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Evaluation of Estonian apple cultivars and hybrids in Latvia

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Abstract. Estonian apples have always been popular in Latvia. At present, 'Tiina' is widely grown commercially as well as in home gardens, and 'Liivika' is promising for organic and home orchards. A number of new Estonian apple cultivars and hybrids have been screened in 1990–2020. Several new selections by breeder Kalju Kask (Polli) are included in field trials at Institute of Horticulture - 'Aule', 'Kastar' and KK 201-2 ('Karlote') since 2011, 'Kersti' since 2014, KK 5-16 ('Kelin') with scab resistance gene *Rvi6* and KK 2812 since 2015. Their trees were planted on dwarfing rootstock B.9 as one-year-old whips at distances 1.5×4 m, in 3 to 5 replications with 2 or 1 trees. Commercial cultivars 'Auksis', 'Antei' and 'Zarya Alatau' were used as controls. The highest productivity had 'Aule' and 'Kastar', the best fruit quality - 'Aule' and 'Kelin'. 'Aule' has been highly esteemed also by some Latvian farmers. Fruits of 'Kelin' had the best storage, which is crucial for a cultivar's commercial success in Latvia. On the other side, 'Kersti' proved to be unsuitable for Latvian conditions, having very strong tree vigour and low yields. 'Kastar' showed a high tendency to fruit cracking at calyx, while KK 201-2 and KK 2812 had irregular or low yields. Of newer acquisitions, scab resistant (gene *Rvi6*) 'Virve' and KK 4-11 show good preliminary results and have been propagated for trials on dwarfing rootstocks. Productivity, tree characteristics, fruit quality traits and taste panel evaluation of Estonian apples in Latvia are discussed.

Key words: *Malus* x *domestica,* productivity, fruit quality, storage, scab resistance.

INTRODUCTION

Estonian apples have been long-time favourites in Latvia because of their winter-hardiness and good fruit quality. Old cultivars 'Suislepp', 'Tallinna Pirnõun' (syn. 'Revaler Birnapfel') and 'Treboux Sämling' (syn. 'Pärnu Tuviõun') have not lost their popularity in home gardens since 19th century. In 1980ties, 'Põltsamaa Taliõun', 'Sidrunkollane Taliõun', 'Talvenauding', 'Tellissaare' and 'Tiina' were recommended for wider planting (Gronskis & Ūdris, 1988). At present, 'Tellissaare' and 'Tiina' are grown commercially, although their share in orchard area is only 1.6% and 1.3%, respectively (Kaufmane et al., 2017), in new plantings 'Tiina' is more popular. 'Sidrunkollane' and 'Talvenauding' are not propagated anymore, although 'Talvenauding' is recommended as a hardy frame-builder, tolerant to canker (*Neonectria ditissima*). Fruits of 'Tellissaare' are used for processing into purée, 'Talvenauding' - mostly for juice. 'Sügisdessert' is sold by nurseries for planting in home gardens. Crab apple 'Kuku' is popular in the home

gardens, for eating fresh and processing, and promising for cider production (Krasnova et al., 2013).

From newer cultivars, 'Liivika' is promising for organic and home orchards and shows rather good storage potential, although prone to flesh browning with incorrect harvest time (Juhnevica-Radenkova et al., 2016). It has been already tested in an earlier trial, planted in 2008 on rootstock B.9, and was not included in the current study. 'Liivika' is promising for organic growing and home gardens in Latvia (Ikase, 2015).

The climate of Latvia requires winter-hardy cultivars, so Estonian apples present significant interest to Latvian growers. On the other side, good storage is a critical demand for commercial growing of a cultivar in Latvia, as the supermarkets do not welcome early apples. The most widely grown commercial cultivar in Latvia 'Auksis' with 200.8 thousand trees (Kaufmane et al., 2017) which is imported in mass also from Lithuania. 'Auksis' is a favourite because of very good eating quality which remains stable from September till March in common storage. It is suited also for ULO and 1-MCP storage (Juhnevica-Radenkova et al., 2016). Its trees are easy in training, productive and relatively regularly bearing. Main drawbacks of 'Auksis' are easy wind drop and medium resistance to scab. Cultivars without these drawbacks may replace 'Auksis' if they have equal fruit quality. Apples with shorter storage than 'Auksis' have limited use, especially if they mature in the same season and are not superior to it in quality.

The geographical location difference in south-north direction may have both positive and negative effect on productivity and fruit quality parameters like size, colour and biochemical composition (Kviklys et al., 2013; Viškelis et al., 2019). As the summers in Latvia are warmer compared to Estonia, many Estonian apple cultivars there ripen earlier and store for a short time, and may have lower acid and higher sugar content than in their home country. For example, cultivar 'Krista', which is promising in Estonia (Kivistik, 2014), in Latvia tastes bland. Infection of apple mildew (*Podosphaera leucotricha*) is more severe, too. In recent years, growing of 'Tiina' in southern Latvia has become problematic because of high mildew infection, killing new growth.

Apple breeding work in Estonia has been intense recently, resulting in many new selections, mostly by Dr. Kalju Kask (Kask et al., 2010; Kask, 2010). There has been also cooperation in breeding with Latvia - in 1997 hybrid seeds were shared with K. Kask at Polli, from 12 populations with scab resistance gene *Vf (Rvi6),* obtained at our Institute. Elite hybrids were selected from crosses 'Lobo' x 'Remo', 'Merrigold' x 'Stars', open pollinated seeds of 'Florina', 'Remo', 'Imrus', 'Siostra Liberty' and hybrid BM41497. Scab (*Venturia inaequalis*) resistant cultivars 'Kalju' and 'Virve' have been registered in Estonia (Univer, 2019). This gives promise for finding new cultivars suitable for growing in Latvia. Yet these cultivars performance in Latvian climate must be tested.

The aim of the research was to evaluate the productivity and fruit quality of new Estonian apple cultivars and hybrids with good storage potential.

MATERIAL AND METHODS

The trial site is located at the Institute of Horticulture, Dobele, in Zemgale region, southern Latvia (56°37′N 23°16′E). The soil of the orchard site is sandy loam, sod carbonate gleyic, with organic matter 2.3%. Soil pH_{KCl} is 6.7, content of phosphorus (P_2O_5) 207 mg kg^{-1}, potassium (K_2O) 255 mg kg^{-1}, magnesium (Mg) 230 mg kg^{-1}.

The climate of the region is among the warmest in Latvia, but rather unstable (Table 1). The summer temperatures exceeding 30 °C may cause fast over-ripening and flesh browning of apple cultivars originated in Northern Europe. This has become more frequent recently (years 2018 and 2019). In this climate, mildew infection on apple-trees is higher than in the rest of Latvia. Spring frosts during apple flowering are uncommon, but in 2019 frost to -3 °C caused significant fruit damages.

Table 1. Long-term climate and apple-tree phenology of the trial site

Length of vegetation season (t° above 5 °C)	198 days
Sum of temperatures over 10 °C	2,000–2,100 °C
Average annual precipitation	581 mm
Extreme summer temperatures	> 3 °C
Extreme winter temperatures	< -30 °C (every 5–10 years)
Apple flowering	Beginning to end of May (depending on year)
Apple harvest	End of July to 1st decade of October (first autumn frosts)

The testing of Estonian apple cultivars and hybrids were done in two stages. It included preliminary trials and second stage trials of the most promising hybrids.

Preliminary trials

A number of new Estonian apple cultivars and hybrids have been screened at the Latvian Institute of Horticulture in 1990–2020. Most were selections of Dr. Kalju Kask, including such recognized cultivars or candidate cultivars as 'Aule', 'Els', 'Kaari', 'Kaimo', 'Kallika', 'Karamba', 'Kastar', 'Katre', 'Kersti', 'Kikitriinu', 'Krista', 'Liivika', scab resistant KK 5-16 ('Kelin'), 'Virve', KK 4-11 with gene *Vf (Rvi6)*, crabapples 'Kuku', 'Ritika', 'Ruti' and other selections, in total 53. Preliminary testing included also new cultivars of Uno Kivistik ('Reuno', 'Tiit') and Asta Kask ('Kasper', 'Koonik').

For preliminary testing, selections were planted in different years (from 1990 till 2016) on rootstocks B.9, M26 or MM106. The number of trees varied from 2 to 5. Evaluation was done at least for 3 years. The tree health, flowering and productivity were evaluated in points (0–9, where 0 – none, 9 – maximum value). Fruits were stored in common storage at 2 ± 1 °C to determine storage length. Fruits at eating maturity were evaluated at least twice by a taste panel. Tree growth and production habit were evaluated visually. After preliminary testing, the most promising cultivars and hybrids - 'Aule', 'Kastar', KK 201-2 ('Karlote') 'Kersti', KK 5-16 ('Kelin') and KK 2812 were selected for second stage trials at our Institute.

Second stage trials

Three trials were planted in 2011, 2014 and 2015.The first trial was established in 2011 with apple cultivars 'Aule', 'Kastar' and KK 201-2 ('Karlote') and control 'Auksis', trees were planted in 3 or 4 replications of 1 tree. The second trial was planted in 2014 with cultivar 'Kersti' and control 'Zarya Alatau', in 3 replications with 2 trees each. The third trial was planted in 2015 with KK 5-16 ('Kelin') and KK 2812, using as control 'Antei', in 5 replications with 2 trees each.

In all second stage trials, the trees were planted on dwarfing rootstock B.9 as one-year-old whips at distances 1.5×4 m. Trees were staked and trained as slender spindle.

Grass was sown in alleyways and regularly mown, keeping tree strips clean with herbicides. Standard spraying (fungicides and pesticides) and fertilizing were used, according to the standard of integrated growing (MK regulation Nr. 1056, 2009). The fruits were thinned by hand.

The following parameters were evaluated in the second stage trials annually:

- Tree general health in spring and summer (points 0–9, where 0 - tree perished, 9 – excellent tree health),
- Flowering and yielding intensity (points 0–9, where 0 - none, 9 - abundant),
- Scab and mildew damages (points 0–9, where 0 – no visible infection, 9 - > 90% infection, almost all tree damaged),
- Full bloom and harvest dates,
- Yield amount from each tree (kg),
- At harvest for a 5–6 kg sample from each tree: average fruit mass (g), amount on non-standard fruits - undersize or damaged (%), type of damage,
- In storage (common storage at 2 ± 1 °C) for a sample of 30–50 fruits, every 2 weeks: amount of damaged fruits (%), type of damage (disease, physiological), date of latest storage (end of storage - over 25% damaged or overripe fruits).

Harvest maturity was determined by starch-iodine test. For select cultivars optimal harvest maturity was determined by calculating Streif index (SI) (Streif, 1996):

$$SI = PE: (RE \times SV)$$

where PE – flesh firmness by penetrometer (kg cm^{-2}); RE – soluble solid content by refractometer (^{o}Brix); SV – starch-iodine coloration index of flesh (points 1–10, where 1–100% iodine coloration, 10 – no coloration).

For determination of Streif Index, a sample of 10 fruits was collected at eye level from 4–5 trees, from both sides of a row. It was done by spraying cut fruit surface with potassium iodide (KI) Lugol solution (10 g KI + 3 g sublimated iodine per 1 litre of solution). Flesh firmness was measured with penetrometer FT 327 (10 mm head) at 2 opposite sides of each fruit. Soluble solids in juice were measured with Atago refractometer PAL-1.

Taste panels were carried out since 2009 and included 10–12 tasters, evaluating the following parameters: fruit look, taste, aroma, juiciness, firmness. For each tasting 5–6 fruits of about 10 cultivars were taken at eating maturity. Whole fruits were evaluated visually then cut into slices for tasting (unpeeled). A 5-point scale was used, where 1 – very poor, 2 – poor, 3 – medium, 4 – good, 5 – very good. Taste panel data were processed mathematically, finding averages and standard error *(Sx)* for each tasting.

Alternance index

For the trial planted in 2011, starting from 3rd cropping year alternance index (AI) was calculated, to characterise regularity of yielding (in kg per tree) between each 2 years (Monselise & Goldschmidt, 1982):

$$AI = (Yield_{\ year\ 2} - Yield_{\ year\ 1}) : (Yield_{\ year\ 2} + Yield_{\ year\ 1})$$

Tree vigour

In 2019, trunk diameter at 20 cm height was measured in trials, and trunk cross section area was calculated, to determine tree vigour:

$$TCSA = \pi\ (d : 2)^2$$

where TCSA – trunk cross section area (cm^2); d – trunk diameter (cm).

Data were processed mathematically using SPSS (IBM Statistics 25), Tukey *HSD* and LSD_{05} criteria. Differences were considered to be significant for *p-value* < 0.05.

RESULTS

Results of preliminary trials

As the number of cultivars and hybrids in preliminary testing was over 50, only a short summary of the results is given here. All new Estonian cultivars and selections in preliminary testing showed good tree health and tolerance to scab. No significant scab damages were observed with 5–6 annual fungicide sprayings applied in the framework of the integrated growing system. However, several of them were susceptible to mildew in the conditions of southern Latvia, especially 'Tiit'.

Most cultivars and hybrids had attractive fruits with sweet taste, but ripened in autumn, at the peak of apple season, and could be stored 1–2 months. Some became mealy or developed water-core in hot summers when temperatures exceeded 30 °C, especially sweet dessert apples 'Els', 'Kallika', Kata 3 ('Madli') and KK 25-1-20 ('Tiiu'). On the other side, 'Kaisa', 'Katre' and 'Krista' stored well and had large attractive fruits but lacked in flavour. Cultivars 'Kaimo', 'Kanni', 'Koonik' ripening in August had good productivity, but short storage and tasted mediocre.

Number of cultivars and hybrids had tree habit difficult in training, with lots of bare wood, like Kata 1, 'Katre', 'Kirki', 'Madli', KK 281-1. Very vigorous trees with poor productivity had 'Kikitriinu', although with attractive and tasty fruits.

Performance of the most interesting cultivars and hybrids from preliminary trials in Latvia is shortly characterized below.

'Kaari' and **KK 281-14 ('Kalar')** are productive and have good quality sweet fruits with storage till December, which puts them in the peak season of Latvian apple market. For this reason, they have difficulty to compete with the main commercial cultivar in Latvia 'Auksis', which has similar fruit look and the same harvest time, but significantly longer consumption period, even with common storage.

'Karamba' is a small, but very tasty, sweet apple ripening in autumn. Tree is productive, late flowering, medium susceptible to mildew. Interesting for home gardens.

'Kasper' is very early ripening, has high productivity. With proper thinning fruits are tasty, but still small and unattractive in colour. Interesting for home gardens.

'Krista' has large, very uniform, firm fruits which can be stored several months but have poor flavour. Fruits drop easily. Flavour could be better in Northern Latvia, as shown by results in Estonia (Kask et al., 2010).

'Reuno' is so similar 'Liivi Kuldrenett' ('Vidzemes Zelta Renete') that often the fruits cannot be told apart; in Latvia their harvest time and storage length are similar. The tree is very productive and has more spreading habit than 'Liivi Kuldrenett'; like it, is medium susceptible to scab and mildew.

Crabapple 'Kuku' is the best tasting in its group; it has small tree with drooping branches and regular good yields. Fruits can be consumed fresh and processed; only in conditions of extreme drought stress (year 2018) may develop some bitterness. The other crab apples 'Ritika', 'Ruti' show some off-taste, but are suitable for processing.

Hybrids from year 1997 crosses with scab resistance gene *Rvi6* selected by K. Kask were received at our institute in years 2014–2016 and have been evaluated for a short time. These were 'Virve', KK 8-5, KK 4-11, KK 4-11 and KK 5-16 ('Kelin'). Of these

only **'Kelin'** is already included in a second stage trial, planted in 2015 (trial results: below). Their fruit tasting data in preliminary testing are given in Table 2.

Table 2. Taste panel evaluation of Estonian apples in preliminary testing since 2014 (*Sx* – standard error)

Cultivar	Year	Look	*Sx*	Taste	*Sx*	Aroma	*Sx*	Firm-ness	*Sx*	Juici-ness	*Sx*
Auksis	2014	4.2	0.3	4.2	0.3	4.0	0.5	4.0	0.5	4.0	0.4
(control)	2015	4.5	0.4	4.4	0.4	3.9	1.0	3.9	0.6	3.9	0.8
	2016	4.3	0.4	4.3	0.5	3.7	0.6	4.0	0.4	3.8	0.6
	2017	4.5	0.4	3.9	0.4	3.2	1.0	3.6	0.5	3.3	0.8
	2018	4.6	0.3	4.3	0.4	4.2	0.6	4.1	0.6	3.9	0.7
	2019	4.4	0.5	4.2	0.7	3.8	1.0	3.8	0.4	3.6	0.5
	Range	4.2-4.6		3.9–4.4		3.2–4.2		3.6–4.1		3.3–4.0	
KK 8-5	2016	4.3	0.4	3.7	0.6	3.4	0.9	3.9	0.4	4.0	0.2
	2018	4.4	0.5	4.0	0.6	3.7	1.2	4.2	1.0	4.2	0.8
	2019	4.4	0.5	3.3	0.9	3.3	1.0	4.1	0.5	4.0	0.5
	Range	4.3–4.4		3.3–4.0		3.3–3.7		3.9–4.2		4.0–4.2	
KK 4-11	2019	4.5	0.3	4.1	0.6	4.0	0.8	4.1	0.3	4.2	0.7
Kelin	2017	4.2	0.6	3.8	0.6	3.4	1.0	4.0	0.7	3.7	0.7
	2018	4.6	0.3	3.9	0.6	3.5	1.0	3.4	0.8	3.3	0.7
	2019	4.4	0.4	4.2	0.4	3.6	1.0	3.8	0.5	3.6	0.6
	Range	4.2–4.6		3.8–4.2		3.4–3.6		3.4–4.0		3.3.–3.7	
Virve	2017	4.3	0.4	3.8	0.5	3.5	0.9	3.4	0.6	3.8	0.4
	2018	4.4	0.3	4.0	0.3	3.8	0.8	4.0	0.8	3.8	0.8
	2019	4.2	0.4	4.1	0.9	4.0	0.9	3.8	0.7	3.8	0.6
	Range	4.2–4.4		3.8–4.1		3.5–4.0		3.4–4.0		3.8	

'Virve' ('Lobo' x 'Remo') has large and tasty fruits, stored till December or January. Tree is productive, with dense crown. The cultivar was planted in a wider trial in 2020.

Hybrid KK 8-5 ('Imrus' o.p.) has productive tree and large fruits with medium to good flavour, ripening in autumn and similar in look to the old cultivar 'Streifling Herbst'.

Hybrid KK 4-11 ('Lobo' x 'Remo') has given only the first yield of bright red, medium size fruits with good eating quality and storage potential. The tree is early bearing, productive and easy in training. Planting in a wider trial is planned in 2022.

By results of preliminary testing, cultivars 'Aule', 'Kastar', 'Kersti', KK 201-2 ('Karlote'), KK 2812 and KK 5-16 ('Kelin') were selected for second stage trials, planted in 2011, 2014 and 2015. Their results are discussed below.

Results of the trial planted in 2011

Productivity and growth. All cultivars in this trial started bearing fruit in 2013. In average of all years, there were no significant differences between cultivars in fruit number, yield per tree and average fruit mass (Table 3). Yet there were significant differences in yield amount between individual years, determined by alternance of bearing.

Table 3. Production apple cultivars and hybrids in a trial planted in 2011 on rootstock B.9

Cultivar, hybrid	Harvest date	Fruit number per tree	Yield, kg per tree	Average fruit mass, g	Non-standard fruits, %	Type of non-standard
	2013					
Auksis (control)	12.09.	2.0ab	0.4a	311.7	0.0	
Aule	12.09.	1.7a	0.4a	266.7	7.8	seedless
Kastar	13.09.	15.7c	4.2b	274.6	4.0	cracking; small
KK 201-2 (Karlote)	12.09.	9.0bc	2.4b	271.7	19.2	scab
	2014					
Auksis (control)	08.09.	30.0	4.2	139.2a	10.1a	russet
Aule	18.09.	26.2	4.2	171.0ab	0.0a	
Kastar	03.10.	40.7	7.3	198.5b	35.1b	cracking
KK 201-2 (Karlote)	03.10.	37.5	5.8	157.9ab	8.9a	cracking
	2015					
Auksis (control)	-	0.0a	0.0a	-	-	
Aule	29.09.	16.5a	3.2a	186.9	0.8a	fruit rot
Kastar	29.09.	67.3b	11.0b	165.4	12.6b	cracking
KK 201-2 (Karlote)	-	0.0a	0.0a	-	-	
	2016					
Auksis (control)	07.09.	59.3*	8.0	133.4*	1.4a	scab
Aule	23.09.	72.8	13.3	196.0**	2.0a	scab; small
Kastar	29.09.	70.0	12.1	173.8	23.8b	cracking
KK 201-2 (Karlote)	29.09.	132.3**	19.4	147.7*	6.4a	small
	2017					
Auksis (control)	14.09.	31.7a	5.3b	113.8a	14.3	small
Aule	25.09.	28.7a	3.0ab	165.2b	39.5	aphids; scab
Kastar	17.10.	104.0b	14.6c	140.8ab	26.0	cracking
KK 201-2 (Karlote)	-	0.0a	0.0a	-	-	
	2018					
Auksis (control)	31.08.	94.3b	11.6b	118.9	6.7a	small
Aule	14.09.	78.8b	10.8b	137.7	1.7a	small
Kastar	01.10.	7.5a	1.1a	150.0	100.0b	cracking; rot
KK 201-2 (Karlote)	17.09.	102.0b	11.6b	113.2	15.9a	small
	2019					
Auksis (control)	-	0.0	0.0a	-	-	
Aule	18.09.	41.7	7.7b	191.6b	85.4	frost
Kastar	15.10.	96.5c	12.6b	130.7a	62.3	cracking
KK 201-2 (Karlote)	-	0.0a	0.0a	-	-	
	Average of all years ([x] for yield - sum of 7 years)					
Auksis (control)	IX 1. [1]	28.5	[x]27.3	163.8	7.1ab	
Aule	IX 2. [1]	38.1	[x]42.7	178.1	22.0a	
Kastar	X 1. [1]	54.5	[x]60.9	182.7	34.2b	
KK 201-2 (Karlote)	IX 3. [1]	46.4	[x]46.2	176.7	11.3ab	

Notes. In the same year, the cultivars marked with different letters (a, b, c) differed significantly by *Tukey HSD*; with ** differ significantly from marked with * by LDS_{05}; – no data; [1] month, decade.

'Kastar' had the highest yield in 2013, 2015, 2017 and 2019. It had also significantly lower alternance index than other cultivars, 0.13 in the period of 2015–2016 and 0.09 in 2016–2017 'Aule' showed the lowest alternance index (0.21) in 2018–2019

and yield similar with ‘Auksis’ in most years. ’Auksis’ had no yield in 2019, KK 201-2 (‘Karlote’) in 2017 and 2019. Yield amount in 2019 was affected by spring frost, but ‘Karlote’ in 2017 was also weakened by excess yield of 2016.

Measurements of trunk diameter in 2019 showed that trees of ‘Aule’ are much more vigorous than ‘Auksis’, with TCSA respectively 293.4 cm^2 and 167.6 cm^2.

Fruit quality

Average fruit mass of ‘Aule’ was significantly the highest in 2016, 2017 and 2019. Fruits were very uniform in size and shape. Significant differences in all years were found for amount of non-standard fruits. The highest amount of damaged fruits had ‘Kastar’, which has a high tendency to cracking at calyx, on average 34.2%. In 2018 cracking reached 100%. On the other side, control cultivar ‘Auksis’ had only 7.1% non-standard fruits on average.

In 2019, ‘Aule’ had significant spring frost damages, 85.4% of fruits. These damages were similar with ‘Auksis’ in the same orchard plot on trees bearing fruits.

Harvest time and storage

Harvest date of ‘Aule’ was in the 2nd half of September, while control ‘Auksis’ was harvested in beginning of September. Their length of storage was similar, till mid-February or mid-March, but fruits of ‘Aule’ hold on tree much better than ‘Auksis’. ‘Kastar’ was picked later, usually beginning of October, and could be stored till 2nd half of March. ‘Karlote’ produced fruits only in 3 years, its picking dates varied from mid-September to October, and storage length from mid-December till mid-February.

Fruit tasting for these cultivars was carried out since preliminary trials, and so includes many year data, with some exceptions (Table 4). It showed the best results for ‘Auksis’ and only slightly lower for ‘Aule’, although in the hot summer of 2019 the quality of ‘Aule’ decreased, as fruits soon became overripe. Tasting results of ‘Kastar’ and ‘Karlote’ were poor in several years.

Results of the trial planted in 2014

Productivity and growth

Both cultivar ‘Kersti’ and control ‘Zarya Alatau’ in this trial started bearing fruit in 2016. All years ‘Kersti’ had lower number of fruits per tree, but higher fruit mass, 218 g on average. As fruits of ‘Zarya Alatau’ were smaller, yield in kg per tree did not differ significantly either in separate years or on average of all years (Table 5).

Both cultivars in the first years had vigorous, upright trees of similar size, with TCSA in 6th year 19.8 cm^2 for ‘Kersti’ and 21.2 cm^2 for ‘Zarya Alatau’. Strong growth was determined by low yields till 2017, when ‘Kersti’ gave 2.3 kg and ‘Zarya Alatau’ 4.2 kg per tree. By year 2019 the average yields per tree had reached 16.2 kg for ‘Zarya Alatau’ and 9.5 kg for ‘Kersti’. Several older trials have shown that ‘Zarya Alatau’ is highly productive (Rubauskis & Skrivele, 2007), while trees of ‘Kersti’ planted in 2011, in preliminary trial on rootstock MM106, have not yet produced good yield.

Fruit quality

In 2019, 83.6% fruits of ‘Kersti’ were damaged by spring frost, significantly more than ‘Zarya Alatau’, but in 2018 ‘Zarya Alatau’ had the highest amount of undersize fruits, 37.7%.

Taste panel evaluation of ‘Kersti’ could be carried out only in 2 years, including preliminary testing; the rating was good (Table 4).

Table 4. Taste panel evaluation of Estonian apples in second stage trials (*Sx* – standard error)

Cultivar, hybrid	Year	Look	*Sx*	Taste	*Sx*	Aroma	*Sx*	Firm-ness	*Sx*	Juici-ness	*Sx*
Auksis (control)	2009	4.5	0.4	4.6	0.3	4.4	0.5	4.4	0.5	4.8	0.2
	2010	4.3	0.4	4.3	0.4	3.9	0.3	3.7	0.5	4.6	0.5
	2011	4.5	0.3	4.3	0.3	4.3	0.4	4.1	0.4	4.4	0.5
	2012	4.2	0.4	4.1	0.5	3.8	0.7	4.0	0.8	4.6	0.5
	2013	4.5	0.4	4.4	0.4	3.7	1.0	4.0	0.7	4.2	0.8
	2014	4.2	0.3	4.2	0.3	4.0	0.5	4.0	0.5	4.0	0.4
	2015	4.5	0.4	4.4	0.4	3.9	1.0	3.9	0.6	3.9	0.8
	2016	4.3	0.4	4.3	0.5	3.7	0.6	4.0	0.4	3.8	0.6
	2017	4.5	0.4	3.9	0.4	3.2	1.0	3.6	0.5	3.3	0.8
	2018	4.6	0.3	4.3	0.4	4.2	0.6	4.1	0.6	3.9	0.7
	2019	4.4	0.5	4.2	0.7	3.8	1.0	3.8	0.4	3.6	0.5
	Range	4.2–4.6		3.9–4.6		3.2–4.4		3.6–4.4		3.3–4.8	
Aule	2009	4.4	0.4	4.3	0.4	3.9	0.6	4.1	0.5	4.9	0.2
	2010	4.6	0.4	4.5	0.4	4.0	0.6	4.3	0.5	4.9	0.2
	2011	4.3	0.4	3.9	0.8	3.9	0.6	3.6	0.9	4.5	0.5
	2012	4.5	0.2	4.5	0.3	4.2	0.4	4.3	0.5	4.7	0.4
	2014	3.9	0.4	4.2	0.4	3.8	1.0	4.1	0.6	4.2	0.4
	2015	4.4	0.4	3.9	0.6	3.8	0.9	4.1	0.5	4.0	0.7
	2017	4.4	0.4	4.1	0.7	3.8	0.8	3.9	0.5	3.9	0.6
	2018	4.3	0.2	4.0	0.9	3.7	1.0	3.7	0.5	4.0	0.6
	2019	3.9	0.4	3.9	0.7	3.3	0.9	3.4	0.5	3.2	0.7
	Range	3.9–4.6		3.9–4.5		3.3–4.2		3.4–4.3		3.2–4.7	
Karlote	2009	4.4	0.4	4.2	0.4	4.3	0.4	4.2	0.3	5.0	0.1
	2010	4.4	0.4	4.0	0.7	4.1	0.5	3.8	0.4	4.8	0.3
	2011	4.1	0.5	3.9	0.6	3.7	0.5	3.9	0.9	4.3	0.4
	2013	4.1	0.6	4.0	0.7	3.5	0.9	3.5	0.7	3.3	0.8
	2016	4.4	0.4	3.9	0.5	3.6	0.9	3.7	0.5	4.1	0.5
	2018	4.1	0.5	3.2	0.8	2.9	1.0	3.3	0.4	3.2	0.5
	Range	4.1–4.4		3.2–4.2		2.9–4.3		3.3–4.2		3.2–5.0	
Kastar	2009	4.3	0.2	3.8	0.5	3.9	0.6	3.7	0.6	4.9	0.2
	2010	4.0	0.7	3.3	0.6	3.7	0.7	2.8	0.8	4.9	0.3
	2011	4.5	0.3	4.1	0.4	4.3	0.5	3.3	0.9	4.5	0.5
	2012	3.7	0.6	3.7	0.7	4.2	0.7	3.3	1.1	4.7	0.4
	2013	3.9	0.6	3.7	0.8	3.5	1.1	4.2	0.4	3.3	1.3
	2015	4.2	0.4	3.3	0.6	3.1	0.8	3.8	0.9	3.0	0.8
	Range	3.7–4.5		3.3–4.1		3.1–4.3		2.8–4.2		3.0–4.9	
Kersti	2014	4.1	0.7	4.2	0.5	3.6	0.8	4.3	0.4	4.1	0.4
	2017	4.4	0.4	4.3	0.4	3.9	0.9	4.2	0.7	4.1	0.6
	Range	4.1–4.4		4.2–4.3		3.6–3.9		4.2–4.3		4.1	
KK 2812	2018	4.5	0.5	4.5	0.4	4.1	1.0	4.0	0.7	3.8	0.6
	2019	3.9	0.4	4.5	0.4	3.6	0.9	3.9	0.5	3.8	0.6
	Range	3.9–4.5		4.5		3.6–4.1		3.9–4.0		3.8	

Table 5. Production of apple cultivars in a trial planted in 2014 on rootstock B.9

Cultivar, hybrid	Harvest date	Fruit number per tree	Yield, kg per tree	Average fruit mass, g	Non-standard fruits, %	Type of non-standard
	2016					
Kersti	-	0.2a	0.3	-	-	
Zarya Alatau (control)	26.09.	6.1b	1.0	169.7	10.0	bitter pit
	2017					
Kersti	09.10.	10.7	2.3	219.0b	4.2	bitter pit, russet
Zarya Alatau (control)	09.10.	30.4	4.2	131.0a	16.0	small; fruit rot
	2018					
Kersti	13.09.	23.2a	4.8	211.4b	1.3a	bitter pit
Zarya Alatau (control)	02.10.	58.7b	8.9	149.3a	35.7b	small; cracking
	2019					
Kersti	20.09.	45.0a	9.5	224.0b	83.6b	frost
Zarya Alatau (control)	11.10.	128.9b	16.2	129.2a	41.5a	frost, hail
	Average of all years ([x] for yield - sum of 4 years)					
Kersti	IX 2. [1]	19.8a	[x]16.8	218.0b	32.9	
Zarya Alatau (control)	X 1. [1]	56.0b	[x]30.4	142.9a	27.0	

Notes. In the same year, the cultivars marked with different letters (a, b) differed significantly by *Tukey HSD*; – no data [1] month, decade.

Harvest time and storage

Fruit harvest of 'Kersti' for most years was the 2nd half of September, they stored till February or March. Control - late winter control cultivar 'Zarya Alatau' was harvested in beginning of October and stored till April.

Results of the trial planted in 2015

Productivity and growth

Control cultivar 'Antei' and KK 5-16 ('Kelin') in this trial started bearing first few apples already in 2016, while KK 2812 in 2017, and has given only few fruits (Table 6). Significant cultivar differences in all-year average yield per tree were not statistically provable, but differences were found in 2018 and 2019). 'Antei' had the highest yield both these years, reaching 10.8 kg in 2019, when 'Kelin' gave 7.9 kg. Trunk measurements in 2019 showed weaker vigour for 'Kelin' than 'Antei', with TCSA respectively 9.5 cm^2 and 12.6 cm^2 in the 5th year of growth.

Fruit quality

The average fruit mass of 'Kelin' in all years was the lowest*)* as compared with both other cultivars producing very large fruits, but still acceptable, 152.4 g. The highest average amount of non-standard fruits had KK 2812*),* mostly due to frost and hail damages in 2019 reaching 64.2%.

Harvest time and storage

Fruits of 'Antei' in this trial were harvested in beginning of October (except the extremely hot year 2019) and stored till February or March. The best harvest time and storage length of 'Kelin' and especially KK2812 still need to be found, as the first pickings were tentative, lacking previous knowledge.

Table 6. Production of apple cultivars and hybrids in a trial planted in 2015 on rootstock B.9

Cultivar, hybrid	Harvest date	Fruit number per tree	Yield, kg per tree	Average fruit mass, g	Non-standard fruits, %	Type of non-standard
	2016					
Antei (control)	26.09.	1.6	0.3	154.7	0.0	
KK 5-16 ('Kelin')	26.09.	3.3	0.5	139.8	0.0	
KK 2812	-	0.0	0.0	-	-	
	2017					
Antei (control)	09.10.	0.7	1.5	251.7	0.0	
KK 5-16 ('Kelin')	26.09.	0.0	0.0	-	-	
KK 2812	-	0.4	0.0	-	-	
	2018					
Antei (control)	03.10.	14.0b	3.8b	273.9b	1.7a	small
KK 5-16 ('Kelin')	03.10.	12.0b	1.4ab	166.9a	0.6a	cracking
KK 2812	03.10.	3.4a	1.0a	297.1b	17.3b	watercore
	2019					
Antei (control)	11.10.	49.1b	10.8b	223.3b	23.6a	hail, frost, bitter pit
KK 5-16 ('Kelin')	19.09.	62.3b	7.9a	128.8a	24.4a	frost, hail
KK 2812	18.09.	29.6a	7.3a	257.0b	64.2b	frost, hail
	Average of all years (^{x} for yield - sum of 4 years)					
Antei (control)	X 1.[1]	16.4	^{x}15.2	243.0b	8.7a	
KK 5-16 ('Kelin')	IX 3. [1]	19.4	^{x}10.4	152.4a	8.7a	
KK 2812	IX 3. [1]	8.3	^{x}8.4	253.5b	45.5b	

Notes. In the same year, cultivars marked with different letters (a, b, c) differed significantly by *Tukey HSD*; – no data; [1] month, decade

'Kelin' seems to have a long harvest window, from 2nd half of September till early October, as they hold very well on tree, but with late picking they have low juiciness as shown by tasting results in 2018 (Table 2). In general, its taste rating was good and may improve with finding appropriate harvest time. Fruits can be stored till February, maybe longer, without any storage damages.

DISCUSSION

Most Estonian apple cultivars in Latvia ripen in midseason and for this reason have hard competition with the most widely grown commercial apple 'Auksis'. Estonian cultivars can compete with it only if they combine high yields, excellent fruit quality, good fruit storage and disease resistance. From this aspect, new scab resistant *(Rvi6)* selections 'Virve', and possibly KK 4-11 look very promising, as they seem to combine all mentioned characteristics, yet they need more testing.

More results were obtained in the trials planted from 2011 to 2015 at Dobele, where six Estonian cultivars and selections showed various results. Their value for planting in Latvia is discussed below.

‘Aule’

Early winter cultivar with attractive, uniform fruits, looking similar with ‘Auksis’, but with different, refreshing flavour. The over-colour often is weaker, striped. Trees are vigorous, easy to train and have good productivity. Resistance to scab is medium. Fruits may be damaged by spring frost to the same extent as ‘Auksis’. Its value lays both in fruit visual similarity to ‘Auksis’ and later harvest season, as well a good fruit holding on tree. Fruits may have poorer storage and shelf life after hot summers. It is a promising cultivar, recommended for farm trials.

‘Kastar’

Winter cultivar with high productivity and sweet fruits, resembling Latvian cultivar ‘Stars’; like it, may somewhat lack juiciness. Has a strong tendency to fruit cracking at eye, which makes its commercial growing in Latvia non-profitable.

KK 201-2 (‘Karlote’)

This winter apple has very unreliable performance, with good yields and fruit quality only in some years. Not promising.

‘Kersti’

This winter cultivar has large, tasty fruits, but poor productivity and late bearing, too large trees in Latvian conditions. Possibly longer and warmer summers are responsible for the too vigorous growth. The fruit surface often is bumpy, looking like aphid damage. Not promising.

KK 5-16 (‘Kelin’)

Early winter apple with attractive sweet and firm fruits which hold strongly on tree and store very well. Medium juicy, with late picking may be lacking juiciness. First results show relatively weak tree vigour and medium productivity. Resistant to scab *(Rvi6)* and not injured by mildew, unlike ‘Tiina’. It is worth wider testing.

KK 2812

Was selected as a large ‘Antonovka’ type apple with compact tree, but so far has yielded very poorly. More observations are needed, but unlikely to be promising.

Cultivar **‘Liivika’**, which was included in earlier trials, certainly also deserves mentioning here. It has bright yellow, tasty fruits; average 10-year taste panel rating is 4.2 for fruit look, 4.1 for flavour. Harvested in mid-September and can be stored till January. Optimal harvest maturity (Streif index) is 0.07–0.1, must be picked when colour is well-developed. Trees are below medium vigour, production medium (12 kg per tree on B.9) and biennial. Has fruit quality as good, but better storage and smaller trees than the similar cultivar ‘Liivi Kuldrenett’ (‘Vidzemes Zelta Renete’) popular in Latvia. Although medium productivity and lack of uniformity in fruit shape may limit its use for commercial planting, it is recommended for home gardens and organic growing (Ikase, 2015).

The trial place in Dobele, southern Latvia has warmer climate than other regions in Latvia, and this certainly affected trial results. High mildew infection on Estonian cultivars like 'Tiina' and 'Tiit' is regularly observed in Dobele, while farmers from Northern and Eastern Latvia report no such problem. Summer temperatures exceeding 30 °C, which occur more frequently in latest years, lead to over-ripening and poor storage of apples, and were the main reason for discarding of many selections in preliminary testing. Early softening of fruits often causes poorer coloration and taste (Warrington et al., 1999; Lin-Wang et al., 2011). In the discussed trials, such negative effect was observed for 'Aule' in 2019. Also, number of cultivars and selections in preliminary testing showed lower acidity than observed in Estonia, rated in tasters notes as sweet or insipid while in Estonia they are sub-acid (Kask, 2010; Kivistik, 2014). This may be explained by faster fruit maturing. On the other side, climate in Latvia varies significantly between regions, the same as in Estonia (Kask et al., 2010). As northern regions of Latvia lie close to Estonia, it is only logical to suggest that Estonian cultivars there will perform better, and their high winter-hardiness may be the decisive factor planting 'Kaari' or 'Krista' instead of 'Auksis', as these cultivars have shown good performance in Estonia.

CONCLUSIONS

1. Estonian apple cultivars 'Liivika' and 'Aule' are recommended for trial planting at farms in different regions of Latvia.
2. By first results, scab resistant *(Rvi6)* apples 'Virve', KK 5-16 ('Kelin') and KK 4-11 may have promise for growing in Latvia but need longer trials.
3. Cultivars 'Kastar', 'Kersti' and hybrid KK 201-2 ('Karlote') cannot be recommended for planting in Latvia.
4. Midseason ripening Estonian apple cultivars have hard competition in Latvia with the most widely grown commercial apple 'Auksis', and can compete with it only combining high yields, very good fruit quality, good storage and disease resistance.
5. Performance of most Estonian cultivars in southern Latvia is affected by higher summer temperatures, and the results may be better in Northern Latvia.

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