90.0	71.4
		2001	29	63.3	46.7
	La France	2002	29	100.0	24.1
		2002	56	100.0	17.9
	Précoce	2002	56	100.0	17.9
	Conference	2002	45	100.0	46.7
Nagano	La France	2001	29	86.2	86.2
		2002	61	98.4	96.7
	Le Lectier	2002	59	49.1	40.7
	Passe Crassane	2002	55	76.3	58.2
	Seigneur d'Espéren	2002	29	69.0	65.5
	Starkrimson	2002	30	0.0	0.0

Table 4. Comparison of the fruit traits between parthenocarpic and seeded fruits.

Cultivars	Origin of Fruits	No. of fruits	No. of seeds per fruit treated	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Rate of Length/diameter	Soluble solids content (Brix)
Bartlett	Parthenocarpic	7	0.0	178.4a ^z	9.1a	6.2a	1.45	10.3a
	Cross-pollinated (× Grand Champion)	14	8.2 ± 0.3	251.5b	9.8a	7.5b	1.31	11.1a
Flemish Beauty	Parthenocarpic	8	0.0	306.1a	9.4a	8.2a	1.15	10.4a
	Cross-pollinated (× La France)	12	7.3 ± 0.4	443.7b	10.5b	9.2b	1.28	11.2b
La France (Nagano)	Parthenocarpic	28	0.0	468.9a	97.8a	99.3a	0.98	n.d. ^y
	Cross-pollinated (× Passe Crassane)	26	7.9 ± 0.5	500.2a	95.3a	101.7a	0.94	n.d.
Conference	Parthenocarpic	9	0.4	188.9a	9.7a	6.6a	1.48	n.d.
	Cross-pollinated (× Starkrimson)	18	2.1 ± 0.5	237.1b	10.4a	7.4b	1.42	n.d.
Le Lectier	Parthenocarpic	8	0.0	334.3a	11.3a	8.3a	1.36	17.5a
	Cross-pollinated (× Passe Crassane)	24	7.4 ± 0.3	436.3b	11.0a	9.5b	1.16	17.9a

^z Different letters between parthenocarpic and cross-pollinated fruits represent significant differences at $P=0.05$ by t -test.^y n.d. : Not determined.

In our study, a new method and criterion were established for judging incompatibility or compatibility in European pear; the pollination with one flower per cluster and the introduction of the SI index as a criterion. Our method and criterion categorized 'Grand Champion' as being partially self-compatible and the others as self-incompatible. Most cultivars possessed parthenocarpic potential, but seed development is required for the production of large, good quality fruits. *S*-genotype assignments in European pear will become very important for the deciding the preferable pollinizers in European pear orchards. Recently, *S*-genotype assignments have been attempted by using PCR methods based on *S-RNase* (Zisovich et al., 2004; Zuccherelli et al., 2002). Our method and criterion will facilitate the discovery of other cross-incompatible combinations, and the confirmation of the *S*-genotypes assigned by *S-RNase* based on PCR methods.

Acknowledgements

We thank Mr. S. Kato, Mr. T. Yamachika, and Ms. M. Minemura (Nagano Fruit Tree Experiment Station) for providing European pear trees.

Literature Cited

- Abe, Y., T. Yoneno, K. Nishimura, M. Ishiguro and I. Sato. 1996. New European pear cultivar 'Yamaen P-1'. J. Japan. Soc. Hort. Sci. 65 (Suppl. 2): 154–155 (In Japanese).
- Crane, M. B. and D. Lewis. 1942. Genetical studies in pears III. Incompatibility and sterility. J. Genet. 43: 31–44.
- Crane, M. B. and P. T. Thomas. 1939. Genetical studies in pears I. The origin and behaviour of a new giant form. J. Genet. 37: 287–299.
- Griggs, W. H. and B. T. Iwakiri. 1954. Pollination and parthenocarpy in the production of Bartlett pears in California. Hilgardia 22: 643–678.
- Kester, D. E., T. M. Gradziel and W. C. Micke. 1994. Identifying Pollen Incompatibility Groups in California Almond Cultivars. J. Amer. Soc. Hort. Sci. 119: 106–109.
- Kobel, F., P. Steinegger and J. Anliker. 1939. Weitere Untersuchungen über die Befruchtungsverhältnisse der Apfel- und Birnsorten. Landwirtschaftliches Jahrbuch der Schweiz 53: 160–191.
- Komori, S., J. Soejima, Y. Ito, H. Bessho, K. Abe and N. Kotoda. 1998. Analysis of self-incompatibility genotypes in some apple cultivars. J. Japan. Soc. Hort. Sci. 67: 917–926 (In Japanese).
- Kubo, T., J. Araya, and N., Kudo. 1989. Pollination Trial on Pears 1. Cross-compatibility among several cultivars. Tohoku Agric. Res. 42: 253–254 (In Japanese).
- Lewis, D. and I. Modlibowska. 1942. Genetical Studies in Pears IV. Pollen-tube growth and incompatibility. J. Genet. 43: 211–222.
- Modlibowska, I. 1945. Pollen tube growth and embryo-sac development in apples and pears. J. Pomol. 21: 57–89.
- Nyékí, J., M. G. Pintér and Z. Szabo. 1994. Recent data on fertilization of pear varieties. Acta Hort. 367: 87–96.
- Onoda, K. and A. Ito. 1987. Cross compatibility in European pear. J. Japan. Soc. Hort. Sci. 56 (suppl 2): 76–77 (In Japanese).
- Rawes, A. N. 1933. Contributions from the Wisley Laboratory LXVIII. – Pollination in Orchards (IX). Summary of investigations on pear pollination. J. Royal Hort. Soc. 58: 288–295.
- Sanzol, J. and M. Herrero. 2002. Identification of self-incompatibility alleles in pear cultivars (*Pyrus communis* L.). Euphytica 128: 325–331.
- Sato, Y., K. Abe, T. Saito and K. Kotobuki. 1992. Selection

- of *S*-gene homozygotes and its utilization for *S*-genotype analysis of 'Osa-Nijisseiki'. J. Japan. Soc. Hort. Sci. 61 (suppl. 2): 16–17 (In Japanese).
- Tehrani, G. and S. K. Brown. 1992. Pollen-incompatibility and self-fertility in sweet cherry. Plant Breed. Rev. 9: 367–389.
- Terami, H., H. Torikata and Y. Shimazu. 1946. Analysis of the sterility factors existing in varieties of the Japanese pear (*Pyrus serotina* Rehd. var. *culta* Rehd). Studies Hort. Inst. Kyoto Imp. Univ. 3: 267–271 (In Japanese with English summary).
- Tomimoto, Y., T. Nakazaki, H. Ikehashi, H. Ueno and R. Hayashi. 1996. Analysis of self incompatibility-related ribonucleases (*S*-RNases) in two species of pears, *Pyrus communis* and *Pyrus ussuriensis*. Scientia Hort. 66: 159–167.
- Zisovich, A. H., R. A. Stern, S. Shafir and M. Goldway. 2004. Identification of seven *S*-alleles from the European pear (*Pyrus communis*) and the determination of compatibility among cultivars. J. Hort. Sci. Biotech. 79: 101–106.
- Zuccherelli, S., P. Tassinari, W. Broothaerts, S. Tartarini, L. Dondini and S. Sansavini. 2002. *S*-Allele characterization in self-incompatible pear (*Pyrus communis* L.). Sex. Plant Reprod. 15: 153–158.

セイヨウナシ 10 品種における単為結果性と自家および交雑不和合性

守谷友紀¹・高井良裕¹・岡田和馬¹・伊藤大雄²・塩崎雄之輔²・中西テツ^{1,3}・高崎剛志³

¹ 神戸大学大学院自然科学研究科 657-8501 神戸市灘区六甲台町

² 弘前大学農学生命科学部藤崎農場 038-3802 青森県藤崎町

³ 神戸大学農学部 657-8501 神戸市灘区六甲台町

摘 要

セイヨウナシ (*Pyrus communis* L.) の自家および交雑不和合性は結実率や種子数により判定されてきたが、それらの評価は明確ではない。本研究では交雑による不和合・和合の判定方法を確立するため、セイヨウナシ 10 品種を用いて 1 花そう 1 花の除雄無受粉、自家受粉および他家受粉を行い、各品種の単為結果性、自家不和合性および品種間の交雑不和合性を調査した。ほぼすべての品種が単為結果性を有し、結実率による不和合・和合の識別はできなかった。しかし、新たに提案した self-incompatibility (SI) index ((評価対象の交配における交配花数当たりの充実種子数)/(和合交配におけ

る交配花数当たりの充実種子数) × 100) により不和合・和合の判定が可能になった。その結果、'グラント・チャンピオン' は部分的自家和合性であり、他の品種は自家不和合性であることが明らかになった。有種子果実の品質は単為結果果実よりも優れており、単為結果性を有するセイヨウナシでも安定的な良質果実の生産には和合花粉の受粉が必要であることが明らかになった。'フレミッシュ・ビューティー' と 'スタークリムソン' および 'パートレット' と 'セニョール・デスペラン' の二つの組み合わせが交雑不和合を示した。