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Evaluation of certain pomological and phenological traits of selected asian pear varieties growing in Middle European conditions

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Abstract: The cultivation and breeding of new pear tree varieties have great potential, especially with the changing climate. The introduction of genetic resources and varieties from regions with a high genetic diversity can have a positive effect on the cultivation of pear trees in our region. In this experiment, a total of 23 Asian pear varieties originating from Japan and China were assessed. Based on the values obtained, the varieties were sorted, and suitable varieties for the conditions of the Czech Republic were selected. The early-maturing varieties that proved to be promising were 'Shinseiki' and 'Zao Su Li' due to their refreshing juiciness, plasticity and ease of cultivation. generally low demand. The 'Shinseiki' bears medium- to small-sized fruits (103 g on average). The size of the fruits of the evaluated cultivar 'Zao Su Li' can reach very large sizes (255 g on average). The medium-maturity varieties suitable for the conditions of the Czech Republic were 'Hosui' and 'Dangshansu Li' (ripening on the September 11–19 on average) and another interesting variety, 'Kirgizkaja zimnaja'. Other suitable medium-maturity varieties are 'Nijisseiki', 'Sha Li' and 'Pung Su'. Of the assessed late-maturing varieties, the promising ones were 'Ya Li' and 'Mut Chen', especially due to their relatively high storability under cold storage.

Keywords: *Pyrus*; pomological traits; phenology; fruit quality; Nashi

Pear are among the most important fruit tree species that have been cultivated in Europe and Asia for more than two to three thousand years. Pear trees are cultivated in all the temperate zone regions, which constitutes more than 50 countries (Bell 1991; Bell et al. 1996). Hedrick (1921) divided pear trees into two main groups: European and Asian. Asian pear trees are then divided into five main groups: Japanese pears (*Pyrus pyrifolia* (Burm.f.) Nakai.), Chinese white pears (*Pyrus* × *bretschneideri* Rehder), Chinese sand pears (*Pyrus pyrifolia* (Burm.f.) Nakai.), Xinjiang pears (*Pyrus* × *sinkangensis* T.T. Yu) and Ussurian pears (*Pyrus ussuriensis* Maxim. ex Rupr) (Kikuchi 1948; Shen 1980; Teng 2004).

According to the Food and Agriculture Organization of the United Nations (FAO 2018) database, the overall global production of pears reached 24.1 million tonnes in 2017. The largest producer, China, produced 16.5 million tonnes, and Europe produced 2.8 million tonnes, 2.4 mil. tonnes of which was produced by EU countries. China's share of the global production of pears was, thus, 68.5%, Europe's share was 11.6%, and the EU countries' share was 10%. The countries with the highest production of pears in Europe were Italy (772.5 thousand tonnes), Spain (361 thousand tonnes), the Netherlands (330 thousand t), Belgium (302 thousand tonnes) and Portugal (202 thousand tonnes) in 2017.

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According to the United States Department of Agriculture (USDA 2019) estimates, the total global production of pears reached 19.4 million t in 2018, 13.1 mil. t of which was produced by China. Spring frosts during the flowering stage, especially in the main production areas such as Hebei and Shandong, were the factor contributing to the significant decrease in China's production, which dropped by as much as 20% from the average production.

The trend of pear production over a 10-year period (2008–2017) shows an increase in the total global production of 12.8% (2008 – 21.1 mil. tonnes; 2017 – 24.2 mil. tonnes), a 17% increase in China's production (2008 – 13.7 mil. tonnes; 2017 – 16.5 mil. tonnes) and a 3.6% increase in Europe's production (2008 – 2.7 mil. tonnes; 2017 – 2.8 mil. tonnes).

High-quality fruits are the main objective of the efforts of all plant breeders and growers, as well as the characteristics that consumer demands also. The parameters that define the quality of a fruit are among others, the following critical characteristics: the fruit weight, fruit colour, and sugar and acid contents (their ratio). Other important parameters include the taste, structure (texture), appearance and juiciness (Hancock, Lobos 2008). The physical characteristics of a fruit are very important for the processing, transport, sorting and packaging of the fruits (Ertekin et al. 2006).

Since Asian pears are mainly cultivated for direct consumption, the attractive appearance of the fruit is of high importance, with the colour of the fruit being the most important factor. The colour spectrum of a pear's skin is wide, with the most important ground or over colours being from green, yellow-green, yellow brown, yellowish red brown to red brown (Thibault et al. 1983; UPOV 1994, 2000). red and brown. The preferred pear varieties are those with a yellow or green skin, but mainly those with a red skin. The attractiveness of the fruit is chiefly determined by the brightness of the skin colour, not its depth. According to Kappel et al. (1995), the skin colour is important in evaluating the attractiveness of the fruit. The results published in their work indicate that yellow is the colour that consumers consider the most appealing in pears, possibly with a weak, blurred, red overcolour. According to Manning (2009), whose data still apply, the research shows that the most attractive varieties, from the customer's point of view, are those with a yellow-green skin with a touch of pink, such as 'Flamingo' and 'Rosemarie'. The varieties that were evaluated as the worst were those with purple ('Red d´Anjou') and brown (3D-37-38 hybrid) skin colours.

Another critical attribute is the fruit size, which is a very important factor for both pear growers and consumers. In Asian pear varieties, the fruit size ranges from 35 g to 1 000 g. Varieties with very large (an average size larger than 300 g), large (larger than 200 g), medium-sized (from 100 g to 200 g) and small (smaller than 100 g) fruits constitute approximately 11.7%, 18.3%, 51.5% and 18.5% of Asian pear varieties, respectively. Notably, the varieties with large and very large fruits originate from *Pyrus* × *bretschneideri* Rehder and *Pyrus pyrifolia* (Burm.f.) Nakai. (Jun, Hongsheng 2002).

In fruit production, it is usually the early-ripening varieties that bring growers higher profits. This also applies to pears (both Asian and European). In China, the period of ripening of Asian pear varieties lasts from the end of July until the end of October. The Institute of China Fruits carried out a mapping of 715 Asian pear tree varieties and discovered that the percentage of early-ripening varieties was only 8.5%, that of middle-ripening varieties was 27.7%, and that of late-ripening varieties was 63.8%. One of the methods of obtaining very early- and early-ripening varieties is crossbreeding Asian varieties with early European varieties (*Pyrus communis* L.) (Cao et al. 2000).

MATERIAL AND METHODS

In this work, 26 pear varieties were studied (23 Asian pear varieties and 3 European pear varieties), which are listed in Table 1. The pear trees were planted in the experimental orchard of the Faculty of Horticulture at Mendel University in Brno located in the municipality of Lednice (48°47'59''N 16°48'12''E) in Southern Moravia, Czech Republic (170 m a.s.l.). Lednice is one of the warmest regions in the Czech Republic, with an average annual temperature of 9.1 °C and an average annual rainfall of 422 mm. The study was carried out from 2012 to 2016. Pear seedlings (Lodder Unterlagen Ltd. Germany) were used as the rootstock, and the trees were pruned as free spindles with a spacing of 5 m (between rows) × 3 m (within rows). The orchard was equipped with supplementary irrigation. Fruit thinning was performed every year, where 2 fruits per flower cluster were left. The flower clusters were separated 10–15 cm from each other on the shoots.

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Table 1. The name, species, pedigree and origin of the pear cultivars assessed in the experiment

Name	Species	Pedigree	Origin
Ju Li	*P.* × *bretschneideri* (probably)	unknown	unknown
Zao Su Li	*P.* × *bretschneideri*	Ping Guo Li × Shenbuzhi	China 1977
Shinseiki	*P. pyrifolia*	Nijisseiki × Chojuro	Japan 1945
Williams	*P. communis*	Chance seedling	England 1770
Clapp's favourite	*P. communis*	Flemish Beauty × Williams	Massachusetts (USA) 1860
Pung Su	*P. pyrifolia* (probably)	unknown	unknown
Man San Gill	*P. pyrifolia* (probably)	unknown	unknown
Kumt Ghant Chu	*P. pyrifolia* (probably)	unknown	unknown
Hosui	*P. pyrifolia*	Ri-14 (Kikusui × Yakumo) × Yakumo	Japan 1954
Chojuro	*P. pyrifolia*	chance seedling	Japan 1889
Jin Hua	*P.* × *bretschneideri*	unknown	unknown
Kirgizkaja zimnaja	*P. communis* (probably)	unknown	unknown
Talgarskaja krasavica	*P. communis* (probably)	chance seedling Forest Beauty	Kazakhstan
Xue Hua Li	*P.* × *bretschneideri*	unknown	unknown
Sha Li	*P. pyrifolia*	old special, unknown	China
Nijisseiki	*P. pyrifolia*	chance seedling	Japan 1898
Kumoi	*P. pyrifolia*	Ishii Wase × Yakumo	Japan 1955
Shinko	*P. pyrifolia*	chance seedling Nijisseiki	Japan 1941
Wu Jiu Xiang	interspecific hybrid	Ya Li × Williams	China
Conference	*P. communis*	Seedling of Leon Leclerc de Laval	England 1885
Ya Li	*P.* × *bretschneideri*	old special, unknown	China
Ping Guo Li	*P. ussuriensis* (probably)	*P. ussuriensis* × *P. pyrifolia* (probably)	Korean peninsula
Dangshansu Li	*P.* × *bretschneideri*	old special, unknown	China
Kieffer	interspecific hybrid	*P. pyrifolia* × Williams	Philadelphia 1863
Hood	interspecific hybrid	unknown	Florida (USA)
Mut Chen	*P. pyrifolia* (probably)	unknown	unknown

The flowering and maturity dates were monitored for all the assessed pear tree varieties, as well as the flowering intensity and fruit set. The flowering date was determined as the beginning of the flowering (when 25% of the blossoms were fully open). The maturity date was determined as the day when the fruits were mature based on the fruit colour, as recommended by Tvergyak (1985).

Tvergyak recommends, as a maturity criterion, a change in colour from green to brown to orange or gold in the Asian russet varieties. According to the author, the colour changes during the maturation as follows: yellow Asian fruit varieties change from green to light yellow, green varieties change from grass green to light green to yellow green. Some of the green Chinese verities remain green. Since it was the first experimental evaluation of the ripeness of the fruit, the determination of maturity was based on the combination of sensory taste perception and the colour change. The flowering intensity and fruit set were assessed using a scale from 1 to 9 (where 1 represents no blossoms/fruits on a tree and 9 represents the maximum number of blossoms/fruits on a tree).

To assess the quality characteristics, 50 pieces of fruit were picked at the optimum harvest maturity. The fruits were then carried to the laboratory while wrapped in plastic bags to eliminate any water loss during transport. The fruits were washed and wrapped again in plastic bags and stored at 8 °C until further processing.

The pomological, physical and nutritional characteristics of all the studied pear varieties were then assessed in the following way: fifteen fruits were selected randomly from the 50 harvested pieces, and they were weighed on an analytical scale to calcu-

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late the average weight in grams. Then, the flesh firmness and the total soluble solid content, including the total titratable acids, were determined.

The flesh firmness was determined with a stationary penetrometer (*TR Turoni*, Italy) using an 8-mm-diameter plunger. The acid content was measured by titration with 0.1 M NaOH to a pH of 8.1 and expressed as malic acid (Pekmezci 1983). The total soluble solids (TSS) content was determined using a stationary refractometer (Krüss, Germany) at 25 °C, and the result was expressed in %.

The statistical analysis of the obtained data was carried out on the Statistica 12 software using an analysis of variance (ANOVA) and Tukey's HSD test.

RESULTS AND DISCUSSION

The experiment produced a large amount of data and interesting findings about the characteristics of the Asian pear varieties cultivated under the conditions of southern Moravia. This article presents the preliminary results that provide basic information and inferences related to the problem of cultivating Asian pear trees in the Czech Republic.

Flowering and ripening of the assessed varieties. The tested varieties selected from the collection of the Asian pear trees cultivated in Lednice include varieties with different ripening periods and flowering dates. The flowering dates varied, on average, from April 5 ('Hood' variety) to the April 1 ('Talgarskaja krasavica' and 'Kirgizkaja zimnaja' varieties) in 2012–2016. Each year, the flowering periods of the individual varieties depended on the weather conditions during the spring of that year. The statistical testing (significance level ≥ 0.95) did not confirm any significant differences in the flowering dates between the varieties from the data collected between years 2012–2016 (Table 2). The differences between the studied years were highly statistically significant, with the exception of 2013 and 2014, where no significant differences were confirmed. In 2012, the average flowering date for the studied set of varieties was the April 13. In 2013, it was as late as the April 26. In 2014, it was as early as the April 4; in 2015, the April 16; and in 2016, the April 8. The average flowering date for the whole study period was the April 13. The varieties with the earliest flowering dates (Figure 1) were 'Hood', 'Mut Chen' and 'Kieffer', whereas the varieties with the latest flowering dates included 'Kirgizkaja zimnaja', 'Talgarskaja krasavica' and 'Kumoi'. In 2016, the flowers were substantially damaged by late spring frosts. In 2017, the late spring frosts occurred as well, however, the flowers were not damaged as much as in 2016 and the yield was not affected at all, it was average.

The factors that considerably affect the period of ripening and maturity are the flowering date and temperatures during the period from the flowering to the ripening. The statistical testing (significance level ≥ 0.95) confirmed no significant differences in the maturity dates between the studied varieties, from the data collected between years 2012–2016 (Table 2).

Highly significant differences were confirmed between 2013 and 2014, in contrast to 2012, 2015 and 2016, for which no significant differences were confirmed. For the studied set of varieties, the maturity date varied in 2012–2016 from the August10 ('Ju Li') to the October 7 ('Mut Chen'). In 2012, the interval of ripening varied from the August 7 until the September 29 ('Ju Li'/'Mut Chen'); in 2013, it was from the August 10 until the October 3 ('Ju Li'/'Ping Guo Li'). In 2014, the interval of ripening started on the August 11 and ended on the October 13 ('Ju Li' and 'Shinseiki'/'Mut Chen'); in 2015, it was from the August 16 until the November 1 ('Ju Li' and 'Zao Su Li'/'Ping Guo Li'), and in 2016, it lasted from the 8th of August 8 until the September 28 ('Ju Li'/'Mut Chen').

Within the assessed period, the varieties with the earliest maturity dates were 'Ju Li', 'Shinseiki' and 'Zao Su Li', the average ripening of which was earlier than that of 'Clapp's' summer variety (Figure 1). The very late-ripening varieties, on the other hand, included 'Ping Guo Li', 'Ya Li', 'Xue Hua Li' and 'Mut Chen', which reached their harvest maturity an average of 14 to 21 days after the 'Conference' (depending on the conditions in Lednice). The studied Asian varieties exhibited a relatively high variability in the maturity dates between the assessed years. In contrast to the European varieties, it was impossible to determine which of the studied Asian varieties was the latest-ripening one, as it was a different variety each year. It is not completely clear at present what, apart from the fruit set, is causing this effect.

Flowering intensity, fruit set and fruit weight. The quality of a variety is determined by its productivity, among other factors. The productivity is influenced by the differentiation of the flower buds, which is assessed as the flowering intensity, and the development of small fruits, assessed as the fruit

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Table 2. The results of the phenophases and qualitative pomological traits with a statistically significant difference (ANOVA, significance level > 95%) in the assessed pears

Cultivars	No. of days to flowering*	Flowering standard error	Number of days to maturity**	Maturity standard error	Average of flesh firmness (kg/cm^2)	Flesh firmness standard error	Average of entire titratable acids (%)	Titratable acids standard error	Refractometric soluble solids (%)	Soluble solids standard error
Ju Li	105.8	3.48 abcd	222.6	5.41 a	2.731	0.168 cdefghi	0.21	0.03 abcd	11.08	0.19 a
Shinseiki	106.6	3.48 abcd	230.0	5.41 ab	2.058	0.168 abcde	0.15	0.03 abc	14.79	0.19 jk
Zao Su Li	103.0	3.48 abc	230.4	5.54 abc	2.027	0.168 abcd	0.23	0.03 bcdef	13.14	0.19 def
Clapp's favourite	111.8	5.51 cd	237.5	8.55 abcdef	1.592	0.168 a	0.39	0.03 h	14.64	0.19 ijk
Hood	94.3	3.89 a	241.0	8.55 abcdef	1.470	0.492 abcdefgh	0.33	0.03 fgh	12.57	0.63 cd
Williams	111.6	5.51 d	241.0	8.55 abcdef	1.683	0.168 ab	0.36	0.03 gh	14.97	0.19 kl
Man San Gill	103.3	3.48 abcd	244.8	5.54 abcde	2.893	0.168 defghij	0.28	0.03 defg	14.03	0.19 ghi
Chojuro	103.0	3.48 abcd	252.8	5.41 bcdef	2.987	0.168 fghij	0.16	0.03 abc	15.57	0.19 l
Kumt Ghant Chu	104.5	3.48 abcd	246.6	5.54 abcdef	2.122	0.184 abcdef	0.23	0.03 bcde	13.74	0.21 fgh
Talgarskaja krasavica	111.5	3.89 bcd	256.5	6.04 bcdef	2.237	0.194 abcdefg	0.12	0.034 a	14.08	0.22 ghi
Wu Jiu Xiang	102.3	3.48 abc	254.5	6.04 bcdef	3.279	0.188 hij	0.36	0.03 gh	13.89	0.19 gh
Pung Su	103.3	3.48 abcd	239.8	5.41 abcd	3.005	0.168 fghij	0.23	0.03 bcdef	13.16	0.19 def
Hosui	103.0	3.48 abcd	250.6	5.41 abcdef	1.967	0.168 abc	0.19	0.03 abcd	14.17	0.19 hij
Conference	106.0	3.48 abcd	256.0	6.04 bcdef	2.106	0.168 abcde	0.18	0.03 abcd	15.18	0.19 kl
Nijisseiki	105.0	3.48 abcd	257.3	6.98 bcdef	2.580	0.168 cdefghi	0.19	0.03 abcd	12.21	0.22 bc
Sha Li	103.3	3.48 abcd	260.6	6.98 bcdef	3.559	0.220 ab	0.17	0.03 abc	12.15	0.21 bc
Kirgizkaja zimnaja	110.7	3.89 bcd	261.0	6.04 cdef	2.684	0.194 cdefghi	0.25	0.034 cdef	12.68	0.22 cd
Dangshansu Li	101.0	3.89 ab	262.3	6.98 bcdef	2.516	0.168 bcdefgh	0.14	0.03 ab	12.19	0.19 bc
Jin Hua	101.5	3.48 ab	263.4	5.41 def	2.383	0.168 abcdefgh	0.18	0.03 abcd	12.18	0.19 bc
Shinko	104.0	3.48 abcd	261.7	6.04 def	2.932	0.201 defghij	0.31	0.03 efgh	13.73	0.22 fgh
Kumoi	106.7	3.89 abcd	265.0	8.55 bcdef	2.877	0.194 cdefghij	0.14	0.03 ab	13.42	0.25 efg
Kieffer	98.7	3.89 ab	270.3	6.98 def	3.691	0.168 a	0.32	0.03 efgh	11.62	0.19 ab
Ping Guo Li	102.3	3.48 abc	272.8	5.54 ef	3.146	0.168 ghij	0.28	0.03 defg	15.21	0.19 kl
Ya Li	102.3	3.48 abc	267.8	5.41 def	2.307	0.168 abcdefg	0.23	0.03 bcde	11.75	0.19 ab
Xue Hua Li	104.8	3.48 abcd	266.8	5.54 def	2.904	0.168 efghij	0.15	0.03 abc	12.97	0.19 de
Mut Chen	97.3	3.89 a	276.2	6.04 f	2.807	0.168 cdefghi	0.12	0.03 a	11.99	0.19 bc

* number of days from the 1st January until flowering time; ** number of days from the 1st January until maturity

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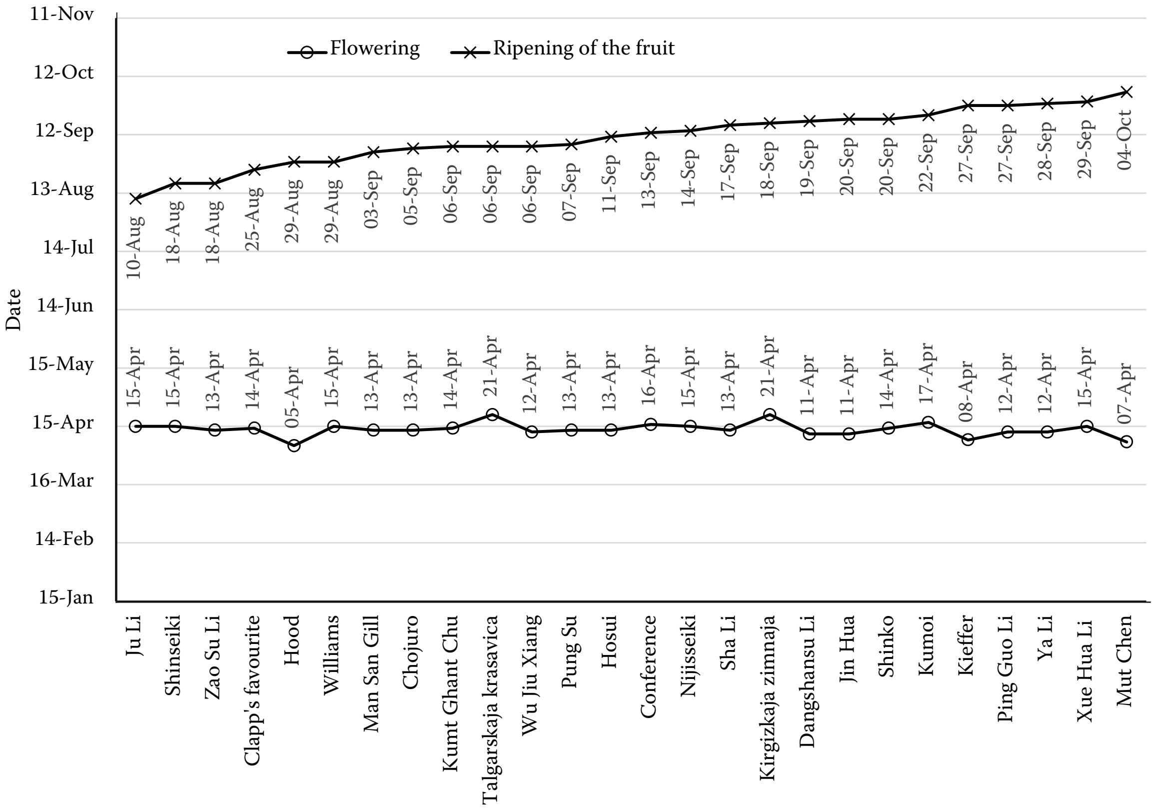

Figure 1. The average flowering and maturity dates for the period of 2012–2016

set. Because the selected set of varieties are cross-pollinated and have different tendencies to express parthenocarpy, their ability to produce a sufficient fruit set can be assessed using precisely these parameters. There are strong relationships between the flowering intensity and the fruit set, and they are significantly influenced by both the tree's own metabolism and its external conditions (especially by the temperature, which affects the pollination). A low flowering intensity causes low productivity; overbearing, on the other hand, has a negative effect on the flower bud differentiation (giving rise to an alternate bearing) and the fruit size (frequent in the Asian varieties).

The flowering intensity is a quantitative attribute that is affected each year by the flower bud differentiation. The differentiation itself then depends on many factors that are affected by both the internal conditions of the tree and its external environment. In the studied years, the obtained values of the flowering intensity index varied from 4.0 (weakly flowering varieties 'Clapp's', 'Sha Li' and 'Ju Li') to 8.3 in the varieties with a high flowering intensity ('Kumoi' and 'Dangshansu Li') (Figure 2). The statistical testing (significance level ≥ 0.95) confirmed no significant differences in the flowering intensity between the studied varieties or between the studied years of the experiment. In 2012, the average values of the flowering intensity of the Asian pear varieties ranged from 4.3 ('Sha Li') to 8.3 ('Kumoi'); in 2013, it was 3.0 ('Ping Guo Li') to 9.0 ('Kumoi' and 'Nijisseiki'); in 2014, it was 2.0 ('Sha Li') to 9.0 (e.g., 'Jin Hua' and 'Xue Hua Li'); in 2015, the values ranged from 2.0 (e.g., 'Jin Hua' and 'Sha Li') to 9.0 (e.g., 'Hosui' and 'Shinseiki'); and in 2016, they were 1.0 (e.g., 'Shinko' and 'Nijisseiki') to 9.0 (e.g., 'Ya Li' and 'Mut Chen'). In an experiment on European varieties carried out in Latvia by Lāce and Lācis (2015), the lowest values were recorded for the 'Concorde' variety, whereas the highest flowering intensity index was observed in the 'Talgarskaja krasavica' variety. At the same time, in this experiment, the 'Talgarskaja krasavica' variety was shown to have highly frost-tolerant blossoms.

The fruit set is mainly affected by the pollination, i.e., the availability of suitable, pollination-compatible varieties, and by the temperature, which affects the insect pollinator activity and stigma receptivity. Generally, under the conditions of the Czech Republic, Asian pear varieties have a tendency

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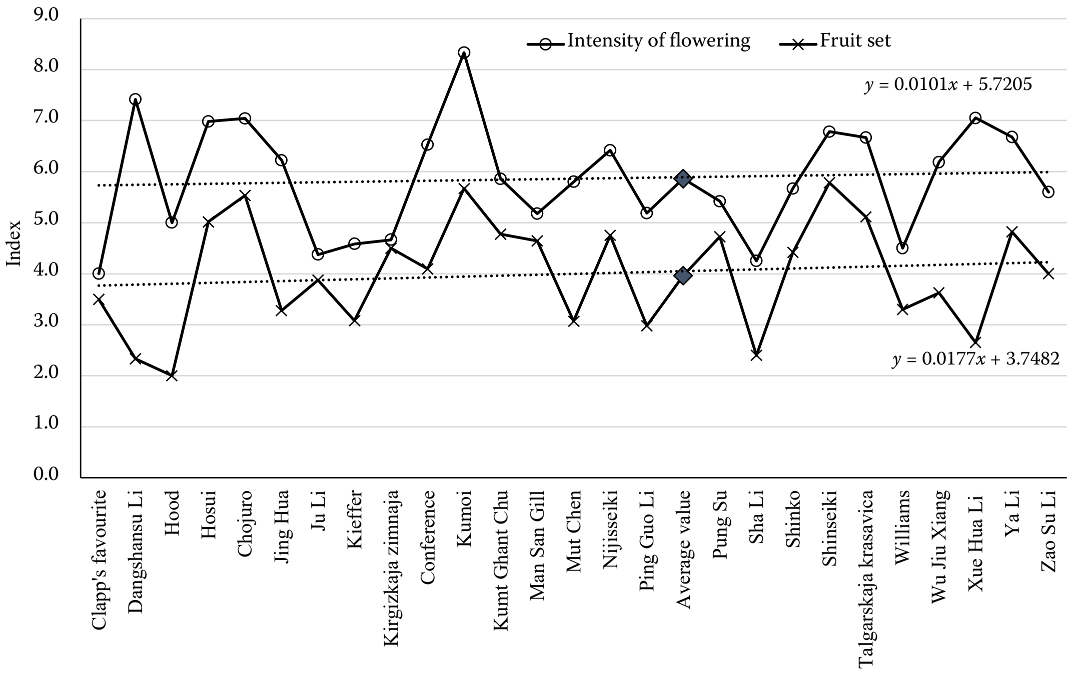

Figure 2. The average flowering intensity index and fruit set index for the period of 2012–2016

to overbear. This is caused by their corymb having a larger number of blossoms than the corymb of most of the European varieties. For this reason, Asian varieties require relatively strong fruit thinning to obtain large and good-quality fruits.

In our experiment, the fruit set index (Figure 2) for the studied period of 2012–2016 reached average values of 2.3 ('Dangshansu Li') to 5.8 ('Shinseiki'). The statistical testing (significance level ≥ 0.95) showed no significant differences in the flowering intensity between the varieties. The analyses of the data obtained each year revealed significant differences among the years 2013, 2015 and 2016. The fruit set index of the individual varieties (Figure 2) for the individual years reached the following values: in 2012, from 2.3 ('Dangshansu Li') to 5.8 ('Shinseiki'); in 2013, from 1.0 ('Ping Guo Li') to 7.0 ('Nijisseiki'); in 2014, from 2.0 (e.g., 'Shinko' and 'Pung Su' varieties) to 7.0 ('Hosui' and 'Ju Li'); in 2015, from 1.0 ('Jin Hua') to 9.0 (e.g., 'Man San Gill' and 'Shinseiki' varieties); and in 2016, from 1.0 ('Shinko') to 7.0 ('Ya Li'). The assessment clearly shows that when a variety flowers well, it does not necessarily exhibit a high mean fruit production; e.g., in the 'Dangshansu Li' variety, the high flowering intensity was observed, but its fruit set was always distinctly lower.

The weight of the fruits depends largely on the fruit set and fruit thinning. It is a characteristic feature of Asian varieties that the flowering in the corymb progresses from the edge towards the centre, and the inflorescence usually contains more than seven blossoms. The inflorescence in the Asian varieties has a larger number of blossoms than that in the European varieties. For this reason, the Asian varieties develop more fruits after pollination, which is why the varieties derived from *P. pyrifolia* tend to overbear fruit. When overbearing, in extreme cases, these varieties may produce fruits with a weight no larger than 50 g. The optimum fruit weight is considered to be 150 to 250 g (Kappel et al. 1995).

Figure 3 presents the average fruit weight for the studied period. Figure 4 shows highly significant differences between the evaluated years and shows an increase in the fruit weight from the beginning of the tree productivity until the end of the assessment period. Figure 3 shows that the varieties with the lowest average fruit weight are also the varieties derived from *P. pyrifolia* ('Shinko', 'Shinseiki', 'Nijisseiki', 'Man San Gill', 'Kumt Ghant Chu' and 'Chojuro'), with the interspecific hybrid 'Hood' being an exception. The fact that the 'Talgarskaja Krasavica' variety generally produces only small to below-average-sized fruits was also confirmed in Lāce and Lācis (2015). In contrast, the varieties with extremely large fruits were 'Zao Su Li', 'Xue Hua Li', 'Jin Hua', 'Dangshansu Li', 'Sha Li' and 'Wu Jiu Xiang', which bear fruits as large as 500 g in some cases. In Sosna (2018), the varieties providing the best yield within

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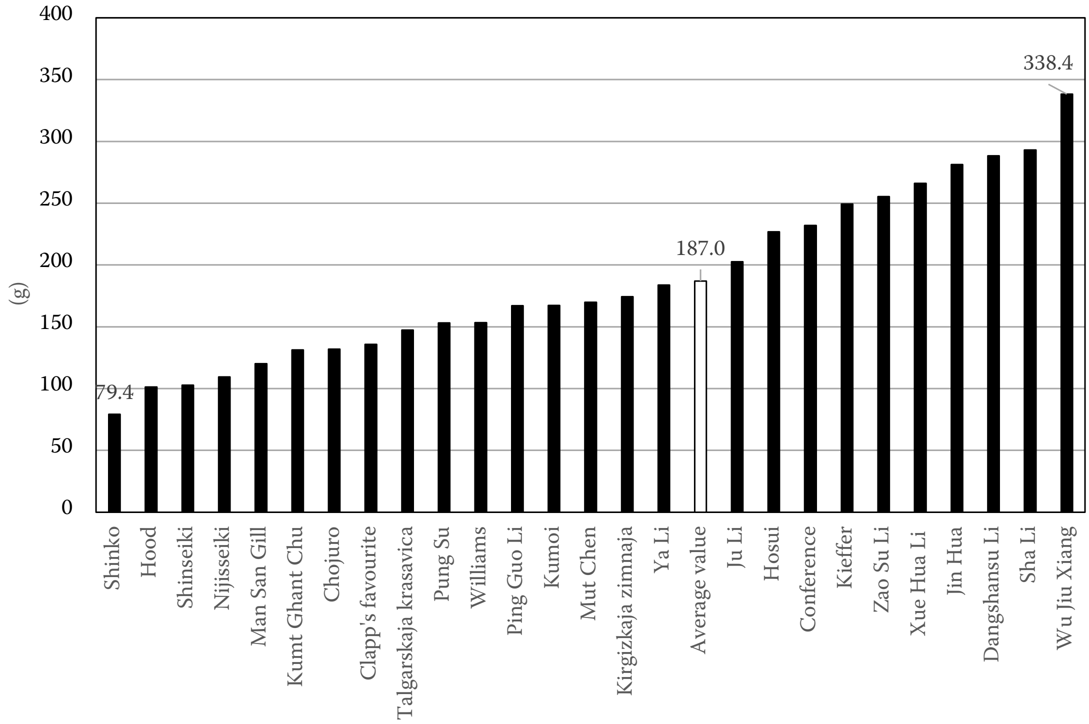

Figure 3. The average fruit weight for the studied varieties within 2012–2016

the assessed eight-year period after planting were 'Chojuro' and 'Shinseiki', while the smallest fruits were produced by the 'Nijisseiki' variety. The fruits with the significantly highest weight and largest size were produced by the Chinese cultivar 'Shu Li'.

The ideal-sized fruits in the present study were from the varieties 'Pung Su', 'Ping Guo Li', 'Kumoi', 'Mut chen', 'Kirgizkaja Zimnaja', 'Ya Li', 'Ju Li', 'Hosui', and 'Conference' and the interspecific hybrid 'Kieffer'.

Assessment of qualitative attributes of Asian pear fruits. The flesh firmness parameter is used worldwide to assess the fruit maturity. The parameters normally appropriate for determining the maturity of apple fruits are very often unsuitable for pear

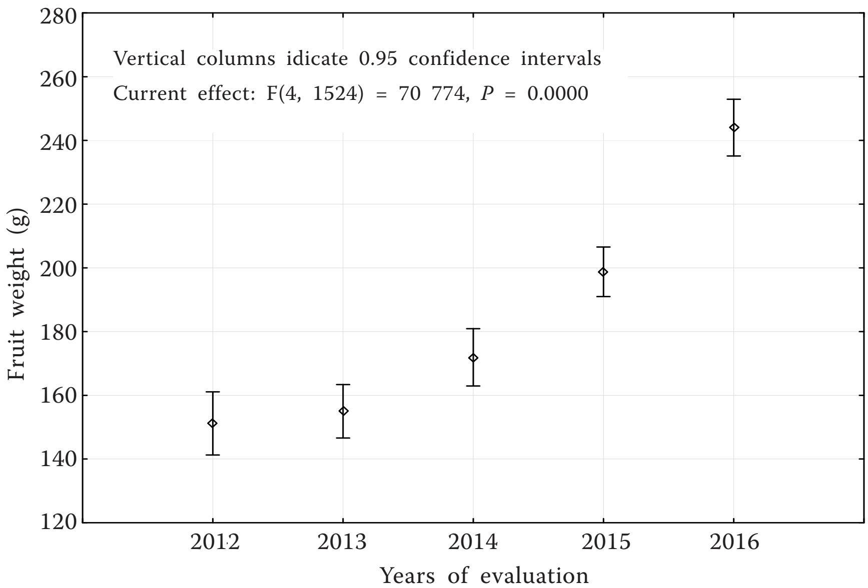

Figure 4. The statistical analysis of the year-dependent pear fruit yield and the increase in the average fruit weight with the increasing tree age

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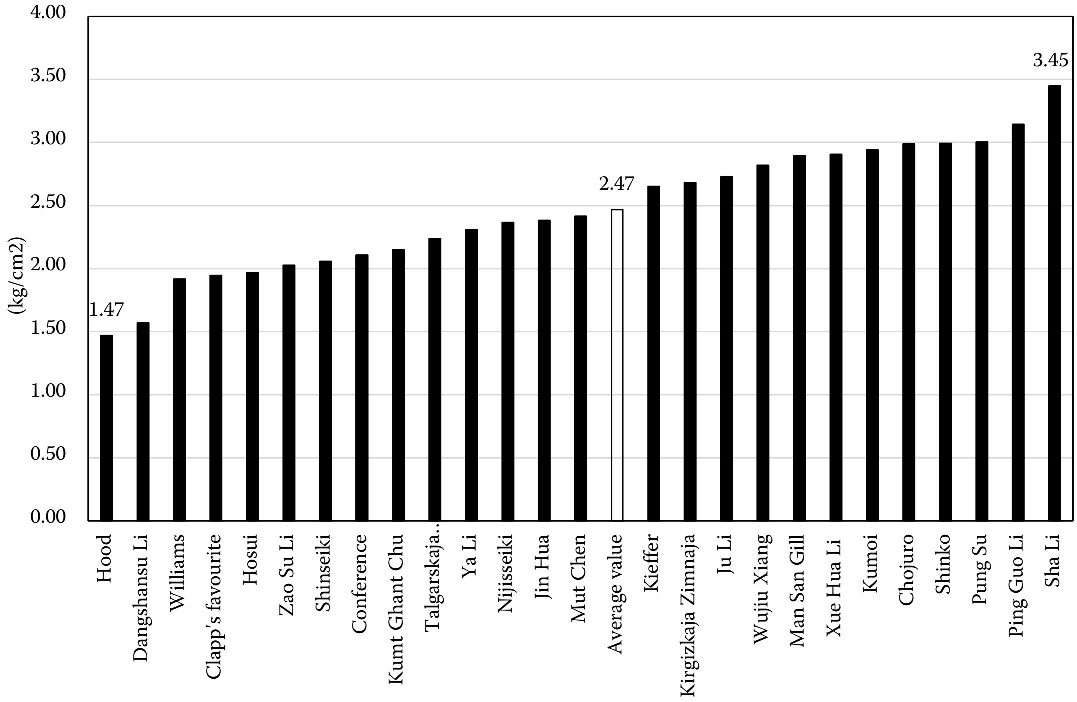

Figure 5. The average flesh firmness values in the assessed varieties in 2012–2016

fruits, and, as stated above, in the paragraph on maturity dates, these parameters are influenced by the conditions of the particular year and by the character of the plantation. Two methods are usually used to determine the maturity of pear fruits.

The first method is based on the (large) number of days from the full flowering until harvesting. However, the influence of the conditions during the particular year is highly significant. According to Tvergyak (1985), 120–150 days are the average number of days from flowering until harvesting for the model variety 'Anjou'; 110–133 days for 'Williams'; 130–145 days for 'Beurré Bosc'; and 112–150 days for Asian varieties.

The second, more precise method which is only usable for European pears varieties is based on measuring the flesh firmness. The ideal values are defined by the marketing strategy based on the subsequent use of the fruits. The fruits intended for immediate sale or short-term storage in cold (chilling) are usually harvested during the earlier part of the range. If the pears are intended to be stored in a controlled atmosphere, they are harvested during the latter part of the range. Tvergyak (1985) recommends firmness ranges that are measured by a penetrometer as follows: 2.08–1.95 kg/cm^2 for 'Anjou'; 2.23–2.08 kg/cm^2 for 'Williams'; and 2.16–2.02 kg/cm^2 for 'Beurré Bosc'. However, according to the same author, flesh firmness is not a good indicator of maturity for Asian pear varieties. These varieties are at their best when maturing on a tree up to a firmness of 1.60 to 1.88 kg/cm^2. For Asian pears, the colour and taste are better indicators of the maturity than the flesh firmness.

Figure 5 presents the average values of the flesh firmness measured in our assessment. Our assessment also showed that the flesh firmness is affected by many factors, especially the conditions during the year. The statistical testing (significance level ≥ 0.95) confirmed highly significant differences in the flesh firmness between the varieties (Table 2). Highly significant differences were confirmed between the study years, with the exception of 2013 and 2014, which exhibited no significant differences. Each year, a different variety had the highest flesh firmness value. In 2013, it was 'Ping Guo Li' (4.9 kg/cm^2); in 2014, 'Kieffer' (3.16 kg/cm^2); and in 2015 and 2016, 'Wu Jiu Xiang' (4.07 and 4.0 kg/cm^2). The average data indicate that the highest flesh firmness values on the harvest dates were recorded in the 'Sha Li' (3.45 kg/cm^2) an'Ping Guo Li' (3.15 kg/cm^2) varieties, while the lowest values were recorded in the 'Hood' (1.47 kg/cm^2) and 'Dangshansu Li' (1.57 kg/cm^2) varieties.

The amounts of soluble solids in the fruits increase as the fruits approach maturity, especially

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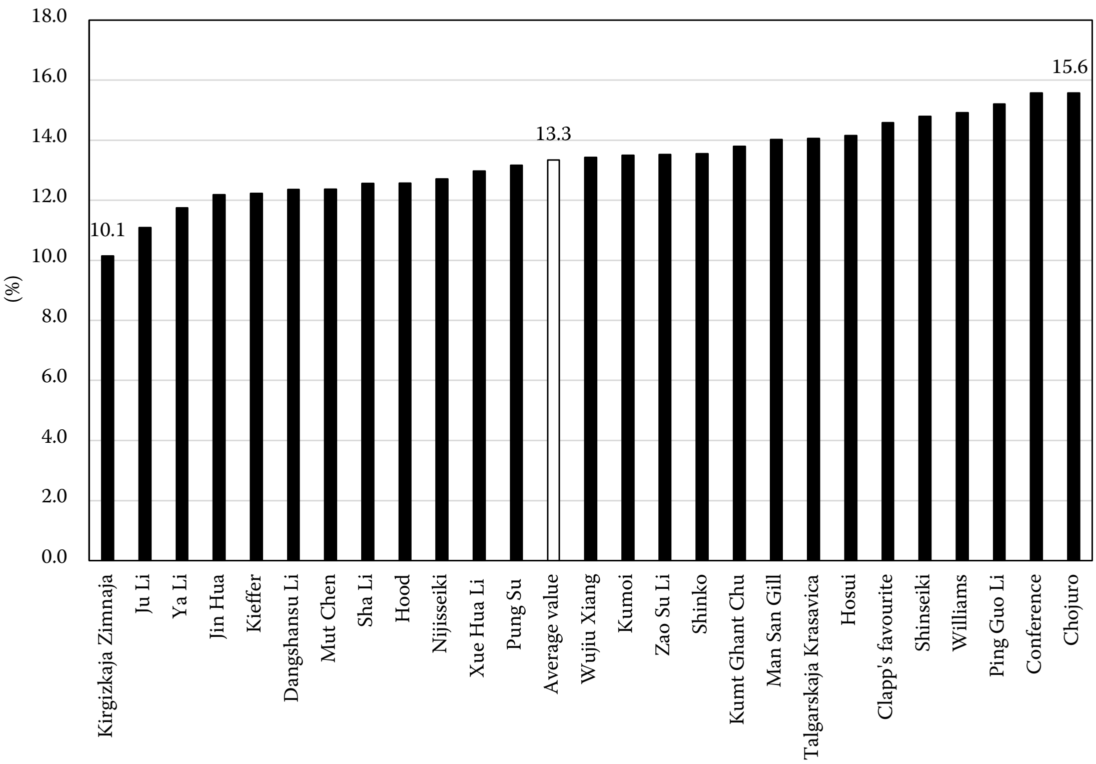

Figure 6. The average values of the soluble solids in the fruits of the assessed varieties in 2012–2016

in Asian pears, where the amounts have a specific value on the optimum harvest date. At the same time, these values depend on a number of external factors (e.g., the fruit set, temperature, irrigation and precipitation, etc.) which are also significantly influenced by the genotype. Tvergyak (1985) recommends that Asian pear varieties have at least 12% soluble solids at the time of harvest. However, for pears intended for storage, the soluble solids value is not a good predictor of fruit maturity, mainly because of the degree to which it varies between the years, sites (orchards) and even individual trees. The soluble solid contents strongly influence the storage of fruits. A minimum value of 10% soluble solids is recommended for the fruits to achieve the best quality and to avoid impairment during storage. For the 'Williams' variety, the ideal value for the storage was determined to be 11% soluble solids by Tvergyak (1985). In Kappel's (1995) experiment, where the author aimed to define ideal qualitative parameters for fruits of European varieties, the soluble solid values ranged from 11.8% to 18.6%, with the optimum value being 13.6. Vangdal (1980), on the other hand, states a threshold value of 11.3% for pears, 12.5% for plums and 14.2% for cherries. The assessment of the soluble solids, or the subjective sensation of the sweetness of a fruit, is also substantially affected by the ratio between the soluble solids and the overall acid content. The "sweet and sour" ratio is an important parameter in evaluating the quality of the fruits. According to Vangdal (1980), however, the acid content in pears is low and exerts no influence on the perception of taste.

Similar to flesh firmness, the soluble solids values are also affected by conditions during the year. This effect is confirmed by the very different values obtained for the studied varieties in the individual years. For example, in 2012, the highest values were recorded in the reference variety 'Clapp's' (17.8%) and in 'Chojuro' (16.1%) within the set of Asian varieties. In 2013, it was 'Ping Guo Li' (17.2%); in 2014, 'Chojuro' (17.0%); in 2015, 'Conference' (16.5%) and, of the Asian varieties, 'Hosui' (16.0%); and in 2016, 'Shinseiki' (15.6%). The average values showed that the variety with the highest values of soluble solids was 'Chojuro' (15.6% on average) as well as the control variety 'Conference'. The lowest average values were recorded in the 'Kirgiskaja Zimnaja' variety (10.1%) (Figure 6).

The acid content in a fruit influences its taste and aroma, but the acid content values are an unsuit-

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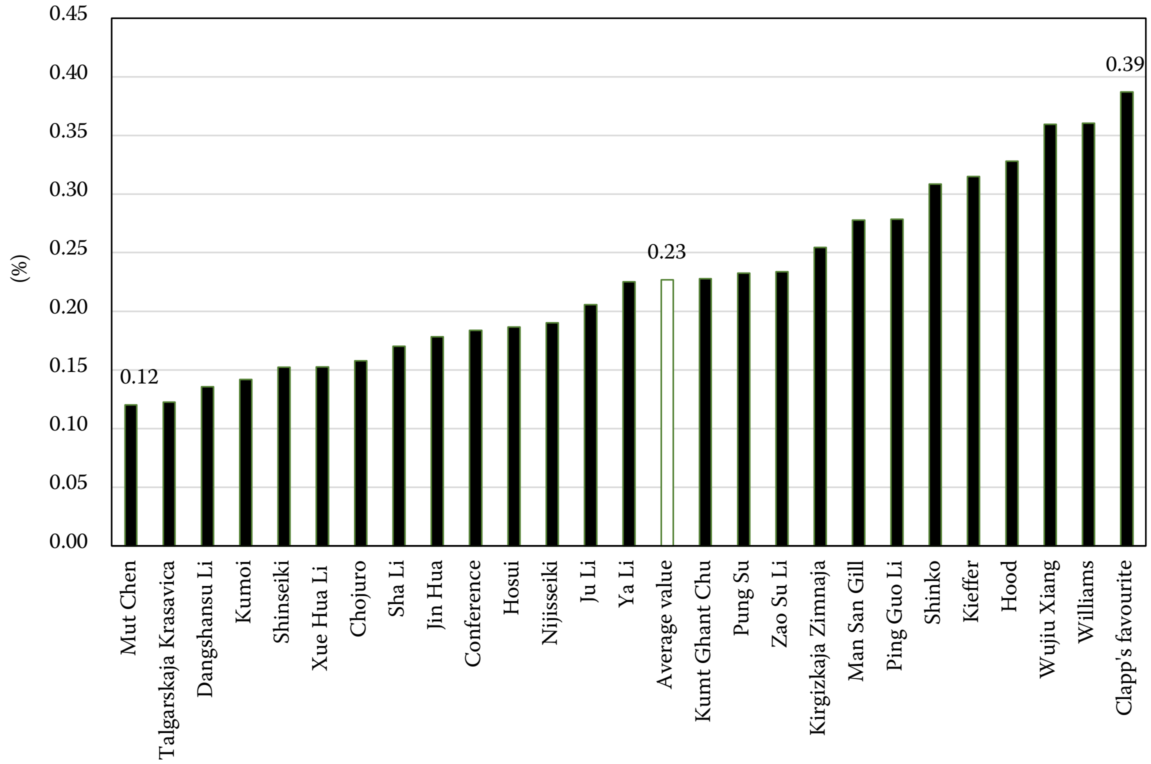

Figure 7. The average values of the total titratable acids in the fruits within the study years of 2012–2016

able factor for the determination of a fruit's maturity. The values change each year and also usually vary between orchards. Tvergyak (1985) mentions that higher levels of acids have a positive effect on the taste of a fruit, which should improve the fruit's quality and its marketability. The optimum levels of acids have not yet been determined. The author also believes that for Asian pears, where taste is an indicator of maturity, the acid content levels may also serve as a good indicator of maturity. Khoshghalb et al. (2008) present, in their work, the dynamics of the changes in the acid content from one month before harvesting until the end of storage for two Asian pear varieties, not specifying them in more detail, but stating that they are derived from *Pyrus pyrifolia* (Burm.f.) Nakai. One month before harvesting, the acid content reached 0.42/0.43 mg/100 g. On the harvesting date, the value was 0.30/0.29 mg/100 g; in the first month of storage, 0.28/0.22 mg/100 g; in the second month of storage, 0.18/0.18 mg/100 g; and in the third month of storage, 0.16/0.16 mg/100 g.

Figure 7 presents the results of our measurements of the titratable acid content. Relatively high values were recorded in both the reference varieties 'Williams' (0.36%) and 'Clapp's' (0.39%). For the control variety 'Conference', the average acid content value was slightly below average (0.18%). Interestingly, except for the above-mentioned reference varieties, the highest values were recorded in all three interspecific hybrids included in the experiment: 'Kieffer' (0.32%), 'Hood' (0.33%) and 'Wu Jiu Xiang' (0.36%). We can assume that this is related to their partially European origin. Another interesting finding was that the lowest value (0.12%) was recorded in the 'Mut Chen' variety, for which it became apparent, across the years, that it is very well suited for storing.

CONCLUSION

Based on the results of the analysed parameters, as well as a subjective evaluation, the varieties with the best potential for cultivation under the conditions of the Czech Republic are as follows:

Early-maturing varieties: 'Shinseiki' and 'Zao Su Li', due to their early maturity, refreshing juiciness, growth plasticity and generally ease of cultivation. 'Shinseiki' bears medium-sized to small fruits, which may be more appealing to a specific group of consumers. In the 'Zao Su Li' variety, the fruit size depends on the fruit set, and after fruit thinning, the fruits may grow to very large sizes.

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Middle-maturing varieties: The varieties worth recommending in this group are 'Hosui', 'Dangshansu Li', and the interesting variety 'Kirgizkaja zimnaja'. The other varieties suitable for our conditions include 'Nijisseiki', 'Sha Li' and 'Pung Su'.

Late-maturing varieties: The 'Ya Li' and 'Mut Chen' varieties are recommended, mainly due to their relatively good storability under normal storage conditions (a cellar and a chilling room). Both of these varieties bear fruits of a medium size that are more suitable for consumption over the course of storage. Another easy to cultivate and well-producing variety that bears high-quality fruits under our conditions is the 'Kieffer' variety (an interspecific hybrid); however, all the Asian pear varieties have low or no affinity with a quince rootstock.

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