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SHORT PAPER

Evaluation of Phenological and Morphological Properties of Some Asian Pear Varieties in the Climatic Conditions of South Moravia Therapeutic Interventions

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Abstract

The cultivation of Asian pear varieties in Czech climatic conditions, specifically South Moravian region, looks very promising. The introduction of new species and varieties can increase the biodiversity, what is an important factor in dealing with current threats in context with climatic changes. Asian pears are especially valuable due to their resistance to *Erwinia amylovora* and Pear decline phytoplasma. They have also excellent tolerance to low temperatures and resistance to European pear scab (caused by *Venturia pyrina*). For this experiment, pomological and phenological properties were analysed on 32 pear varieties. The fruits were maturing from 9th of September ('Zao Su Li') to the 20th of October ('Kieffer'). The heaviest fruits were determined at 'Wu Jiu Xiang' (308 g on average). The lowest weight was detected at 'Nanguo' (66 g on average). 'Wu Jiu Xiang', 'Zao Su Li' and 'Nanguo' have thin skin, which makes them ideal for direct consumption but also, they are prone to damage. 'Baoshy' and 'Dong guo' have thick skin, which provides good damage protection but decreases the organoleptic properties. The thick skin tends to be very bitter and overwhelms the taste of the fruit. The highest values of total soluble solids were measured in 'Nanguo' (17.5 %). The sourest was 'Dong guo' (0.63 %) and 'Nanguo' (0.54 % of total titratable acids). Varieties of Asian pears and their fruits have very diverse characteristics and it is clear that their cultivation is worthwhile in the conditions of South Moravia (i.e. in the conditions of the Middle Europe).

INTRODUCTION

Pears are geographically divided into two main groups – European and Asian pears. Asian pears are further divided into Japanese pears, represented by *Pyrus pyrifolia*, Chinese pears, represented by *Pyrus bretschneiderii* and ussurian pears (*Pyrus ussuriensis*). Ussurian pears have significantly lower fruit quality, but they excel for example in the formation of deep root system, high frost resistance or resistance to scab (Nečas *et al*., 2018).

The area of pear plantations in the Czech Republic has increased by more than 100 ha in the last 10 years, by 2020 the area reached 830 ha (for comparison, apple trees are grown on an area of 7190 ha, but in the last 10 years it has decreased by more than 800 ha). In 2020, the average yield was 8.8 t/ha, for the years (2015–2020) the average was 8.7 t/ha.

The total yield for 2020 in the Czech Republic was 7370 tons. China takes the first place in the world production with 16.5 million tons (Asia produces 18.5 million tons, and thus accounts for 77 % of the world production). The USA is in second place with a huge gap (730 thousand tons), followed by Italy (707 thousand tons) and Argentina (666 thousand tons) (FAO, 2022).

The main purpose of this study was the analysis of collection of different pear cultivars grown on the experimental field of the Faculty of Horticulture in Lednice. There is a unique and biggest collection of Asian pear varieties in Europe. Also, there are grown many botanical species and new interspecific hybrids from the

breeding program of the department of Fruit Growing. The long-term intention of our department is to find and select varieties with good potential for cultivating in the condition of Czech Republic, Central Europe, and enrich the current assortment of existing cultivars.

Asian pears seem to be good donors of desirable characteristics for further breeding. Especially the most valuable features are their resistance to fireblight (*Erwinia amylovora)* and pear decline (caused by *Candidatus Phytoplasma pyri*), which caused big damage to European pear orchards in the past. They also excel in frost and European pear scab resistance. The Asian pears have high pollen yields and are mostly good pollinators, they can hybridize with others (Bieniasz *et al*., 2017). Asian pears and their interspecific hybrids have great potential to enrich diversity and the range of cultivated varieties, reduce the needs of chemical protection and increase the biodiversity in orchards. Based on their properties, they will be better in dealing with the climate changes. It is very important to select adequate rootstock in context of the soil type and water conditions (presence or absence supplementary irrigation) (Nečas *et al*., 2015).

MATERIAL AND METHODS

The assortment of pear varieties evaluated consists of 30 varieties and from which 17 are Asian, 9 European and 4 interspecific hybrids (Table 1). The pear trees are grown in the experimental orchard, on the land of the Mendel University in Brno, concretely the Faculty of Horticulture located in the village of Lednice (48°47'59''N 16°48'12''E) in Southern Moravia, Czech Republic (170 m above sea level). It is one of the warmest areas in the Czech Republic. The average of annual temperature is about 9.1 °C, and the average of annual precipitation is about 420 mm. The evaluation was carried out from autumn 2021 (fruit harvesting) to spring 2022 (flowering phase).

Trees are grown in slender spindle system with spacing 5 x 3 m. There is a drip irrigation system in the orchard. The phase of the beginning of the bud sprouting and the flowering were determined when the 25 % of buds were sprouted and 25 % of blossoms were fully opened.

It was harvested 10 uniform, undamaged and optimally matured fruits of each variety. The following parameters were evaluated: Fruit weight [g], width [mm], length [mm], total soluble solids [%] content which was determined using a stationary refractometer (Krüss, Germany) at 25 °C, penetrometric thickness of skin [kg/cm^2] which was determined with a stationary penetrometer using an 8-mm-diameter plunger (TR Turoni, Italy). Total titratable acids [%] was measured in homogenized fruits by potentiometric titration with 0.1 M NaOH to a pH of 8.1 using a combined SenTix^{TM}81 pH electrode (WTW, Prague, Czech Republic) attached to an inoLab 7110 pH meter (WTW) and expressed as percentage of malic acid equivalent (Pekmezci, 1983).

The software Statistica 12 was used for statistical analysis of results. Single-factor ANOVA analysis (level of significance $p < 0.05$) was used for statistical processing, when the Tukey HSD test was used to evaluate the statistical significance. (Table 1)

RESULTS AND DISCUSSION

The stated data gives an overview about basic parameters of Asian pears grown under the condition of Southern Moravia and shows their qualities and potential for commercial production in Middle Europe. The assortment and values of selected properties of the Asian pears with a statistically significant difference (ANOVA, level of significance $p < 0.05$) is shown in Table 1.

Phenological characteristics

Bud burst of the Asian varieties from the earliest to the latest took almost one month. The first bursting variety was 'Hood' (10th of March) followed by 'Cangxixueli', 'Jing Hua' and 'Dong Guo' and 'Nanguo' (15th of March). Of Asian cultivars, the latest bursting was 'Dang Shan Su Li' (7th of April), followed by common European varieties, 'Bohemica' and 'Bosc' (12th of April) (Figure 1). In Central Anatolia, Turkey, the date of "swollen bud" of several Asian pear cultivars in 2017-2018 ranged from 5th of March to 2nd of April (Pirlak and Mahmut, 2018).

Flowering time started on 4th of April with 'Cangxixueli' and finished on 20th of April with 'Kirgizskaja zimnaja', 'Talgarskaja krasavica' and 'Bosc'. 'Wu Jiu Xiang' flowered on 9th, 'Jing Hua' on 12th and 'Zao Su Li' on 14th of April (Figure 2).

Variety	Fruit weight [g] (average)	Fruit weight [g] (Standard error)		Fruit width [mm] (average)	Fruit width [mm] (Standard error)		Fruit lenght [mm] (average)	Fruit lenght [mm] (Standard error)		Total soluble solids [%] (average)	Total soluble solids (Standard error)		Penetrometric thickness of skin [Mpa] (average)	Penetrometric thickness of skin [Mpa] (Standard error)		Total titratable acids [%] (average)	Total titratable acids [%] (Standard error)	
Anhui Xue Li	155,42	16,76	cdefg	69,73	2,27	defgh	64,79	2,09	defg	14,83	0,37	efghijklm	4,49	0,34	abc	0,11	0,00	b
Baoshy	66,76	4,84	a	50,72	1,06	a	43,74	0,89	a	16,34	0,23	mno	8,08	0,35	j	0,27	0,00	kl
Bohemica	151,27	10,47	cdef	64,46	1,58	cdef	76,40	2,56	ghijk	15,57	0,45	ijklm	7,79	0,27	ij	0,09	0,00	a
Bosc	190,84	10,51	ghijk	71,78	1,26	efghi	95,21	2,03	n	14,91	0,71	fghijklm	5,40	0,34	cdef	0,16	0,00	g
Cangxi Xue Li	211,51	23,09	ijkl	75,37	3,74	ghij	78,63	4,27	hijk	13,98	0,45	defghij	5,82	0,21	cdefgh	0,10	0,00	b
Conference	158,91	7,97	cdefghi	63,73	1,35	cdef	94,90	2,92	n	16,05	0,39	klmn	3,23	0,30	a	0,11	0,00	bc
Dang Shan Su Li	156,64	7,11	cdefgh	66,20	0,93	cdefg	67,37	1,62	defghi	15,83	0,18	klmn	5,23	0,20	bcdef	0,18	0,00	h
Dong Guo	126,27	4,68	bcd	62,27	0,89	cde	59,27	1,04	bcde	15,53	0,23	ijklm	7,22	0,10	hij	0,63	0,01	t
Elektra	171,27	7,76	cdefghij	64,23	0,85	cdef	87,14	1,52	klmn	18,05	0,34	o	6,15	0,34	defgh	0,42	0,00	q
Erika	249,97	11,34	lm	75,91	1,15	ghij	95,86	1,78	n	13,39	0,32	bcde	5,32	0,23	cdef	0,22	0,00	j
Hood	212,71	12,51	jkl	66,75	7,40	cdefgh	75,27	2,19	fghijk	14,63	0,41	efghijklm	4,65	0,50	abcd	0,51	0,00	r
Huang Hua	177,46	8,63	defghij	71,39	1,37	efgh	64,20	1,22	cdefg	15,25	0,35	ghijklm	4,53	0,22	abc	0,41	0,01	q
Chang Ba	152,48	4,32	cdef	66,14	0,82	cdefg	67,00	1,03	defghi	12,59	0,26	bcd	6,34	0,21	efghi	0,40	0,00	pq
Chi Li	142,89	9,63	cdef	66,18	1,40	cdefg	65,52	1,43	defgh	14,52	0,12	efghijkl	6,00	0,21	cdefgh	0,19	0,00	hi
Jing Bai	125,41	3,74	bcd	64,92	0,83	cdef	55,00	0,63	abcd	16,23	0,10	lmn	4,97	0,18	bcde	0,30	0,00	m
Jing Hua	217,27	7,40	kl	70,85	1,33	efgh	85,38	1,35	klmn	11,71	0,28	b	5,09	0,19	bcdef	0,14	0,00	def
Kieffer	247,68	10,26	lm	76,89	1,33	hij	86,86	1,40	klmn	13,44	0,27	bcde	5,94	0,43	cdefgh	0,40	0,00	p
Kirgizskaja Zimnaja	129,72	3,03	bcde	59,79	0,59	abcd	66,54	1,16	defghi	15,70	0,29	jklm	5,36	0,12	cdef	0,37	0,00	o
Lucas	183,99	10,81	efghij	69,01	1,55	defgh	79,32	2,49	ijkl	8,49	0,46	a	5,42	0,37	cdef	0,34	0,00	n
Mut Chen	155,44	3,00	cdefg	66,70	0,46	cdefgh	70,25	1,25	efghij	14,35	0,18	efghijk	6,56	0,27	fghij	0,15	0,00	fg
Nanguo	66,09	3,61	a	51,89	1,04	ab	44,50	0,97	a	17,53	0,19	no	6,64	0,15	fghij	0,54	0,00	s
Nutiika	116,23	6,87	abc	62,69	1,11	cde	51,35	0,90	abc	13,62	0,17	defgh	4,88	0,19	bcde	0,20	0,00	ij
Sha Li	217,46	11,58	kl	73,85	1,28	fghij	66,05	2,76	defghi	13,26	0,13	bcde	7,01	0,22	ghij	0,15	0,00	fg
Shon Shu	210,61	8,02	hijkl	73,68	1,13	fghij	66,29	0,86	defghi	13,52	0,22	cdefg	5,43	0,11	cdefg	0,13	0,00	de
Snow Flower	150,48	8,43	cdef	67,31	1,19	defgh	62,39	1,80	cdef	13,56	0,24	cdefgh	5,72	0,18	cdefgh	0,15	0,00	efg
Talgarskaja Krasavica	160,21	7,58	cdefghi	61,80	1,10	bcde	92,23	1,88	lmn	15,28	0,21	hijklm	4,62	0,13	abcd	0,13	0,00	cd
William's red	209,95	10,69	hijkl	71,20	1,43	efgh	84,84	2,50	klmn	14,39	0,56	efghijk	5,80	0,69	cdefgh	0,26	0,00	k
Wu Jiu Xiang	307,69	18,83	n	81,83	1,90	ij	92,71	9,27	mn	13,90	0,34	defghi	5,69	0,37	cdefgh	0,27	0,00	l
Xin Gao	87,01	4,68	ab	56,60	1,05	abc	47,51	0,95	ab	13,15	0,28	bcde	6,16	0,39	defgh	0,15	0,00	fg
Zao Su Li	275,02	19,67	mn	82,72	2,04	j	81,21	2,46	jklm	11,82	0,27	bc	3,65	0,32	ab	0,18	0,00	h

Table 1. The assortment and values of selected properties of the Asian pears with a statistically significant difference (ANOVA, significance level > 95%)

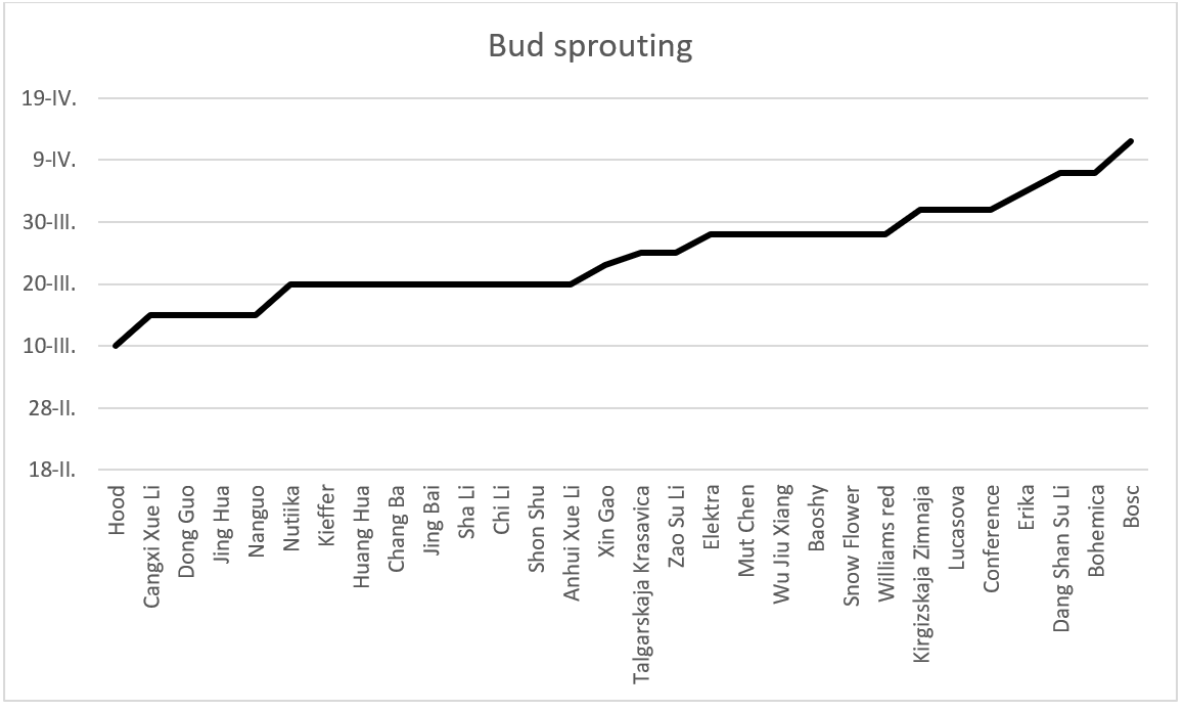

Figure 1. Sprouting time of evaluated pear varieties

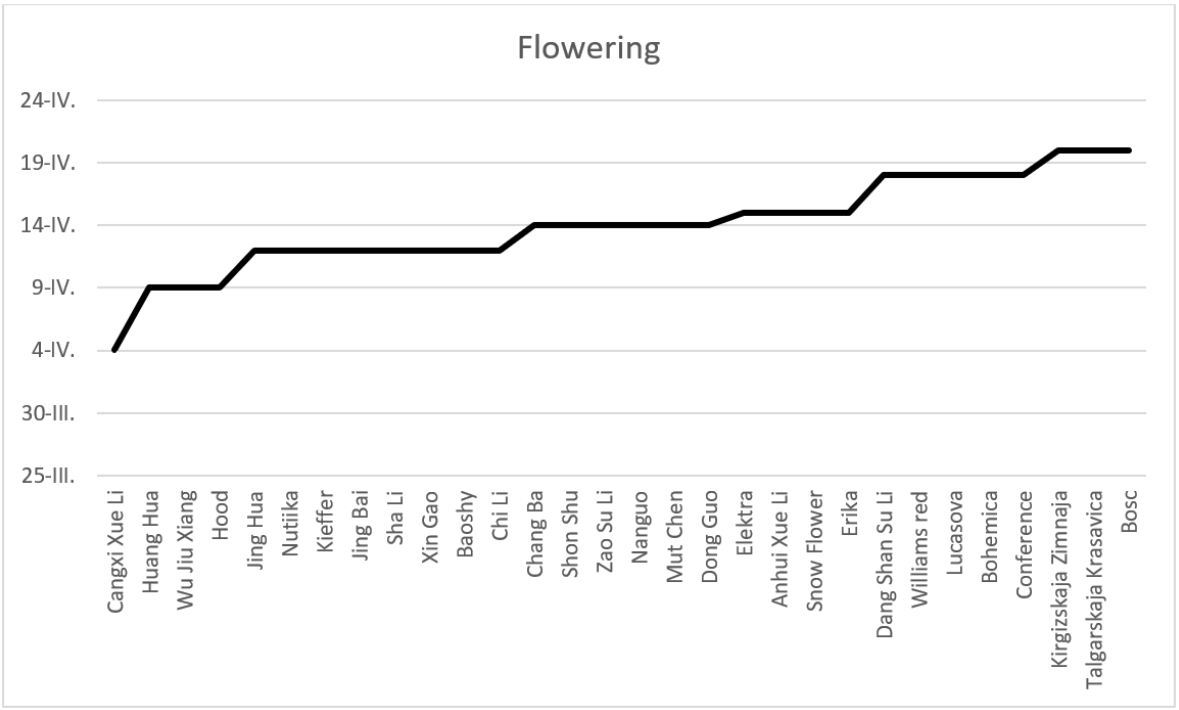

Figure 2. Flowering time of evaluated pear varieties

The date of full bloom varied for 2017-2018 from 26th of March to 25th of April in several Asian pear cultivars grown in Central Anatolia, Turkey (Pirlak and Mahmut, 2018).

These dates are like the dates in the study of Nečas *et al*. (2020), who evaluated pears in the same orchard as was evaluated in this study in years between 2012 and 2016, the average flowering date in these years varied from 5th of April ('Hood') to 21st of April ('Talgarskaja krasavica' and 'Kirgizskaja zimnaja'). 'Wu Jiu Xiang' flowered on 12th, 'Jing Hua' on 11th and 'Zao Su Li' on 13th of April.

The flowering time of 'Conference' was evaluated between 2012 and 2015 in south-western Poland and it varied from 14th of April to 7th of May and it corresponds to our results, where 'Conference' was in full bloom on 18th of April (Sosna, 2018).

The first fruits were ripened, and the harvest began on 9th of September with 'Zao Su Li' (same time as European 'Williams red') and finished on 20th of October with 'Kieffer' and 'Mut Chen' (same time as European 'Erika' and 'Lucas') (Figure 3).

Between 2012 and 2016, Nečas et al. (2020) evaluated the average harvest time of 'Zao Su Li' on 18th of August. Dates usually range from 2 to 3 weeks depending on the annual weather conditions. In south-western Poland, where the harvest time of 'Conference' between 2012 and 2015 varied from 17th to 23rd of September. In case of this study, the harvest time in 2021 for this variety was on 20th of September (Sosna, 2018).

The harvest date in several Asian pear cultivars from Central Anatolia for 2017 and 2018 varied from 14th of August to 9th of September (Pirlak and Mahmut, 2018). The harvest in wide assortment of Asian pears in Nepal took from 4th week of July to 4th week of September (Dhakal *et al*. 2021).

Pomological characteristics

The biggest fruits with heaviest weight reached were in 'Wu Jiu Xiang' (308 g on average) and 'Zao Su Li' (275 g on average). The lowest weight reached were 'Nanguo' (66 g on average) and 'Baoshy' (67 g on average), which had both extremely high fruit set (Figure 4). In this study, the fruit of 'Conference' weighed on average 159 g. 'Conference' was also evaluated in years between 2012 and 2015, in southwestern Poland, with average fruit weight 172 g (Sosna, 2018). The average fruit weight evaluated in number of Asian pear varieties was 137-206 g (Pirlak and Mahmut, 2018). The lowest average fruit weight of Asian pears in Soon Valley, Pakistan was 79 g and the highest was 205 g. The extremely low fruit weight is mainly caused by overbearing (Abbas *et al*., 2018).

The widest fruit was 'Zao Su Li' (82.7 mm), closely followed by 'Wu Jiu Xiang' (81.8 mm). On the contrary, the smallest widths were reached by the round varieties 'Baoshy' (50.7 mm) and 'Nanguo' (51.9 mm) (Figure 5). The average diameter of Asian pears in Central Anatolia, Turkey was 60.1-72.8 mm (Pirlak and Mahmut, 2018). The highest fruit diameter was in 'Anjou' (57.6 mm) and the lowest was in 'Nittaka' (32.5 mm) in Nepal (Dhakal *et al*., 2021). In Soon Valley, Pakistan, the fruit width of Asian pears varied from 37.4 to 65.15 mm (Abbas *et al*., 2018).

The longest fruits give most of European varieties (Erika 95.9 mm, Bosc 95.2 mm, Conference 94.9 mm on average) and the interspecial hybrid 'Wu Jiu Xiang' with European pear shape and fruit long 92.7 mm on average. In contrast, the shortest fruits are from Asian varieties, which had small and round fruits (Baoshy 43.7 mm, Nanguo 44.5 mm on average) (Figure 6). Wide, but different assortment of cultivars was assessed in the warm temperate region of Nepal, the longest fruit was 58.8 mm long ('Anjou') and the shortest was32.5 mm ('Nittaka') (Dhakal *et al*., 2021). The fruits from Central Anatolia were 47.9-70 mm long (Pirlak and Mahmut, 2018). It was only Asian cultivars with round fruit, with similar values as those in our assortment. The longest are naturally typical European pear-shaped fruits. In Soon Valley, Pakistan, the shortest fruit in the assortment of Asian pears was 44.38 mm short and the longest was 87 mm long (Abbas *et al*., 2018).

Thickness of the fruit skin is an important parameter. 'Conference' had the lowest values; its skin was punched with 3.2 kg/cm^2. 'Zao Su Li' (punched with 3.7 kg/cm^2) has thin skin which is good for direct consumption but also, it is prone to damage. By contrast, 'Baoshy' (skin punched with 8.1 kg/cm^2) has the thickest skin which gives good damage protection but worsens the sensory properties. The thick skin tends to be very bitter and overwhelms the taste of the fruit

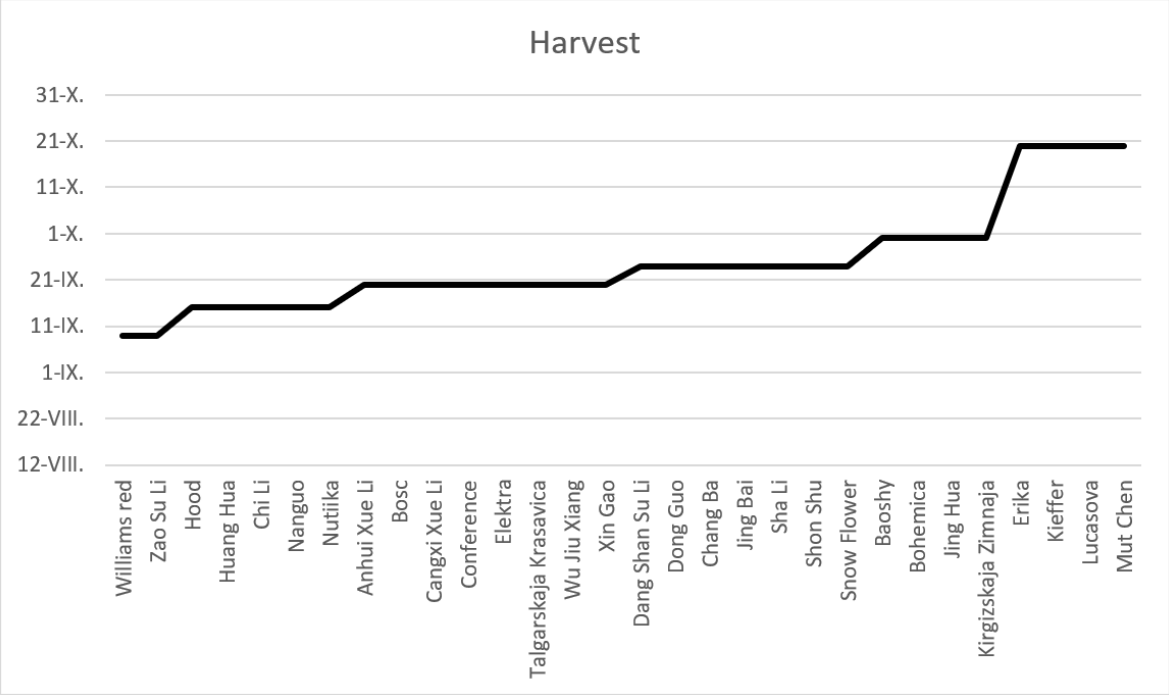

Figure 3. Harvest time of evaluated pear varieties

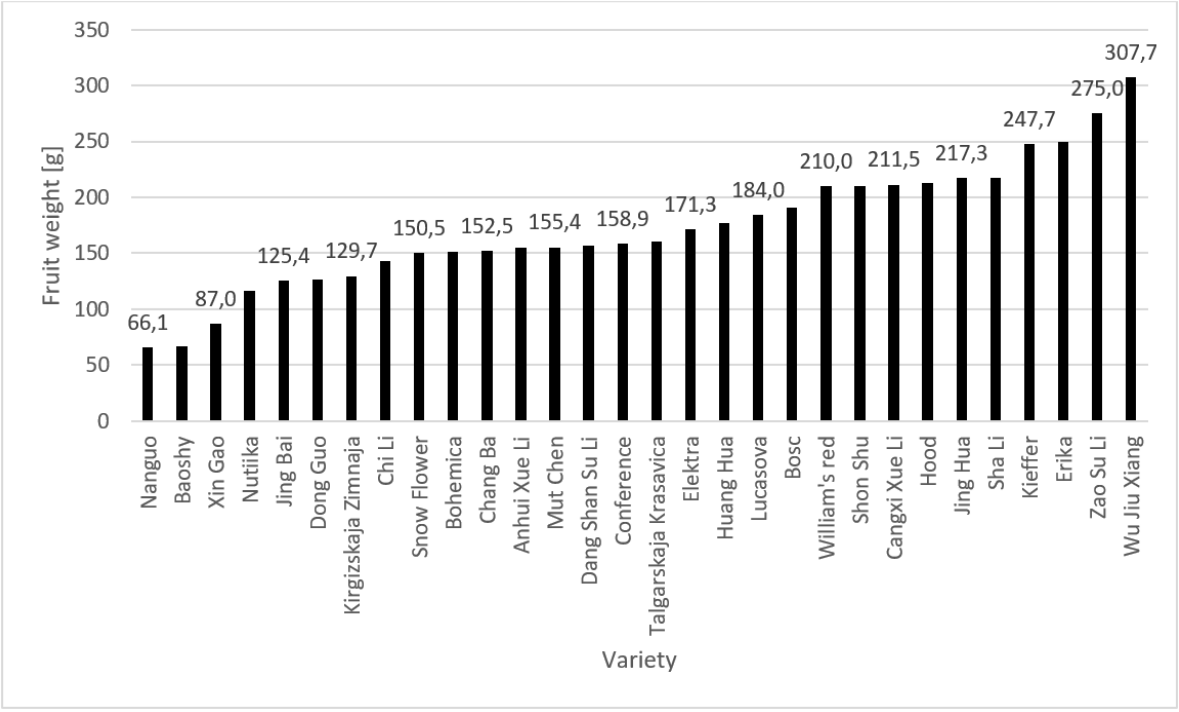

Figure 4. The average fruit weight of evaluated pear varieties

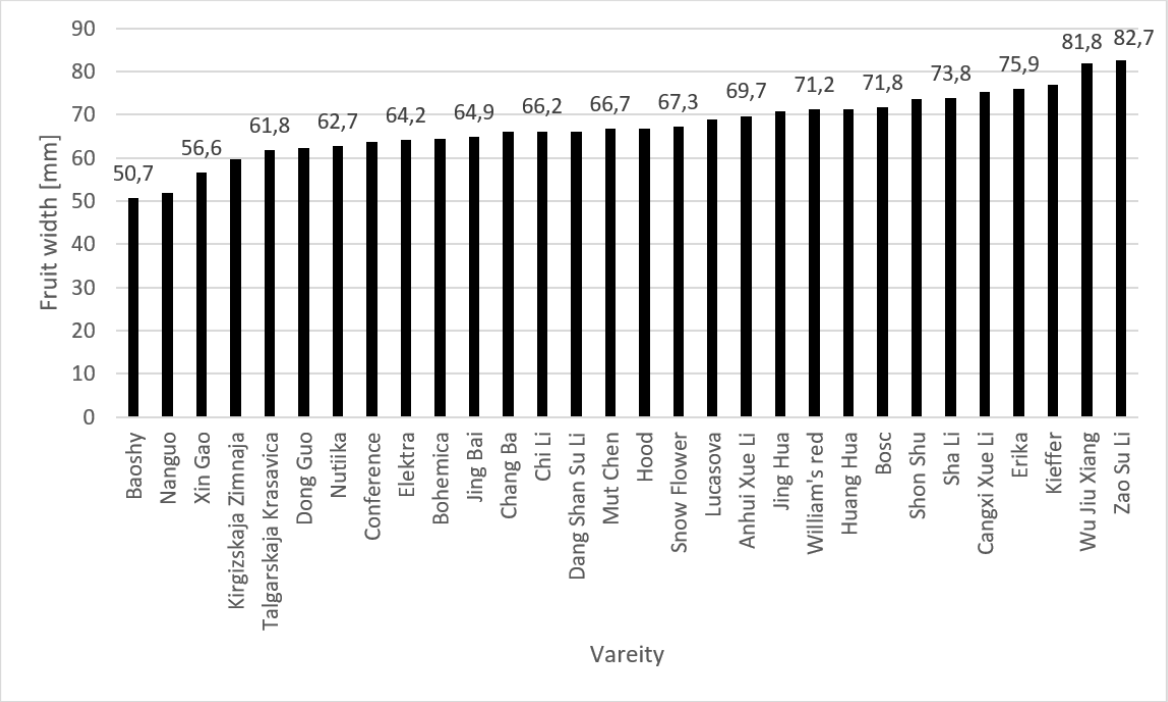

Figure 5. The average fruit width of evaluated pear varieties

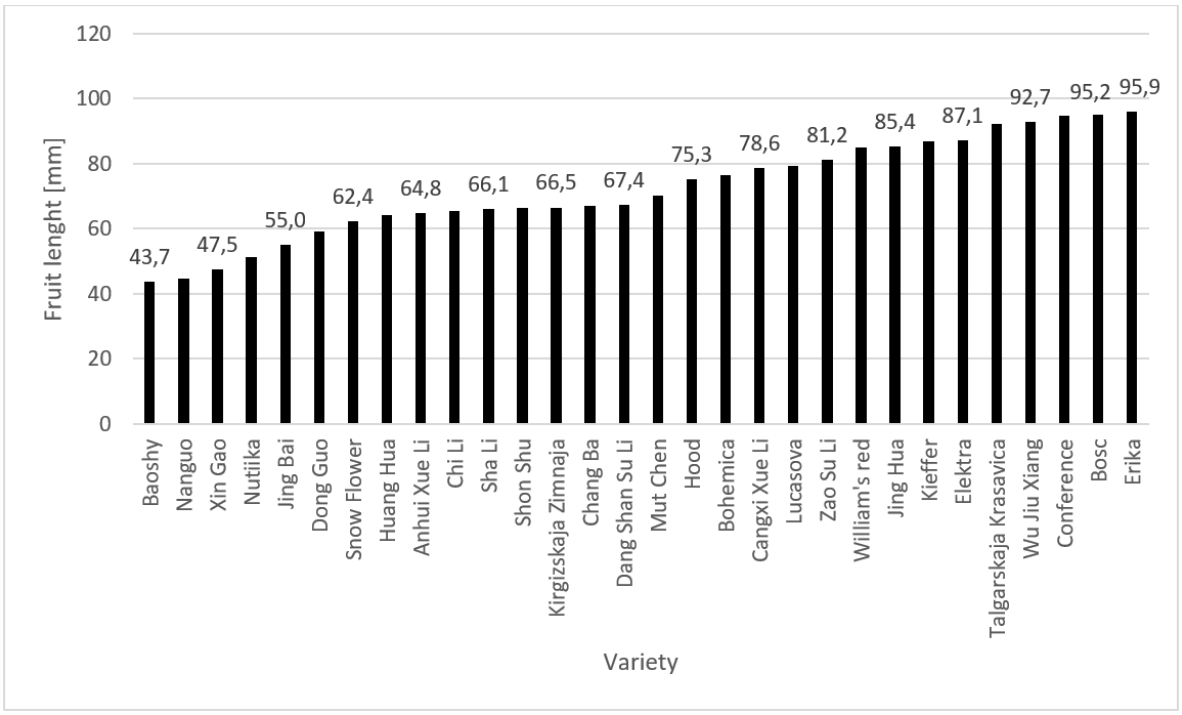

Figure 6. The average fruit length of evaluated pear varieties

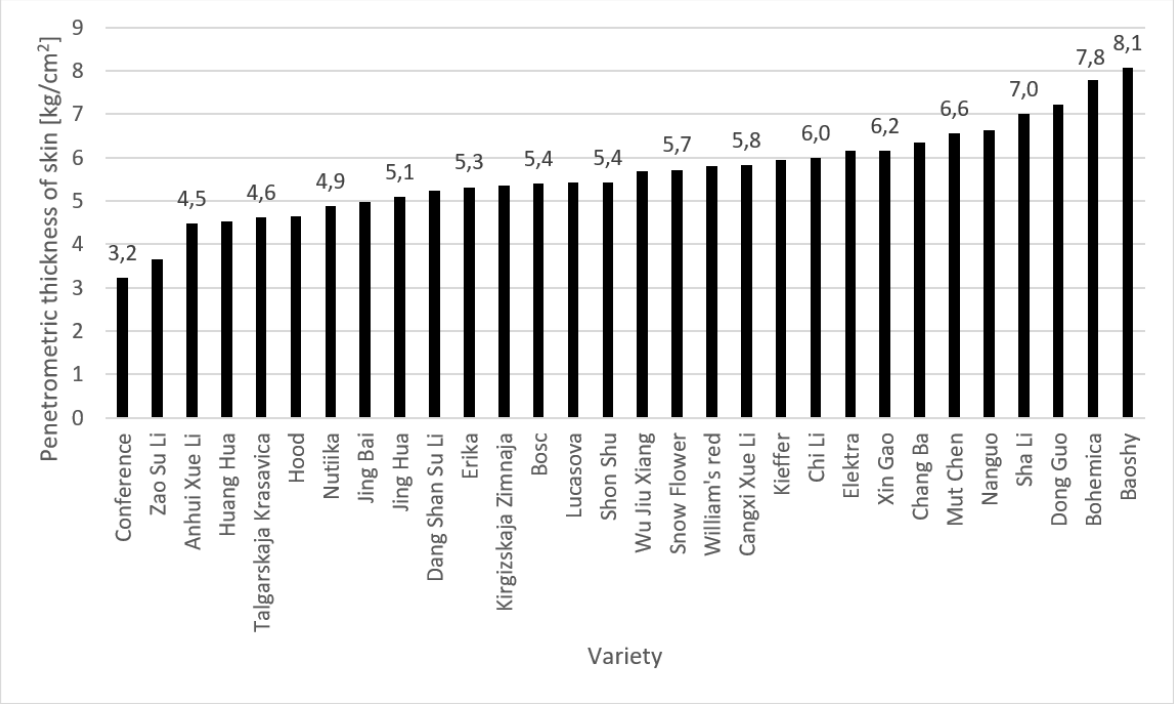

Figure 7. The average thickness of fruit skin of evaluated pear varieties

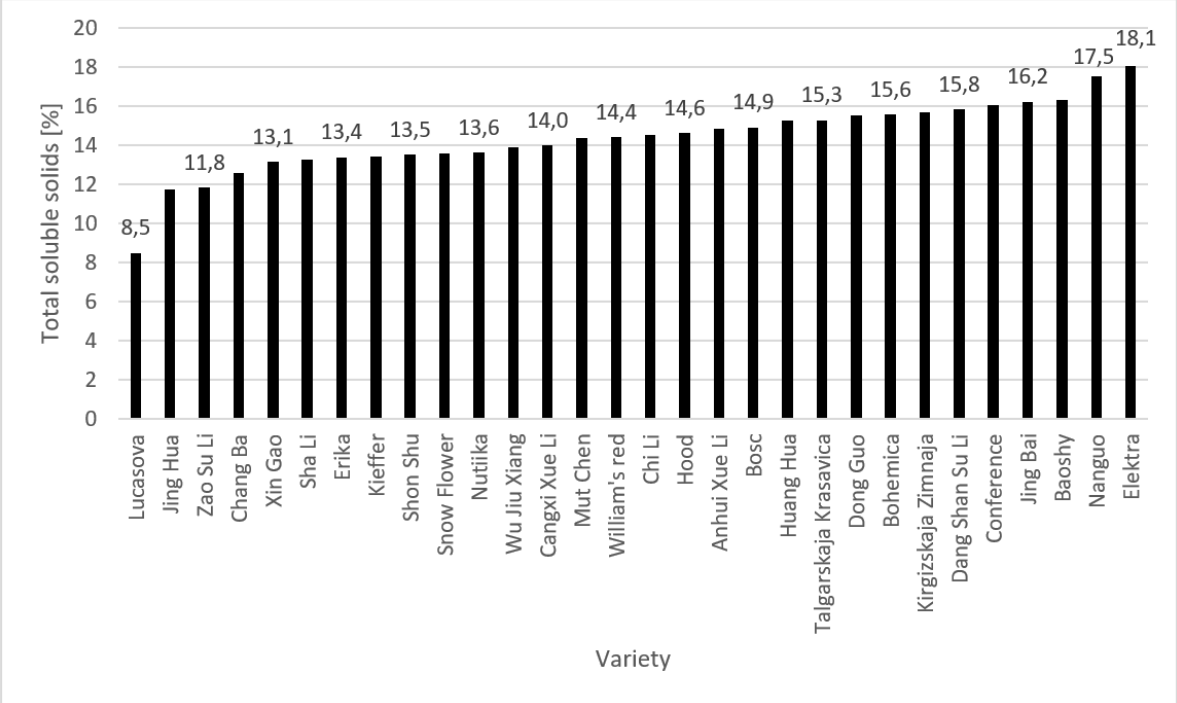

Figure 8. The average content of total soluable solids of evaluated pear varieties

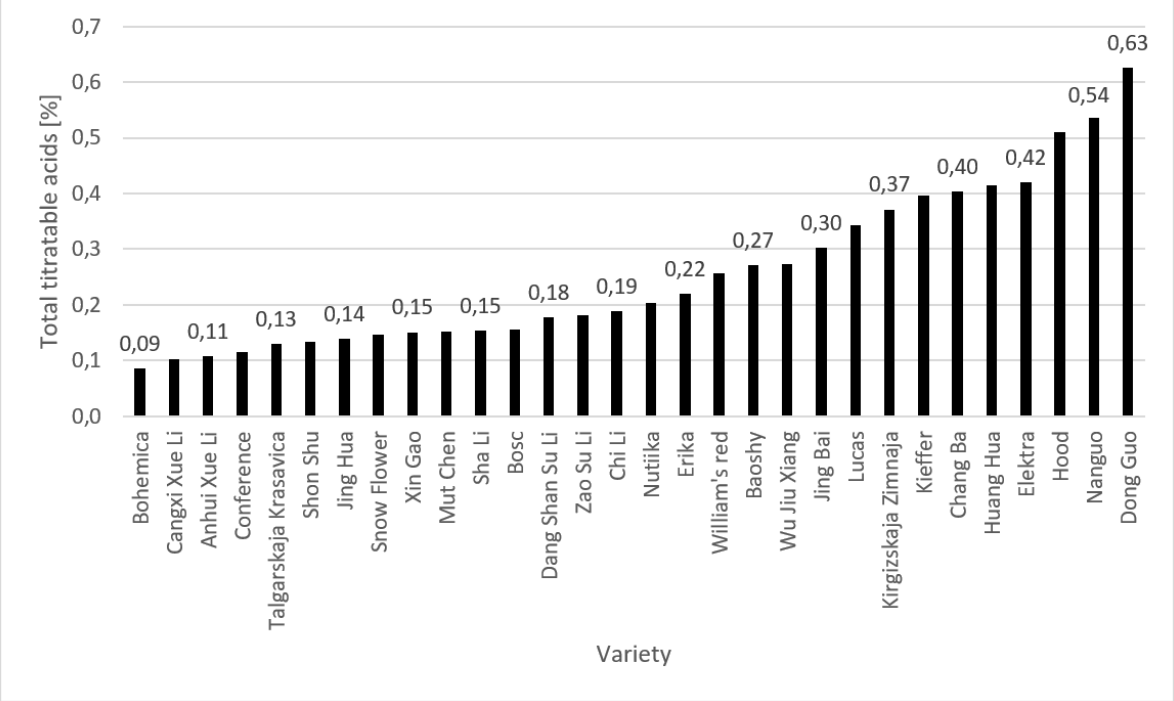

Figure 9. The average content of total titratable acids of evaluated pear varieties

(Figure 7). The thickness of skin of selected Asian pear cultivars varied from 4.7 to 8.1 kg/cm^2 (Pirlak and Mahmut, 2018).

The content of total soluble solids was measured optically by a refractometer. The highest values were in 'Elektra' (18.1 %) and 'Nanguo' (17.5 %). By contrast, the lowest values had 'Jing Hua' (11.7 %) and 'Zao Su Li' (11.8 %) (Figure 8). 'Conference' in South-western Poland, 2012-2015, had 13.4 % of total soluble solids (Sosna 2018). In this study 'Conference' had 16 %, which matches with Nečas *et al*. (2018), in that study 'Conference' had 16.5 % in 2015 and the total average for years 2012-2016 was 15.6 % of total soluble solids. The Asian pears from Central Anatolia, Turkey, contained 11.8-16.9 % of total soluble solids (Pirlak and Mahmut, 2018). In Soon Valley, Pakistan, the content ranged from 6.6 % to 15 % (Abbas *et al*., 2018).

The measurement of total acids was performed using pH meter and results were expressed as % of total titratable acids. The sourest was 'Dong Guo' (0.63 %), followed by 'Nanguo' (0.54 %) and also 'Hood' had high total acid content (0.51 %). The lowest values measured were in 'Cangxi Xue Li' and 'Anhui Xue Li' (0.1 %) (Figure 9). In between 2012 and 2016, the average content of total acids in 'Conference' was 0.18 %, in 'Kieffer' 0.32 %, and in 'Hood' 0.33 % (Nečas *et al*., 2018). Values of total titratable acids in Soon Valley, Pakistan ranged from 0.29 % to 0.44 % (Abbas *et al*., 2018).

CONCLUSION

In this study, 30 pear varieties were evaluated and in context to their phenological and pomological traits, some of them outperform others and have a great potential for growing in middle European climatic conditions. In general, the Asian pear varieties sprouted 2 to 3 weeks and flowered 1 to 2 weeks earlier than the European ones. In maturing, Asian and European pears together range from early September to the half of October. 'Zao Su Li' and 'Williams red' were the earliest. The latest Asian variety was 'Mut Chen', which gives also good quality of fruit and has great storability.

As for the weight of the fruit, the highest potential has 'Zao Su Li' and 'Wu Jiu Xiang', also 'Kieffer', 'Sha Li', 'Snow Flower', 'Shon Shu', 'Jing Hua', 'Hood' and 'Cangxi Xue Li' give big fruit

with good quality.

Of Asian pear varieties, 'Zao Su Li' have the thinnest skin, which is good for direct consumption, also 'Talgarskaja krasavica' has smooth and thin skin. These types of cultivars are generally prone to damage. Varieties, which have thick skin, have usually good damage protection, long storability, but also worse taste. The bitterness of the skin overcharges the taste of the fruit.

Pears have commonly low content of total acids. 'Dong guo' and 'Nanguo' have good percentual and also sensory acidity. In total soluble solids content exceled 'Elektra' and 'Nanguo'. It is important to mention that the acidity and values of soluble solids are closely related to the ripening and the date of harvest.

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