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EVALUATION OF SEVERAL ASIAN PEAR CULTIVARS IN THE CLIMATIC CONDITIONS OF LOWER SILESIA

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ABSTRACT

The Asian pear tree (Nashi), originated in China and Japan, where it is commonly grown. In Europe, in Poland in particular, it remains almost unknown, despite the fact that its cultivation has been proven to be possible there. The aim of the experiment – carried out between 2008 and 2015 at the Fruit Experimental Station Samotwór, next to Wrocław – was to evaluate the growth intensity and yielding of several Asian pear tree cultivars: 'Kosui', 'Shinseiki', 'Nijisseiki', 'Chojuro', 'Hosui', and 'Shu Li'; as well as the quality and biological value of their fruits. 'Conference', which is widespread in Europe, was chosen as the control variety. 'Conference', 'Shu Li', and 'Hosui' showed highest growth intensity, whereas the trees of 'Shinseiki' were the smallest. In terms of yields over the period of eight years following the planting, 'Chojuro' and 'Shinseiki' performed best, while the least fruits were obtained from the 'Nijisseiki' cultivar. Significantly heaviest and biggest fruits were collected from the Chinese 'Shu Li' cultivar. In 2012, Nashi fruits had similar carotenoid, calcium, and magnesium contents as the fruits of 'Conference'.

Key words: Nashi, *Pyrus pyrifolia*, biological value, blooming, yield, growth

INTRODUCTION

The Asian pear tree (Nashi), also known as the Oriental or Japanese pear tree, originated in China. It was cultivated there as long as three thousand years ago. In recent years, red-coloured cultivars of the species were discovered in the Yunnan and Sichuan provinces. Nashi fruits are rich in fiber, vitamin C, folic acid, potassium, magnesium, and other minerals. Their consumption promotes recovery from urinary and gastrointestinal ailments [Cieślik and Gębusia 2012].

In the last few decades, Asian pear tree cultivars were grown not only in Asia (mainly in China, Japan, and Korea), but also in commercial orchards of western United States, Canada, France, and Italy; and in the southern hemisphere – in Australia, New Zealand, Chile, and Brazil [Griggs and Iwakiri 1977, Rohitha 1989, Faoro and Nakasu 2002, Pitera et al. 2009]. In New Zealand, the most widespread variety is 'Hosui' and in Australia – 'Nijisseiki' [White 2002]. In Japan, over 1200 cultivar names have been recorded, and wild trees are still preserved. 'Kosui' is the most important cultivar there, making 40% of the plantings. Japanese consumers seek Nashi that are sweet, juicy, and have a nongritty texture, as well as a low price. In order to reduce production costs, a new breeding program has been started. It aims at introducing self-compatibility and self-thinning genes, which would remove the need for artificial pollination and for manual thinning of fruitlets [Kajiura

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2002, Saito 2016]. In Europe, consumer demand for Asian pears remains minimal. However, this is starting to change [Pitera and Odziemkowski 2004].

The beginning and the end of dormancy of the Asian pear tree are determined primarily by temperature. Trees suffer easily from cold and frosts, but at the same time require exposure to low temperatures in the winter period. Under a mild winter scenario, the blooming, bud break, and vegetative growth of Nashi pear trees become prolonged, and physiological disorders, resulting in a reduced number of flowers per bud, develop [Petri and Herter 2002]. There is a high variation among cultivars with respect to the minimum required length of exposure to cold. For instance, 'Nijisseiki' needs more than 700 hours, whereas for 'Kosui', 400 hours suffice [Faoro and Nakasu 2002]. Some of the Asian pears, such as 'Hosui' and 'Kosui', are sensitive to fire blight (*Erwinia amylovora*) and other bark and wood diseases – especially in conditions of a humid climate [Griggs and Iwakiri 1977, Petri et al. 2008, Walsh et al. 2015, 2016]. On the other hand, they exhibit a high degree of resistance towards pear scab (*Venturia pirina*) [Villalta et al. 2005, Pitera et al. 2010]. As demonstrated by Molenda et al. [2009], fruit buds of Nashi pear trees are much more susceptible to apple blossom weevil (*Anthonomus pomorum* L.) infestation than in case of European pear trees.

Asian pears are precocious and very productive, with trees blooming and bearing fruit as early as in the second year after the planting [Walsh et al. 2015]. Due to the tendency towards an excessive fruit set, they require thinning of fruitlets. This intervention results in a clear improvement of the yield quality [Buler et al. 2008]. Trees grafted on a dwarf quince rootstock within several years develop symptoms of severe physiological incompatibility, which ultimately leads to their death. For this reason, only pear seedlings should be used as a rootstock [Bielicki et al. 2009]. Unlike European pear, such as 'Conference', Japanese pears are round and ripen on the tree. They are firm, crispy, very juicy, and tend to develop a russet skin [Kajiura 2002]. These attractive fruits remain almost unknown on the Polish market, yet their atypical appearance and intriguing refreshing taste draw the attention of the consumers [Kopera et al. 2005].

The aim of the presented experiment – which was carried out between 2008 and 2015 at the Fruit Experimental Station in Samotwór next to Wrocław – was to evaluate growth intensity as well as yield and external and internal quality of fruits obtained from several Asian pear tree cultivars grown in the climatic and soil conditions of the Lower Silesia. The Wrocław area is among the warmest regions of Poland, which makes it suitable for growing of species characterized by high temperature requirements, such as the peach, pear, and sweet cherry.

MATERIAL AND METHODS

The experiment was established in the spring 2008 at the Fruit Experimental Station in Samotwór next to Wrocław (51°06'12"N; 16°49'52"E) in the Lower Silesia. The orchard was located on a fawn soil consisting of slightly sandy, light clay over medium clay and representing the IIIb class of the Polish economical soil classification. The research was carried out on the one-year-old maidens of 'Kosui', 'Shinseiki', 'Nijisseiki', 'Chojuro', 'Hosui' (*Pyrus pyrifolia* Nakai) and 'Shu Li' (*Pyrus bretschneideri*) Asian pear cultivars budded on *Pyrus communis var. caucasica* Fed. seedlings. The standard cultivar was well known and widely cultivated 'Conference' (*Pyrus communis* L.) budded on the same rootstock. The planting pattern followed the randomized block design with four replications and 5 trees per plot. The in-row tree spacing was 1.7 m whereas the distance between rows equalled 3.5 m (1681 trees per hectare). In the first three years after planting, tree canopies were formed as a spindle with minimum pruning after blooming time and shoots maximally bending down by using concrete weights. The trees were annually pruned soon after the petal fall, starting from the fourth year following the orchard establishment. No irrigation was applied. The fruitlets were hand thinned in some years but mainly in upper part in the leaders. The orchard floor management system consisted of herbicide fallow in the tree rows and sward in the alleyways – both introduced in the year of the tree planting. The chemical protection was carried out according to up-to-date recommendations of the Orchard Protection Program.

In 2008–2015, tree growth, bloom abundance and fruit yield per tree as well as mean fruit weight, size and biological value were assessed. For the purpose of data collection, each cultivar was harvested following a single-picking schedule, and the fruit from each tree were collected into separate boxes. To determine external crop quality, for each experimental plot two boxes of pears were randomly selected and a sample of 20 fruits per tree was taken from them. This was followed by weighting the fruits, and in 2012–2014 fruit diameters were recorded. In 2012, the biological value of fruit was assessed. For chemical analysis, 4–5 pieces of fruit were randomly collected from each replication. Soluble solids (extract), vitamin C and polyphenols contents were determined immediately after harvest in fresh fruit matter. Chemical analysis of carotenoids, K, Ca, Mg and P contents were done after the fruit drying. The content of the following parameters was determined: soluble solids – using an Abbe refractometer, vitamin C – the titration method (PN-90/A-75101/11), carotenoids – the spectrophotometric method, and polyphenols – the Folin-Ciocalteu's reagent method. The concentrations of P and Mg were determined colourimetrically, in 2% acetic acid, with the use of a universal method developed by Nowosielski, whereas the levels of K and Ca were measured by flame photometry.

In 2010–2015, bloom abundance was rated for each tree on a scale of 0 to 5, where 0 = no bloom, and 5 = very abundant bloom. Each year in mid-October, the extent of vegetative growth was assessed by measuring trunk circumference 30 cm above bud union and calculating TCSA values as well as their two-year increments. In autumn 2011, 2013 and 2015 tree height and canopy width in two directions were recorded. Volume of canopy was calculated using a formula for cone volume. The last set of TCSA together with the 2009–2015 fruit yield sums were used to calculate of cumulative yield efficiency coefficients (CYEC), which were obtained at the end of the study.

The collected experimental data were subjected to statistical analysis based on the analysis of variance (ANOVA) approach involving a model appropriate for the randomized block design. Significant differences at the $\alpha = 0.05$ level were obtained using the Duncan's multiple range test.

RESULTS AND DISCUSSION

The most intensive vegetative growth, given by the number and total length of annual shoots, canopy volume, and trunk cross-sectional area, was obtained in case of the control cultivar 'Conference' (tab. 1). Studies by other authors [Buler et al. 2008, Bielicki et al. 2009, Pitera et al. 2010] corroborate the significantly higher growth intensity of the European 'Conference' variety with respect to Asian pear trees. Pitera and Odziemkowski [2004], Reighard and Ouellette [2008], and Necas et al. [2015] observed strong growth of 'Hosui' trees. In the presented study, the growth of the 'Shinseiki' trees was the weakest. 'Nijisseiki' and 'Chojuro' developed trunks of a similar cross-sectional area and growth intensity measured over the two-year period. Weak vegetative growth of these cultivars was noted also by other authors [Larsen and Higgins 1998, Pitera et al. 2009].

In the conditions of south-western Poland, the investigated Asian pears bloomed for about eleven days, which is in accordance with results of other studies [Hodun et al. 2000, Reighard et al. 2008]. In the 2012–2015 period, the European 'Conference' cultivar developed flowers at a later date than the Nashi. The delay, which ranged from three ('Kosui' and 'Nijisseiki') to as many as eight days ('Shinseiki'), explains the higher sensitivity of Asian pear trees to spring frosts (tab. 2). In contrast, in the study by Pitera and Odziemkowski [2004], the bloom pattern of 'Conference' trees was similar to the one of Nashi, with observed differences between the cultivars not exceeding two days. Among the Asian pear trees, 'Shinseiki' and 'Chojuro' were the first, whereas 'Kosui' and 'Nijisseiki' — the last to develop flowers. A similar order of tree bloom commencement was noted by Larsen and Higgins [1999], Hodun et al. [2000], and Necas et al. [2015]. In subsequent years of the research, flowering of the Asian pear trees did not exhibit an excessive tendency towards alternated fruit bearing. The only exception was 'Nijisseiki'. In 2014, i.e. in the seventh year following the orchard establishment, the trees of this cultivar developed a small number of flowers, and fruit yields were very poor.

Table 1. Biometric measurements of some Asian pear cultivars on Caucasian pear seedlings

Cultivar	Annual shoots			Trunk cross-sectional area TCSA (cm^2)		Canopy volume (m^3)		
	(nr $tree^{-1}$) 2008–2010	(cm $tree^{-1}$) 2008–2010	mean length (cm)	autumn 2015	increment 2013–2015	autumn 2011	autumn 2013	autumn 2015
'Conference' – standard	128.4 d*	3550 c	27.6 a	80.7 d	25.2 d	3.0 a	4.1 ab	6.0 b
'Kosui'	68.6 ab	2682 b	39.1 c	49.0 bc	16.4 b	3.5 a	3.6 a	4.6 a
'Shinseiki'	68.3 ab	1826 a	26.7 a	36.7 a	11.7 a	2.8 a	3.4 a	4.4 a
'Nijisseiki'	54.9 a	2075 ab	37.8 c	39.0 ab	12.2 a	3.4 a	3.6 a	4.4 a
'Chojuro'	76.7 bc	2498 ab	32.6 b	39.8 ab	12.0 a	3.1 a	3.8 ab	4.2 a
'Hosui'	95.7 c	3710 c	38.8 c	52.8 c	16.6 b	3.9 a	4.3 ab	5.2 ab
'Shu Li'	68.6 ab	2448 ab	35.7 bc	54.4 c	20.2 c	4.0 a	4.7 b	6.4 b

* Means indicate by the same letter within the columns do not significantly differ at $P \leq 0.05$ according to Duncan's t-test

Table 2. Blooming intensity of some Asian pear cultivars on Caucasian pear seedlings

Cultivar	Full bloom date (day/month) 2012–2015	Mean number of flowers (nr $tree^{-1}$) 2009	Blooming intensity (scale 0–5)					
			2010	2011	2012	2013	2014	2015
'Conference' – standard	14.IV to 07.V	0.3 a*	1.1 a	2.8 b	2.9 b	2.5 a	2.6 c	3.2 a
'Kosui'	11.IV to 06.V	69.5 bc	2.7 b	3.5 c	3.3 c	3.2 bc	2.7 c	3.8 bc
'Shinseiki'	06.IV to 03.V	72.8 c	2.8 b	3.4 c	3.4 cd	3.1 b	2.8 c	3.5 ab
'Nijisseiki'	11.IV to 06.V	32.0 ab	1.2 a	2.5 ab	2.1 a	3.3 bc	0.7 a	3.8 bc
'Chojuro'	07.IV to 04.V	124.4 d	3.9 c	3.6 c	3.7 d	3.4 c	3.4 d	3.7 ab
'Hosui'	09.IV to 05.V	25.6 a	2.6 b	2.2 a	2.2 a	3.7 d	2.0 b	4.0 bc
'Shu Li'	09.IV to 05.V	3.0 a	2.5 b	2.7 b	2.6 b	3.3 bc	2.3 bc	4.3 c

* see Table 1

Table 3. Yielding and crop efficiency coefficient (CEC) of some Asian pear cultivars (year of tree planting – the spring 2008)

Cultivar	Yield (kg $tree^{-1}$)							Cumulative yield (kg $tree^{-1}$) 2009–2015	CYE (kg cm^{-2}) 2008–2015
	2009	2010**	2011**	2012	2013	2014	2015		
'Conference' – standard	0.0 a*	0.8 a	2.0 c	17.4 ab	22.8 a	21.3 c	20.1 ab	84.4 a–c	1.05 a
'Kosui'	1.5 b	3.4 b	1.6 c	21.3 b	30.0 a	20.3 bc	17.1 a	95.2 bc	1.94 d
'Shinseiki'	2.9 c	5.2 c	1.8 c	21.8 b	30.9 a	23.2 c	23.7 bc	109.5 cd	2.98 e
'Nijisseiki'	1.9 b	1.3 a	1.4 bc	13.7 a	27.3 a	1.6 a	17.4 a	64.6 a	1.66 c
'Chojuro'	2.7 c	1.5 a	0.4 ab	33.9 c	31.3 a	29.3 c	28.5 c	127.6 d	3.21 e
'Hosui'	0.7 a	1.9 ab	0.3 a	19.2 ab	41.6 b	4.1 a	19.8 ab	87.6 a–c	1.66 c
'Shu Li'	0.2 a	1.2 a	0.0 a	15.8 ab	24.6 a	9.6 ab	25.4 bc	76.8 ab	1.41 b

* see Table 1
** strong spring frost

Although Japanese cultivars, especially 'Kosui' and 'Nijisseiki', are partially self-pollinating, they still required cross-pollination for obtaining a commercially satisfactory crop of fruits [Griggs and Iwakiri 1977, Rohitha 1989]. A cool and wet weather in the blooming period can decrease tree yields by negatively affecting the activity of pollinating insects. Fruit bearing of pear trees can be substantially impaired also by spring frosts. Between 2009 and 2015, night air temperature in the flowering period almost every year descended to 1–2 degrees Celsius below zero. Moderate temperature drops of this kind can be viewed as beneficial, as they contribute to natural flower thinning, without negatively affecting yields. However, on 23rd April 2010, the temperature dropped to –4°C, and on 4th May of the following year — to as little as –5°C, causing a severe damage of not only flowers, but also fruitlets. In those two years, very poor yields were obtained from all of the investigated cultivars, including the European 'Conference'. The Asian pear trees began to bear fruit as early as in the 2nd–3rd year following the planting, 1–2 years sooner than 'Conference' did (tabs 2 and 3). Precocious yielding of Asian cultivars with respect to European ones grafted on *Pyrus caucasica* seedlings was noted also by Pitera and Odziemkowski [2004] and Bielicki et al. [2009]. In the presented study, the highest yields over the period of eight years following the orchard establishment were obtained from the 'Chojuro' and 'Shinseiki' cultivars, whereas the Japanese 'Nijisseiki' gave the smallest crop. This pattern is in agreement with the findings reported by Larsen and Higgins [1998], Petri et al. [2008], and Bielicki et al. [2009]. In contrast, Buler et al. [2008] observed higher yields in case of 'Nijisseiki' than 'Chojuro'. Similarly, the poor yields obtained from the 'Hosui' cultivar do not agree with earlier findings by Petri et al. [2008] and Pitera et al. [2010]. Such small amounts of fruits were collected by [Tabakov et al. 2002] in the conditions of Bulgaria. The cumulative yield coefficient was significantly highest for 'Chojuro' and 'Shinseiki'; and lowest for the European 'Conference' cultivar (tab. 3). High productivity of the above mentioned Asian cultivars is confirmed by other authors [Larsen and Higgins 1999, Tabakov et al. 2002, Pitera et al. 2010].

The investigated cultivars differed substantially in terms of the timing of fruit maturation (tab. 4). Fruits from 'Kosui' and 'Shinseiki' were the first to be picked (usually, at the end of August), whereas the ones from the Chinese 'Shu Li' cultivar – the last (first decade of October). Based on the research by the Institute in Skierniewice [Hodun et al. 2000], 'Kosui' was classified as an early, 'Nijisseiki' as a midearly, while 'Chojuro' and 'Hosui' – as mid-late cultivars. The late maturation of the varieties bred in China was confirmed in American studies [Reighard et al. 2008]. In another experiment, which was carried out in eastern United States, the 'Kosui' fruit harvest took place on average six days later than in case of the 'Hosui' variety [Walsh et al. 2016]. In 2008, at the Warszawa-Wilanów and Warszawa-Ursynów research stations the cultivars 'Shinseiki', 'Chojuro', and 'Hosui' reached the harvest maturity stage about a week later than in Samotwór next to Wrocław [Pitera et al. 2009]. In the presented experiment, the significantly heaviest and biggest fruits were collected from the trees of the Chinese, late-maturing 'Shu Li' variety (192 g), whereas 'Nijisseiki' and 'Kosui' developed smallest pears (99 g and 115 g, respectively). In terms of quality, the fruits were comparable to the ones obtained at the Warszawa-Wilanów station, but worse in comparison to the crop from the Ursynów station [Pitera et al. 2009]. In other experiments, mean weight of fruits of Asian cultivars was much higher, in many cases exceeding 200 g, or even 300 g [Faoro and Nakasu 2002, Reighard et al. 2008, Faoro and Orth 2010, Sakamoto et al. 2016, Shen et al. 2016]. Such large fruits can be obtained only in regions characterized by the optimal climate, i.e. much warmer than the one found in Poland, and with radical fruit thinning. Without this operation, the crop quality of Asian pear trees deteriorates substantially [McArtney and Wells 1995, Tabakov et al. 2002, Buler et al. 2008].

Table 4. Fruit quality of some Asian pear cultivars on Caucasian pear seedlings

Cultivar	Harvest time (day/month) 2012–2015	Mean fruit weight (g) 2010–2015	Mean percentage of fruit with the diameter (2012–2014)			
			> 8.0 cm	7.0–8.0 cm	6.0–7.0 cm	< 6.0 cm
'Conference' – standard	17 to 23.IX	172 e*	3.0	25.1	62.4	9.5
'Kosui'	28.VIII to 09.IX	115 b	0.4	12.4	48.2	39.0
'Shinseiki'	28.VIII to 09.IX	140 c	0.8	32.6	54.5	12.1
'Nijisseiki'	28.VIII to 16.IX	99 a	0.5	9.8	52.9	36.8
'Chojuro'	10 to 23.IX	155 d	0.4	31.2	58.2	10.2
'Hosui'	10 to 23.IX	146 cd	19.9	38.1	35.2	6.8
'Shu Li'	03 to 08.X	192 f	31.5	44.0	22.9	1.6

*see Table 1

Table 5. Biological value of some Asian pear cvs. fruit (2012)

Cultivar	Extract (% f.m.)	Vitamin C (mg kg^{-1} f.m.)	Carotenoids (mg kg^{-1} d.m.)	Polyphenols (g kg^{-1} f.m.)	Macronutrients (g kg^{-1} d.m.)			
					K	Mg	Ca	P
'Conference' – standard	13.4 d*	111.2 c	0.61 ab	1.09 a	7.28 a	1.35 b	4.56 a	0.68 a
'Kosui'	12.9 cd	62.3 a	0.59 ab	1.21 ab	8.25 ab	1.08 ab	4.56 a	1.03 c
'Shinseiki'	10.3 a	61.9 a	0.33 a	1.37 a–c	8.19 ab	0.73 a	4.31 a	0.87 b
'Nijisseiki'	11.5 b	66.4 ab	1.02 b	1.44 a–c	10.00 c	1.16 b	4.50 a	1.09 c
'Chojuro'	11.9 bc	64.4 ab	0.51 ab	1.73 cd	7.13 a	1.08 ab	4.50 a	0.77 ab
'Hosui'	12.2 bc	71.9 b	0.87 ab	1.54 b–d	8.81 bc	1.42 b	4.44 a	0.77 ab
'Shu Li'	12.0 bc	115.2 c	0.37 a	1.90 d	8.56 b	1.10 ab	4.31 a	0.68 a

* see Table 1

In comparison to 'Conference', in 2012 Nashi fruits were characterized by a similar content of carotenoids, calcium, and magnesium but a lower content of extract and vitamin C (with the exceptions of, respectively, 'Kosui' and 'Shu Li') – tab. 5. Similarly, in the experiments by Kopera et al. [2005] and Yim and Nam [2016], European pears had significantly higher concentrations of extract with respect to Nashi fruits. The observed patterns do not agree with the findings of Iranian authors [Arzani et. al. 2008]. Among the investigated Asian pear tree cultivars, the highest concentration of extract – similar to 'Hosui', 'Shu Li' i 'Chojuro' – was found in the fruits of 'Kosui' (12,9%), whereas 'Shinseiki' had least extract (10,3%). Similar results were obtained by Faoro and Orth [2010] and Sakamoto et al. [2016] with regard to the 'Kosui', 'Hosui', and 'Nijisseiki' cvs. Soluble sugar content in fruits from other research centers was both lower (the cultivars: 'Chojuro', 'Nijisseiki', 'Kosui, 'Hosui', 'Shinseiki' [Chen et al. 1987, McArtney and Wells 1995, Larsen et al. 2013, Shen et al. 2016]) and higher ('Nijisseiki', 'Shinseiki', 'Chojuro' [Chen et al. 1987, Kopera and Mitek 2003, 2004]). In the presented study, the fruits of 'Chojuro', 'Hosui', and 'Shu Li' had more polyphenols, whereas

'Kosui', 'Shinseiki', and 'Nijisseiki' – more phosphorus than pears collected from 'Conference'. The highest potassium concentration was found in case of 'Nijisseiki' and 'Hosui'. In their study, Kopera and Mitek [2003] reported a lower content of polyphenolic substances in the fruits of 'Chojuro' and 'Hosui', and a higher one in case of the 'Shinseiki' cultivar. According to Kopera et al. [2005], polyphenol concentration was highest in case of 'Chojuro' (a significant difference with respect to 'Conference'), and lowest in case of 'Shinseiki'. A similar pattern among the Asian cultivars was noted in the presented study. However, the differences could not be statistically confirmed. In Iranian research, Asian pears had more polyphenols, vitamin C, and calcium than European ones [Arzani et al. 2008]. This observation (polyphenols) was in accordance with findings obtained in Korea [Yim and Nam 2016]. The authors of the same study reported no significant differences regarding calcium and magnesium contents between Asian and European varieties. Among the eight Nashi cultivars, only two had significantly less potassium than in case of *Pyrus communis*. The results pertaining to phosphorus and carotenoid contents could not be compared with other research due to the lack of relevant data in the available literature.

CONCLUSIONS

1. During eight years of the research, based on yield, CYE and mean fruit weight, the 'Chojuro' and 'Shinseiki' Asian pear tree cultivars occurred to be most suitable for commercial cultivation in the climatic and soil conditions of the Wrocław area (Lower Silesia).

2. In comparison to the Nashi pear trees, the European 'Conference' cultivar was in general characterized by a higher growth intensity, comparable yields, and (with the exception of 'Shu Li') larger fruits.

3. Based on the one-year observation, the carotenoid, calcium, and magnesium contents found in the Asian and the European pears were similar. The latter had more extract and vitamin C (with the exception of 'Shu Li').

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