
Magdolna Tóth, Gitta Ficzek, Ildikó Király, Szilvia Kovács, and Mária Hevesi
Department of Pomology, Corvinus University of Budapest, Villányi u. 35-43, Budapest H-1118, Hungary

Júlia Halász
Department of Genetics and Plant Breeding, Corvinus University of Budapest, Ménesi u. 44, Budapest H-1118, Hungary

Zsolt Szani
National Food Chain Safety Office, Keleti Károly u. 24, Budapest H-1024, Hungary

Additional index words. Malus × domestica, Venturia inaequalis, Erwinia amylovora, Podosphaera leucotricha, fruit quality, S-genotype

‘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 medium resistance to the apple powdery mildew. They have good resistance to the apple powdery mildew for both fresh consumption and making into apple products, and ‘Rosmerta’ 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 purposes. It is a potential alternative cultivar for ‘Jonathan’; the latter is highly susceptible to various diseases.

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 93 seedlings were 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 apple 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 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 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 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 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.
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>
<thead>
<tr>
<th>Cultivar</th>
<th>Potential parents</th>
<th>Presence of parental alleles (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artemisz</td>
<td>Prima Jonathan</td>
<td>100 100</td>
</tr>
<tr>
<td>Cordelia</td>
<td>Prima Granny Smith</td>
<td>100 100</td>
</tr>
<tr>
<td>Hesztia</td>
<td>Prima Unknown</td>
<td>100 —</td>
</tr>
<tr>
<td>Rosmerta</td>
<td>All Red Prima</td>
<td>100 100</td>
</tr>
</tbody>
</table>

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

‘List of loci (based on the reference map ‘Fiesta’ × ‘Discovery’): CH01f02 (LG12), CH01h01 (LG17), CH02e02 (LG2), CH02e09 (LG15), CH05c03 (LG3), CH04e03 (LG5), CH05d11 (LG12), CH03g07 (LG2), CH02c11 (LG10), CH02d08 (LG11), CH03a02 (LG14), CH05c04 (LG13).
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 cm 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.

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.

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 (S2, S7, S9, S10, and S23) 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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Blooming time groupings</th>
<th>Blooming duration (days)</th>
<th>Pollen germination rate (%)</th>
<th>S-genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artemisz</td>
<td>Midearly to midlate</td>
<td>12</td>
<td>33</td>
<td>S2S7w</td>
</tr>
<tr>
<td>Cordelia</td>
<td>Early to midearly</td>
<td>13</td>
<td>22</td>
<td>S2S23w</td>
</tr>
<tr>
<td>Heszzia</td>
<td>Midlate to late</td>
<td>12</td>
<td>37</td>
<td>S7S10w</td>
</tr>
<tr>
<td>Rosmerta</td>
<td>Midearly</td>
<td>12</td>
<td>54</td>
<td>S9S10y</td>
</tr>
<tr>
<td>Freedom</td>
<td>Midlate to late</td>
<td>14</td>
<td>28</td>
<td>S5S9y</td>
</tr>
<tr>
<td>Liberty</td>
<td>Early</td>
<td>12</td>
<td>28</td>
<td>S5S9S10y</td>
</tr>
<tr>
<td>Prima</td>
<td>Early</td>
<td>13</td>
<td>23</td>
<td>S2S8y</td>
</tr>
</tbody>
</table>

1Bodor (2009).
2Sakurai et al. (2000).
3Broothaerts et al. (2004).
4New data.

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

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Fruit wt (g)</th>
<th>Covered area of overcolor (%)</th>
<th>Fruit firmness (kg·cm−2)</th>
<th>Total soluble solids (%)</th>
<th>Total titratable acidity (% malic acid)</th>
<th>Sugar:acid ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artemisz</td>
<td>147 d°</td>
<td>97</td>
<td>7.96 a</td>
<td>13.94 a</td>
<td>0.94 a</td>
<td>15.33 c</td>
</tr>
<tr>
<td>Cordelia</td>
<td>269 a</td>
<td>59</td>
<td>8.30 a</td>
<td>13.90 a</td>
<td>0.73 b</td>
<td>19.35 b</td>
</tr>
<tr>
<td>Heszzia</td>
<td>246 b</td>
<td>88</td>
<td>6.72 b</td>
<td>13.40 a</td>
<td>0.69 b</td>
<td>19.90 b</td>
</tr>
<tr>
<td>Rosmerta</td>
<td>155 c</td>
<td>67</td>
<td>6.04 c</td>
<td>14.14 a</td>
<td>0.69 b</td>
<td>20.79 b</td>
</tr>
<tr>
<td>Idared</td>
<td>231 b</td>
<td>78</td>
<td>5.54 c</td>
<td>12.90 b</td>
<td>0.63 b</td>
<td>20.55 b</td>
</tr>
<tr>
<td>Gala</td>
<td>144 d</td>
<td>45</td>
<td>7.24 b</td>
<td>12.56 b</td>
<td>0.34 d</td>
<td>37.52 a</td>
</tr>
<tr>
<td>Prima</td>
<td>162 c</td>
<td>82</td>
<td>5.05 d</td>
<td>11.05 b</td>
<td>0.55 c</td>
<td>20.09 b</td>
</tr>
</tbody>
</table>

The tests were performed immediately after the harvest.
Mean values of 75 fruits/cultivars from visual estimates.
From an ATAGO PR-101 digital refractometer (Codex Alimentarius 3-1-558/93).
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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Pectin (%)</th>
<th>Polyphenol (mg·L−1 gallic acid)</th>
<th>FRAP (mmol·L−1 ascorbic acid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artemisz</td>
<td>0.72 b</td>
<td>191 c</td>
<td>0.75 c</td>
</tr>
<tr>
<td>Cordelia</td>
<td>0.87 a</td>
<td>244 b</td>
<td>0.68 c</td>
</tr>
<tr>
<td>Heszzia</td>
<td>0.74 b</td>
<td>392 a</td>
<td>1.34 a</td>
</tr>
<tr>
<td>Rosmerta</td>
<td>0.71 b</td>
<td>285 b</td>
<td>0.88 b</td>
</tr>
<tr>
<td>Idared</td>
<td>0.76 b</td>
<td>184 c</td>
<td>0.64 c</td>
</tr>
<tr>
<td>Gala</td>
<td>0.33 c</td>
<td>107 c</td>
<td>0.47 d</td>
</tr>
<tr>
<td>Prima</td>
<td>0.69 b</td>
<td>311 a</td>
<td>1.08 a</td>
</tr>
</tbody>
</table>

Data collected in 2009–11.
Using the Folin-Ciocalteau method according to Singleton and Rossi (1965).
Carried out according to Benzie and Strain (1996).
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 (Nótiin et al., 2010).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Density (g·cm−3)</th>
<th>Acid concentration (%)</th>
<th>Polyphenol concentration (mg/100 g)</th>
<th>Transmittance at 420 nm</th>
<th>Turbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artemisz</td>
<td>1.346</td>
<td>3.61</td>
<td>1393</td>
<td>43.4</td>
<td>6.1</td>
</tr>
<tr>
<td>Cordelia</td>
<td>1.355</td>
<td>3.69</td>
<td>1862</td>
<td>30.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Heszzia</td>
<td>1.315</td>
<td>2.38</td>
<td>2311</td>
<td>29.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Rosmerta</td>
<td>1.348</td>
<td>2.85</td>
<td>1961</td>
<td>29.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Idared</td>
<td>1.353</td>
<td>2.77</td>
<td>1113</td>
<td>50.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Jonathan</td>
<td>1.328</td>
<td>3.14</td>
<td>1585</td>
<td>41.5</td>
<td>2.6</td>
</tr>
</tbody>
</table>

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

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% (‘Heszzia’), 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’, ‘Heszzia’, ‘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). ‘Heszzia’ 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; Meulen 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 ‘Heszzia’ 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 (Nőtín 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’ treated with citric acid. ‘Artemisz’ and ‘Cordelia’ according to the method of Oszmianski et al. (2008) presented the highest tendency to branch or bark diseases caused by Nectria galligena Bres. and Pseudomonas syringae pv. syringae. The evaluation by method of Oszmianski et al. (2008). ‘Cordelia’ was reported to be suitable for making apple purée (Nőtín 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 Nőtín 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.

### Resistance to Pathogens

The artificial inoculation test with a mixed conidium suspension (4.5 × 10³ 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 Vf vf 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).

Flower, ‘Hesztia’ was ranked moderately resistant, and ‘Cordelia’ presented 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.

### Literature Cited


