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‘Artemisz’, ‘Cordelia’, ‘Hesztia’, and ‘Rosmerta’: New Hungarian Multiresistant Apple Cultivars

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‘Artemisz’, ‘Cordelia’, ‘Hesztia’, and ‘Rosmerta’ are the first four *Malus ×domestica* (Borkh.) cultivars developed in the apple breeding program of the Corvinus University of Budapest and their registration was accepted by the state in 2011 and 2012. They are mid–early to late-ripening cultivars with the following ripening dates: from the fourth week of August to the first week of September (‘Hesztia’), the second week of September (‘Artemisz’), the third week of September (‘Rosmerta’), and the first 10 d of October (‘Cordelia’) in the growing region between the rivers Danube and Tisza, the central part of Hungary. All four cultivars are resistant to apple scab and also have good resistance to the apple powdery mildew. Their shoots have resistance or moderate resistance to fire blight. The flowers of ‘Hesztia’ exhibited moderate resistance to fire blight. The medium to large fruits (averaging 147 g in weight) of ‘Artemisz’ can be used for both fresh consumption and making into apple chips. ‘Cordelia’ has very large fruit, averaging 269 g, with great flesh firmness (8.3 kg·cm^{-2} on average) and high pectin concentration (0.87%). This cultivar has good storage ability. It is recommended to be used for fresh consumption; however, it can be used for processing purposes based on its physical and chemical properties, e.g., for processing into concentrates, applesauce, and apple chips. The fruit size of ‘Hesztia’ is large, averaging 246 g. On average, the concentrations of gallic acid polyphenols were 392 mg·L^{-1}. It has the highest antioxidant capacity [ferric-reducing ability of plasma (FRAP) 1.34] among the new cultivars. It is suitable for both fresh consumption and processing into apple chips and concentrates. ‘Rosmerta’ (155 g/fruit) is ideal for fresh consumption. However, this cultivar can be potentially used for processing purpose. It is a potential alternative cultivar for ‘Jonathan’; the latter is highly susceptible to various diseases.

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Origin

‘Artemisz’ (tested as MR-03) and ‘Hesztia’ (MR-10) are open-pollinated progeny of ‘Prima’. In 1992, 3434 seeds were collected from ‘Prima’ fruits and germinated, resulting in 3124 seedlings the next year. A molecular analysis using 12 microsatellite markers [simple sequence repeats (SSRs)] presumed that ‘Jonathan’ was the potential pollen parent for ‘Artemisz’ (Table 1). ‘Rosmerta’ (MR-09) was developed from a cross made in 1992 between ‘All Red Jonathan’ and ‘Prima’. A total of 217 seedlings within this progeny, arising from as many as 502 seeds, was grown in 1993. ‘Cordelia’ (MR-12) was a hybrid of ‘Prima’ and ‘Granny Smith’. Crosses were carried out in 1993, and 98 seedlings developed from 134 seeds in the next year.

The seedlings were grown in a greenhouse at Corvinus University of Budapest. All seedlings were screened in early selection tests against scab [*Venturia inaequalis* (Cooke) Wint.] in the first year. Segregation for resistance to apple scab in the progenies was determined by Tóth et al. (1998). Fruit quality of these selections was evaluated on the grafted trees in the next three or four years. Field susceptibility to powdery mildew [*Podosphaera leucotricha* (Ell. & Ev.) Salm.] and scab was continuously monitored, and a negative selection was carried out every year.

Selection and evaluation was carried out in two orchards (lat. 47°23′ N, long. 19°08′ E), one established on M.9 rootstocks in 2003 (two × four trees/cultivar, randomized) and another on M.M.106 rootstocks in 2007 (120 trees/cultivar). These orchards are located in the northwest part of the Great Plain in Hungary, on the flood plain of the River Danube. It has a continental climate with frequent drought, average annual precipitation of 560 mm, average annual temperature of 11.3 °C, and average annual sunshine of 2079 h. The soil of the experimental orchards was characterized as a sandy loam with low organic matter (1.1%) and a soil pH of 7.7.

Description

Criteria of the International Union for the Protection of New Varieties of Plants [under the document titles of TP-14-2 (2006-03-14) and TG/14/9 (2005-04-06)] were used to describe characters of fruits and trees of new cultivars. Data were collected from two years of observation on five plants per cultivar.

Based on the genetic background described by Lespinasse and Delort (1986), all four cultivars could be classified in the “standard Golden” group.

‘Artemisz’

Tree. The mature tree is moderately vigorous with a strong central leader, a spreading architecture, and wide angles between branches. Most bearings came from both spurs and long shoots. The one-year-old shoots are thin or sparse with medium-long internode length. The dormant shoots are dark brown with medium or high density of lenticels. This cultivar is moderately precocious, annual-bearing, and productive.

Foliage. The mature leaves are light green with average length of 5.1 cm, average width of 3.5 cm, and ratio of length/width of 1.49. Leaf margin at the upper half is double crenate; the lower surface is moderate pubescent. Average length of the petiole is 1.4 cm.

Flower. The flower is light pink at the balloon stage and is white at blooming time with a medium diameter. Its stigmas and anthers are at close height.

Fruit. Fruits are conic in shape with moderate ribbing (Fig. 1), average height of 5.5 cm, average diameter of 7.2 cm, ratio of height vs. diameter of 0.8, moderate bloom on the surface, and medium size and density of lenticels. The cover color of the fruits is brown–red or solid flush with almost 100% coverage and inconspicuous red stripes. The ground color is yellow. The cavity is 1.7 cm in depth and 3.4 cm in width with medium extent of russet around the stalk attachment. The basin is 0.9 cm in depth and 3.3 cm in width with strong ribbing at the calyx end. The stalk is 2.3 cm in length and 0.2 cm in diameter. Sepals are medium in size with

moderately open locules. Flesh color is white. Fruit is very firm, crisp, juicy, subacid with a characteristic perfumed flavor.

'Cordelia'

Tree. It is highly vigorous when young and later moderately vigorous. Overall tree shape is spreading with strong central leader and good branch angles. Fruits develop mainly on spurs. The one-year-old shoot is thin with short internode length. The dormant shoots are reddish brown with low density of lenticels. Its tree is precocious with good productivity.

Foliage. The leaves are dark green with an average length of 5.9 cm, average width of 3.3 cm, and ratio of length/width of 1.8. Leaf margin is crenate and the lower surface with moderate pubescence. Average length of petiole is 1.4 cm.

Flower. Predominant color is dark pink at the balloon stage. When fully opened, petals are white, flushed with pink, and slightly overlapped. The diameter of flowers is medium, in which the stigmas are above anthers.

Fruit. The fruits are ellipsoid in shape with a moderately ribbed surface (Fig. 2), average height of 7.8 cm, average diameter of 8.4 cm, ratio of height vs. diameter of 0.93, moderate greasiness on the surface, and medium size and density of lenticels. The ground color of the fruits is yellow–green, and 40% to 60% of the surface is covered by red solid flush and medium wide stripes. Slight sunburn and bitter pit may occur. The cavity is 1.9 cm in depth and 3.3 cm in width. The basin is 0.9 cm in depth and 3.3 cm in width with little or no ribbing at the calyx end. The stalk is 2.1 cm in length and 0.4 cm in diameter. Sepals are large in size with fully open locules. Flesh is cream-colored, very firm, crisp, and moderately juicy; it is a balanced tart–sweet apple with a pleasant strong aromatic flavor. 'Cordelia' may require several picks, depending on fruit coloration.

'Hesztia'

Tree. The tree has medium strong vigor and spreading habit with long branches. Most bearings came from both spurs and long shoots. The one-year-old shoots are medium brown and medium thick having a medium number of lenticels. It is moderately precocious, regular-bearing, and productive with little preharvest drop.

Foliage. The intensity of the green color is light to medium; the lower side of the leaf blade exhibits medium pubescence. The margin is considered crenate. Leaf length is 6.7 cm, width is 4.1 cm, and ratio length/width is 1.67 on average. The length of petiole is 1.7 cm.

Flower. The flower buds are dark pink at the balloon stage and the open flowers have a medium to large diameter. The overlapping petals are white with light pink veining. The stigmas are above the anthers.

Fruit. Fruits are conic in shape with moderate ribbing (Fig. 3), average height of 7.3 cm, average diameter of 8.4 cm, ratio of height vs.

Table 1. Detection of potential parents of four new cultivars based on 12 simple sequence repeat markers[z] (Gianfranceschi et al., 1998; Liebhard et al., 2002).

	Potential parents		Presence of parental alleles (%)	
Cultivar	Seed parent	Pollen parent	Seed	Pollen
Artemisz	Prima	Jonathan	100	100
Cordelia	Prima	Granny Smith	100	100
Hesztia	Prima	Unknown	100	—
Rosmerta	All Red Jonathan	Prima	100	100

[z]List of loci (based on the reference map 'Fiesta' × 'Discovery'): CH01f02 (LG12), CH01h01 (LG17), CH02c02a (LG2), CH02c09 (LG15), CH05e03 (LG3), CH04e03 (LG5), CH05d11 (LG12), CH03g07 (LG2), CH02c11 (LG10), CH02d08 (LG11), CH03a02 (LG14), CH05c04 (LG13).

Fig. 1. Fruit of 'Artemisz' apple.

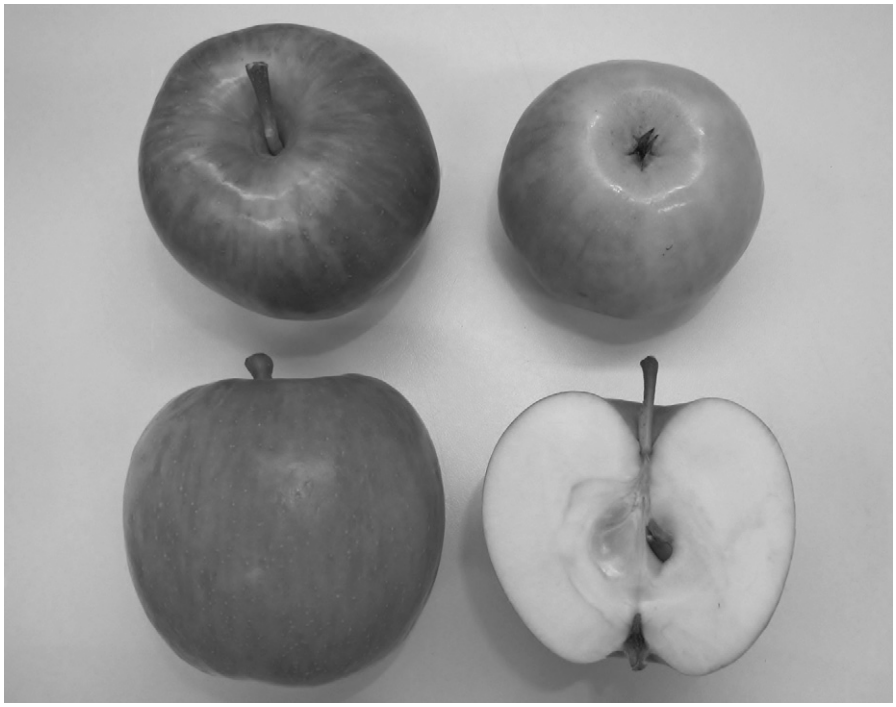

Fig. 2. Fruit of 'Cordelia' apple.

diameter of 0.87, strong bloom, moderate greasiness on the surface, and small size and medium density of lenticels. The ground color is yellow–green, and 60% to 80% of the fruit surface is covered by red. The pattern of cover color is solid flush with wide stripes. The cavity is 1.9 cm in depth and 4.0 cm in width. The basin is 1.0 in depth and 3.4 cm in width with little or no ribbing at the calyx end. The stalk is 1.6 cm in length and 0.3 cm in diameter. Sepals are medium in size with fully open locules. Flesh color is light yellow. Fruit is crisp, quite juicy, balanced sweet-tart, and pleasantly aromatic. 'Hesztia' requires two picks. It develops internal disorders below 2 °C in air storage.

Fig. 3. Fruit of 'Hesztia' apple.

Rosmerta

Tree. The tree is moderately vigorous with a strong central leader and a spreading and rather dense canopy. Fruits are born on both spurs and long shoots. The one-year-old shoots are medium brown, medium thick, with short internode length and few lenticels. 'Rosmerta' is precocious, high-yielding, and bears annually.

Foliage. The color of leaves ranges from light to medium green with average length of 5.6 cm, average width of 3.1 cm, and ratio of length/width of 1.79. The lower surface is covered with fine pubescence, the leaf margins are crenated, and the petiole is medium long (1.5 cm).

Flower. The flower is light pink at the balloon stage and is white and overlapped in blooming time with medium diameter. Its stigmas and anthers are at the close height.

Fruit. Fruits are conic in shape (Fig. 4) with average height of 6.0 cm, average diameter of 7.3 cm, ratio of height vs. diameter of 0.82, very thin bloom and strong greasiness on the surface, and medium size and low density of lenticels. The ground color is yellow–green, the cover color is dark red, and almost 100% of fruit surface is covered by solid flush and dull stripes. The cavity is 1.6 cm in depth and 3.3 cm in width with large extent of russet around the stalk attachment. The basin is 0.8 cm in depth and 3.0 cm in width with strong ribbing at the calyx end. The stalk is 2.3 cm in length and 0.2 cm in diameter. Sepals are medium in size with moderately open locules. Flesh is cream-colored, semifirm, fine-textured, slightly to moderately juicy, sweet, and refreshingly subacid with a weak aroma. 'Rosmerta' is moderately susceptible to lenticel spot, and 'Jonathan' breakdown (under the skin) occurs in air storage.

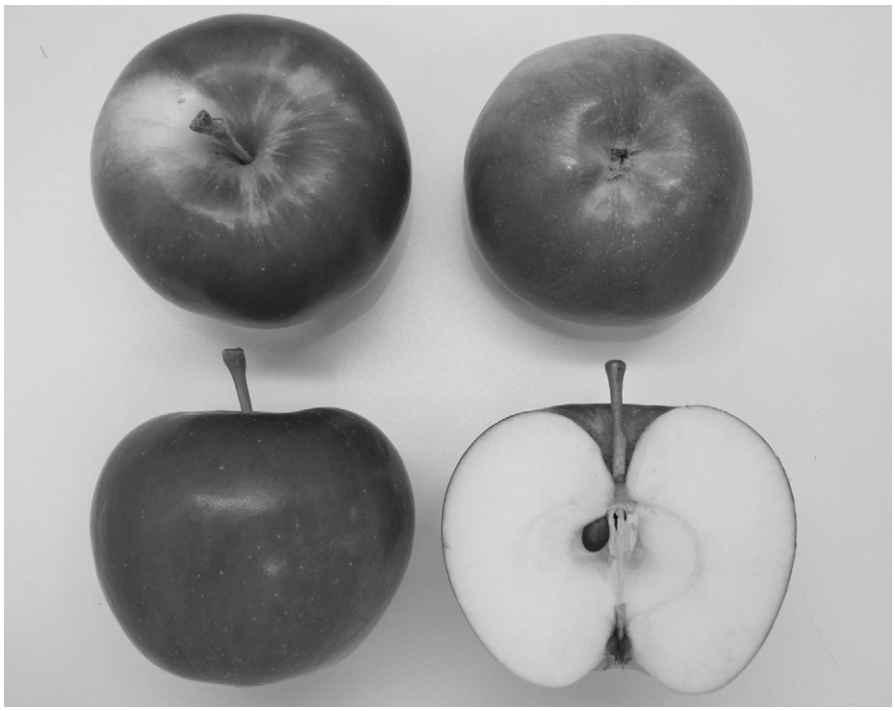

Fig. 4. Fruit of 'Rosmerta' apple.

Inflorescence and Fertilization Biology

Table 2 presents the blooming time and fertilization properties of the new cultivars. Blooming time of four cultivars can be classified into four categories (Table 2). Flow cytometry analysis proved all four cultivars to be diploid (Bodor, 2009).

Pollen germination tests for four cultivars were carried out in 2009 (Janick et al., 1996). Pollen germination ability of these four cultivars was similar to or better than the control cultivars (Table 2).

S-genotypes of the four cultivars were determined by molecular diagnostic analysis using the method of Nybom et al. (2008). Five *S*-alleles (*S*2, *S*7, *S*9, *S*10, and *S*23) were identified in the four new cultivars (Table 2). After comparisons with the *S*-genotypes in the ≈450 commercial cultivars, the new cultivars were found compatible with each other and with these commercial cultivars in most cases. However, incompatibility was found between the new and a few commercial cultivars. For example, 'Cordelia' is incompatible with 'Pink Lady' and 'Hesztia' with 'Fiholms Ribston' or 'Pigeon'. Based on *S*-allele analysis, these four new cultivars presented semicompatibility with the four scab-resistant cultivars currently grown in Hungary

Table 2. Blooming time and duration based on three years of observations at two locations (Bodor, 2009), pollen germination tests, and *S*-genotype analysis in 2009 and 2008.

Cultivar	Blooming time groupings[z]	Blooming duration (days)[z]	Pollen germination rate (%)[z]	*S*-genotype
Artemisz	Midearly to midlate	12	33	*S2S7*[w]
Cordelia	Early to midearly	13	22	*S2S23*[w]
Hesztia	Midlate to late	12	37	*S7S10*[w]
Rosmerta	Midearly	12	54	*S9S10*[w]
Freedom	Midlate to late	14	28	*S5S?*[y]
Liberty	Early	12	28	*S3S5S10*[x]
Prima	Early	13	23	*S2S10*[x]

[z]Bodor (2009).
[y]Sakurai et al. (2000).
[x]Broothaerts et al. (2004).
[w]New data.

Table 3. Fruit quality in four new and three control cultivars grafted on M.9 rootstock (2007–11).[z]

Cultivar	Fruit wt (g)	Covered area of overcolor (%)[y]	Fruit firmness (kg·cm^{-2})	Total soluble solids (%)[x]	Total titratable acidity (% malic acid)[w]	Sugar/acid ratio
Artemisz	147 d[v]	97	7.96 a	13.94 a	0.94 a	15.33 c
Cordelia	269 a	59	8.30 a	13.90 a	0.73 b	19.35 b
Hesztia	246 b	88	6.72 b	13.40 a	0.69 b	19.90 b
Rosmerta	155 c	67	6.04 c	14.14 a	0.69 b	20.79 b
Idared	231 b	78	5.54 c	12.90 b	0.63 b	20.55 b
Gala	144 d	45	7.24 b	12.56 b	0.34 d	37.52 a
Prima	162 c	82	5.05 d	11.05 b	0.55 c	20.09 b

[z]The tests were performed immediately after the harvest.
[y]Mean values of 75 fruits/cultivars from visual estimates.
[x]From an ATAGO PR-101 digital refractometer (Codex Alimentarius 3-1-558/93).
[w]Hungarian Standard No. 3619:1983.
[v]Means with the same letter were nonsignificantly different ($P < 0.05$).

Table 4. Pectin and polyphenol concentrations and antioxidant capacity in four new and three control cultivars after storage of 45 d at –25 °C.[z]

Cultivar	Pectin (%)[y]	Polyphenol (mg·L^{-1} gallic acid)[x]	FRAP (mmol·L^{-1} ascorbic acid)[w]
Artemisz	0.72 b[v]	191 c	0.75 c
Cordelia	0.87 a	244 b	0.68 c
Hesztia	0.74 b	392 a	1.34 a
Rosmerta	0.71 b	285 b	0.88 b
Idared	0.76 b	184 c	0.64 c
Gala	0.33 c	107 c	0.47 d
Prima	0.69 b	311 a	1.08 a

[z]Data collected in 2009–11.
[y]Using the method of Kyriakidis and Psoma (2001).
[x]Using the Folin-Ciocalteau method according to Singleton and Rossi (1965).
[w]Carried out according to Benzie and Strain (1996).
[v]Means with the same letter were nonsignificantly different ($P < 0.05$).
FRAP = ferric-reducing ability of plasma.

Table 5. Properties of four new and two control cultivars potentially used for concentrates (Nótin et al., 2010).

Cultivar	Density (g·cm^{-3})[z]	Acid contentration (%)	Polyphenol contentration (mg/100 g)	Transmittance at 420 nm[y]	Turbidity[x]
	(70% refraction)			(11.5% refraction)	
Artemisz	1.346	3.61	1393	43.4	6.1
Cordelia	1.355	3.69	1862	30.0	3.3
Hesztia	1.315	2.38	2311	29.6	2.8
Rosmerta	1.348	2.85	1961	29.7	5.5
Idared	1.353	2.77	1113	50.1	4.2
Jonathan	1.328	3.14	1585	41.5	2.6

[z]By automatic density meter (DM-340.2; JSC LEMIS Baltic Ltd.).
[y]Transmittance of 10-mm cell against distilled water at 420 nm by Hitachi U-2900 spectrophotometer (Hitachi High-Technologies Europe GmbH, Krefeld, Germany).
[x]By HACH 2100 P Turbidimeter (HACH LANGE GmbH, Düsseldorf, Germany).

('Prima', 'Freedom', 'Florina', and 'Remo') (Table 2). Thus, the new cultivars can be potentially pollinated with local cultivars or other cultivars with common *S*-genotypes (*S*1*S*3, *S*2*S*3, *S*3*S*9, or *S*3*S*5).

Artificial pollination tests confirmed the conclusions drawn by *S*-allele analysis. In addition, the new cultivars had the same flowering time with the major commercial scab-resistant cultivars (Bodor and Tóth, 2008).

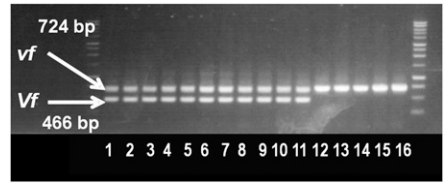

Fig. 5. Amplification of *Vf* and *vf* alleles in Hungarian and control cultivars using AL07S primers: 'Liberty' (lane 1), 'Prima' (lane 2), 'Remo' (lane 3), 'Florina' (lane 4), 'Artemisz' (lane 6), 'Rosmerta' (lane 7), 'Hesztia' (lane 8), 'Cordelia' (lane 10), 'Idared' (lane 12), 'Redchief Delicious' (lane 13), 'Golden Delicious Reinders' (lane 14), 'Regal Prince' (Gala Must) (lane 15), 'Jonathan' (lane 16).

Chemical Contents and Potential Uses of the Fruit

Fruit size of the new cultivars can be classified into two categories (Table 3). SD of the fruit diameter was ≈5% ('Artemisz'), 9% ('Cordelia'), 4% ('Hesztia'), and 3% ('Rosmerta') among observations from five years. Fruits of the four new cultivars are characterized by their high sugar concentrations as well as their high acidity. Except 'Artemisz', three new cultivars had a balanced flavor, similar to 'Idared', based on their ratio of sugar vs. acid concentrations (Table 3).

'Cordelia' had extremely high pectin. The remaining three cultivars also had higher pectin than 'Gala' but close to 'Idared' (Table 4). The average values of 'Artemisz', 'Hesztia', 'Rosmerta', and 'Idared' are similar to 'Fuji' reported by Billy et al. (2008).

Polyphenol concentrations in the new cultivars were close to reported by Khanizadeh et al. (2008). 'Hesztia' had the highest concentration, and 'Cordelia' and 'Rosmerta' were higher than 'Idared' or 'Gala'. 'Artemisz' presented the highest tolerance to flesh browning. The FRAP values, as a measure of antioxidant capacity, showed the same trends as polyphenol contents in the new cultivars.

A trained panel was invited to evaluate the fruit quality. A profile analysis method (Kókai et al., 2004; Sipos et al., 2011) and ProfiSens sensory evaluation software were used to make groupings in fruit quality compared with the controls. Participants of the panel were selected and trained according to the guidelines in ISO/DIS 8586:2011. The panel evaluated 20 descriptive sensory characteristics based on an unstructured 1 to 100 scale. Thirteen items showed significant difference among the six cultivars assessed ($P < 0.05$). 'Cordelia' was better than 'Prima' in shape, size, texture, ripeness, firmness, intensity of acerbity, residual taste, and crispness. Principal components analysis was used to discern the major contributors to the new cultivars (Dahl et al., 2008; Meullenet et al., 2007). These major contributors are: 'Cordelia', large weight, large size, high flesh firmness, hard texture, crispness, ripeness, and a balanced ratio of sugar vs. acid; and 'Hesztia' and 'Rosmerta', yellow ground

color, yellow cover color, distinguished flavor, symmetric shape, tiny lenticels on the skin, high pectin concentrations, and a balanced ratio of sugar vs. acid.

A comparison with two cultivars, 'Idared' and 'Jonathan', widely grown for making apple concentrates in Hungary showed that 'Cordelia' and 'Hesztia' presented the best properties potentially used for processing concentrates (Nótin et al., 2010; Table 5).

Apple purées were made from the fruit of 'Artemisz' and 'Cordelia' according to the method of Oszmianski et al. (2008). 'Cordelia' was reported to be suitable for making apple purée (Nótin et al., 2009). The evaluation by an untrained-panel including 40 participants for the potential use for making apple purée in five cultivars showed that 'Florina' was ranked the best one followed by 'Cordelia'.

Apple chips were made by method of Nótin et al. (2011). Ascorbic and citric acid were used to inhibit enzymatic browning during processing. Results showed that 'Idared' treated with ascorbic acid presented the highest rank for apple chips followed by 'Hesztia' treated with citric acid.

Table 6. Mean susceptibility of apple shoots and flowers to fire blight after inoculation with pathogen *Erwinia amylovora* data collected in four years.

Cultivar	Number of shoots tested	Percentage of shoot necrosis[z]	Susceptibility groupings[w]	Number of flowers tested	Flower susceptibility (0–3)[y]	Susceptibility groupings[v]
Hesztia	58	12.3 a[x]	R	78	0.6 a[u]	mR
Artemisz	58	14.3 a	R	78	1.6 bc	S
Prima	39	24.3 ab	mR	82	1.2 b	mS
Remo	48	31.3 bc	mR	78	1.1 b	mS
Rosmerta	45	35.0 bc	mR	70	1.1 b	mS
Liberty	27	36.3 bc	mR	60	1.5 bc	S
Cordelia	47	36.5 bc	mR	98	1.4 bc	S
Freedom	25	41.9 c	mS	80	0.4 a	R
Jonathan	80	74.9 d	S	54	1.7 c	hS
Idared	84	86.1 d	hS	60	1.5 bc	S

[z]Length of shoot necrosis vs. of the entire shoot length in the four weeks after inoculation.
[y]Flowers collected on the fifth day after inoculation were used for a longitudinal sectioning and susceptibility of scores were based on a modified protocol of by Pusey (1999), where 0 = no necrosis, 1 = detectable necrosis, 2 = up to half of the ovary was necrotic, and 3 = necrosis affecting half to all the ovary, or extending beyond the ovary to the peduncle.
[x]Mean values with the same letter were nonsignificantly different ($P < 0.05$, Tukey test).
[w]Based on Le Lézec et al. (1997) and the result of the Tukey test.
[v]Based on the ratings: R = < 0.4; mR = 0.41–0.8; mS = 0.81–1.2; S = 1.21–1.6; hS > 1.6, and the result of the Duncan test.
[u]Mean values with the same letter were nonsignificantly different ($P < 0.05$, Duncan test).

Resistance to Pathogens

The artificial inoculation test with a mixed conidium suspension (4.5×10^5 conidia/mL) was used to identify resistance in the young seedlings to pathogen *Venturia inaequalis* in the greenhouse. The conidia were collected from pathogenic populations in orchards across the country of Hungary. The heterozygous *Vfvf* genotype of the four cultivars was confirmed by polymerase chain reaction analysis according to Tartarini et al. (1999) using the codominant AL07-SCAR primer pair (Fig. 5). The new cultivars presented resistant to pathogen *Venturia inaequalis* in the all orchards tested. Our investigation confirmed races 1 and 2 in Hungary, whereas presence of races 3 and 5 was uncertain. The breakdown of the *Vf* gene by the pathogen was not observed in Hungary (Papp et al., 2012; Tóth et al., 2003).

Resistance or tolerance to powdery mildew was identified by the method of Krüger (1994) under natural conditions in the field (data not shown). The rating scale of 0 to 3 was used where: 0 = no visible symptoms, 1 = slight mildew sporulation on a few single leaves, 2 = mildew sporulation on leaves or occasionally on the shoot tips, 3 = severe mildew sporulation on more than three shoots. Observation from 16 years in the orchards without application of fungicides showed that 'Artemisz', 'Cordelia', and 'Hesztia' had resistance to powdery mildew. They did not present obvious symptoms except that a slight symptom occasionally occurred on some shoot tips. Cultivar Rosmerta was also completely symptomless in seven years but had an infection rate averaging 1.6 on the 0 to 3 scale in the other years.

A decade of observations revealed no tendency to branch or bark diseases caused by *Nectria galligena* Bres. and *Pseudomonas syringae* pv. *syringae* for any of the cultivars.

The artificial inoculation test was used to identify resistance to fire blight [*Erwinia amylovora* (Burr.) Winslow] in the shoots and flowers of the new cultivars in the greenhouse and in the laboratory. Three *Ea* isolates, Ea2, Ea60, and Ea67, originating from different localities in Hungary were used to make a mixed bacterial suspension (107 cfu·mL^{-1}). Data were collected from four years to obtain a reliable estimate of resistance.

Results showed that 'Hesztia' and 'Artemisz' were resistant and 'Cordelia' and 'Rosmerta' moderately resistant (Table 6). An inoculation test using a mixture of a strongly virulent Polish strain and three strongly virulent German strains (Sobiczewski et al., 2011) showed that 'Hesztia' presented the highest resistance, 'Artemisz' presented moderately resistant, and 'Cordelia' presented moderately susceptible.

Variation of susceptibility was observed between flowers and shoots (Table 6). In flower, 'Hesztia' was ranked moderately resistant, 'Rosmerta' was susceptible, and the flowers of 'Artemisz' and 'Cordelia' were susceptible.

Keller-Przybylkowicz et al. (2009) identified qualitative trait loci alleles potentially associated with fire blight resistance in the three cultivars: 'Artemisz', AE-10-375 (LG 7), CH03g12 (LG 3); 'Cordelia', CH-FP-Fb1 (LG 7), CH03g12 (LG 3); and 'Hesztia', AE10-375 (LG 7), CH-FP-Fb1 (LG 7). The SSR marker CH03e03 (LG 3) described by Peil et al. (2007) may be associated with resistance to fire blight in all of the three Hungarian cultivars (Keller-Przybylkowicz et al., 2009). However, Nybom et al. (2012) doubted genetic association of this SSR marker with fire blight resistance in the genotypes, which are not genetically related to *Malus robusta*.

No chemicals are needed to control these diseases for the new cultivars. Thus, the costs for this aspect were on average deducted 68.5% compared with the susceptible cultivars.

Availability

'Cordelia' and 'Hesztia' are under patent application from the Community Plant Variety Office, Hungary. The licensed virus-free plant materials of all four cultivars and the contact details of the nurseries designated for propagation of these new cultivars can be obtained from the senior coauthor.

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