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Vegetative and generative properties of two apple cultivars ‘Galiwa’ and ‘Story Inored’ in a multi-row system

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Summary: In a five-year (2015-2019) study, some vegetative and generative peculiarities of two resistant apple cultivars (‘Galiwa’ and ‘Story Inored’) were assessed in a young orchard with a multi-row training system. Based on our research, cv. ‘Galiwa’ showed significantly weaker growth, than cv. ‘Story Inored’, which was manifested in lower trunk cross sectional area (TCSA) and lower tree height. Cultivar ‘Story Inored’ reached the optimal tree height (3.1 m) at the age of four, but cv. ‘Galiwa’ could not achieve it neither in five-year-old trees (2.7 m). Cultivar ‘Galiwa’ showed 28.4-32.6 t/ha calculated average yield, while cv. ‘Story Inored’ produced 41.3-102.7 t/ha. Larger fruit size was found in cv. ‘Galiwa’ (72.7-79.1 mm) and smaller in cv. ‘Story Inored’ (66.9-69.2 mm). The fruit surface color was under 50% for cv. ‘Galiwa’ (43-49%), meanwhile cv. ‘Story Inored’ reached higher coloration (87-93%) and an excellent color intensity (4.8-5.0). Shape of cv. ‘Galiwa’ fruits was rather flat, than globular (0.83-0.84 shape index), as cv. ‘Story Inored’ was more elongated (0.95-1.00 shape index).

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Key words: apple, resistant cultivars, double row planting system, young trees, vegetative growth, fruit yield, fruit quality

Introduction

Increasing the cultivation intensity was the most important trend in the development of world fruit production in the last decades, which is related to the increase of productive surface in the canopy (Soltész, 1997; Papp, 2003). Since the 1970s, researches have confirmed close relationship between illumination and available yield, resulting the wider use of smaller trees with better light utilization (Jackson & Palmer, 1972; Palmer et al., 1992; Wünsche et al., 1996; Palmer, 1997; Robinson et al., 2013). Nowadays trees with central leader trained to slender spindle and super spindle are the most widespread in the European and domestic intensive orchards (Robinson, 2011; Csihon et al., 2015, 2022; Sus et al., 2018). Advantages of single row training system regarding illumination are emphasized by several studies, nevertheless more trials aimed to evaluate multi-row systems for better utilization of the available production area and to achieve higher yields (Wertheim et al., 1986; Wagenmakers, 1991; Campbell, 1999; Kierczyńska & Wawrzyniak, 2004; Csihon et al., 2019). Tree number per hectare can only be increased to a certain point, as density over 3000 tree can result in a decrease of yield and fruit quality (Mantinger & Vigl, 1999; Widmer & Krebs, 2001; LicznarMałańczuk, 2004). Although for the profitable production, plantations must ensure high yields and appropriate quality at the same time.

Fruit quality is determined by genetic, environmental and agronomic factors (Musacchi & Serra, 2018). Appearance of fruits has a huge impact on consumers in decision making for consumption (Kays, 1999). Attractiveness of apples depends on several external fruit characteristics, such as size, shape, color and absence of defects.

Consumer’s preference on apple fruit size varies by countries, type of market, family income, region, gender and age (Hampsen et al., 2002; Bonany et al., 2013). European fresh market requires mainly 70-85 mm diameter for apple. Fruits under 70 mm size are not saleable, as apples above 90 mm diameter means problem in storing and packing. Nowadays shape of the fruits is mostly globose with 0.9-1.0 shape index (length/diameter), while oblong fruits are required with certain sports (e.g. ‘Red Delicious’). Among cultivars, red skin color is more favorable, as higher fruit surface color means increased market value (Guerra & Sansavini, 2012; Anton & Willen, 2014).

The aim of this five-year study was to evaluate the vegetative accomplishment, the fruit yield and fruit quality of two resistant apple cultivars (cv. ‘Galiwa’, ‘Inored Story’) in a slender spindle canopy with a double row planting system.

Materials and methods

Location, orchard management

Measurements and observations were performed in a commercial apple orchard, near to the city of Nyírbátor, in Eastern Hungary. Plantation soil type is sandy with low humus content (0.6-0.7%). The „Arany” number of heaviness of the soil is 27-29. Mean temperature of the year is 10-11 °C, while the sunshine hours are 1900-2050 hours/year. The annual mean precipitation of the area is 500-550 mm.

Two prospective cultivars (‘Story Inored’ and ‘Galiwa’) were assessed in the experimental orchard. Cultivars were grafted on dwarfing M.9 rootstock and were planted in

spring of 2015 with a multi-row training system (5357 tree/ha). Distance between the plants is 1.0 meter, while double rows are 1.4 meter next to each other. Space between the doubles rows is 3.5 meter. During canopy training slender spindle form was created with wired trellis support system (***Figure 1-2.***). The plantation was irrigated with a drop irrigation system. Orchard management was based on the European Integrated Fruit Production guidelines. Winter pruning was carried out each year at the end of the dormant periods. During the five observed years (2015-2019) chemical fruit thinning was performed only in 2017 and 2018.

Figure 1. Trees of cultivar 'Galiwa' planted with a multi-row training system (Nyírbátor, Hungary, 2018).

Figure 2. Trees of cultivar 'Story Inored' planted with a multi-row training system (Nyírbátor, Hungary, 2018).

In the experimental orchard, spring frosts caused yield loss in two years during the assessed period. In 2016, both apple cultivars suffered 100% damage. In 2019, total yield loss occurred with cv. 'Galiwa', and partial damage with cv. 'Story Inored'. The annual rainfall ranged from 466 mm to 720 mm among the years.

Assessed parameters

For the assessments, five trees (replicated four times) were selected with similar plant conditions and examined per each cultivar. Two vegetative (trunk thickness, tree height) and eight generative parameters (yield/tree, yield/hectare, fruit number/tree, crop load, fruit diameter, shape index, fruit surface color, fruit color intensity) were evaluated.

The trunk thickness was recorded at the trunk halfway between the graft point and the main scaffold branches, and the given data was expressed in cm^2 (trunk cross sectional area). Height of the trees (cm) was measured between the ground and the top of the canopy without the one-year-old shoots at the top of the tree.

Harvest of the fruits was performed with one pick each year. During harvest fruit number and fruit amount were measured for each tree. Crop load was calculated by dividing fruit number per tree with trunk cross sectional area (cm^2). Describing the fruit size, fruit diameter and fruit length were measured, which were used to calculate the shape index (length/diameter). Fruit surface color was assessed with visual analyses using a color scale (1-100%). Fruit color intensity shows the intensity of the red skin color, which was examined by using a scale ranging from 1-5. Based on Csihon & Gonda (2016) methods, fruit surface color and the color intensity were used to calculate an index number, the fruit coloration index, which describes the skin color in a complex way. This value (1-100) presents the coloration of the fruits by the way that both over color and both the darkness of the red skin are taken into consideration equally.

Results

Trunk cross sectional area (TCSA) of the cultivars, as a main indicator of vegetative performance, showed that cv. 'Story Inored' had more vigorous growth, than cv. 'Galiwa' (***Figure 3***). After the planting (2015) trunk thickness presented only slight differences, but four years later the difference between the two cultivars became almost twofold.

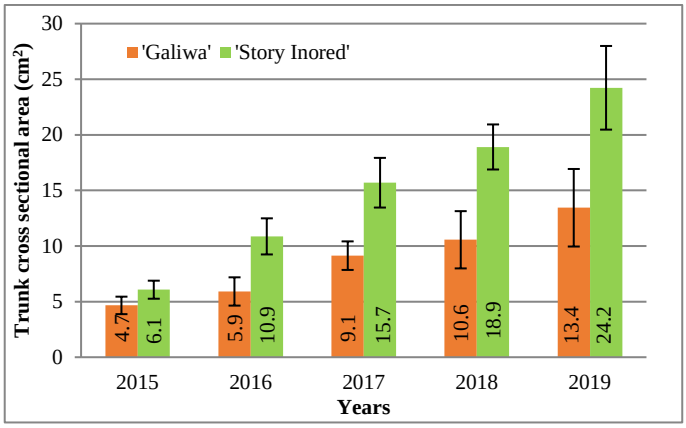

Figure 3. Trunk cross sectional area of two resistant apple cultivars 'Galiwa' and 'Story Inored' (Nyírbátor, Hungary, 2015-2019). Bars represent SE values.

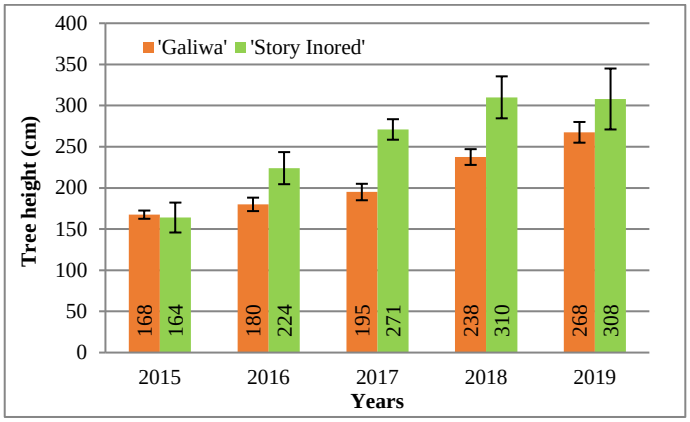

Figure 4. Tree height of two resistant apple cultivars 'Galiwa' and 'Story Inored' (Nyírbátor, Hungary, 2015-2019). Bars represent SE values.

Table 1. Ripening time and five yield parameters for two resistant apple cultivars 'Galiwa' and 'Story Inored' (Nyírbátor, Hungary, 2016-2019).

	'Galiwa'				'Story Inored'			
	2016	2017	2018	2019	2016	2017	2018	2019
Ripening time	no data	07/09	05/09	no data	no data	10/10	02/10	07/10
Yield (kg/tree)	no data	5.3±0.4	6.1±1.3	no data	no data	7.7±1.5	19.2±2.1	14.4±1.7
Fuit number (number/tree)	no data	25±3	49±14	no data	no data	50±14	137±20	104±14
Specific yield (kg/cm^2)	no data	0.59±0.09	0.59±0.11	no data	no data	0.49±0.06	1.02±0.09	0.60±0.07
Specific yield (number/cm^2)	no data	2.7±0.4	4.6±1.0	no data	no data	3.1±0.6	7.2±0.8	4.3±0.5
Yield (t/ha)	no data	28.4	32.6	no data	no data	41.3	103	77

Table 2. Six fruit quality parameters for two resistant apple cultivars 'Galiwa' and 'Story Inored' (Nyírbátor, Hungary, 2016-2019).

	'Galiwa'				'Story Inored'			
	2016	2017	2018	2019	2016	2017	2018	2019
Fruit diameter (mm)	no data	79.1±1.1	72.7±1.7	no data	no data	69.0±0.6	69.2±0.6	66.9±0.4
Shape index	no data	0.84±0.01	0.83±0.02	no data	no data	1.00±0.01	0.95±0.01	0.95±0.01
Fruit weight (g)	no data	220±14	166±13	no data	no data	165±4	165±4	150±5
Fruit surface color (%)	no data	49±4	43±5	no data	no data	93±2	91±3	87±7
Fruit color intensity (1-5)	no data	4.6±0.31	4.4±0.05	no data	no data	5.0±0.0	5.0±0.0	4.8±0.09
Fruit color index (0-100)	no data	45±6	38±4	no data	no data	93±2	91±3	85±7

Regarding tree height, cvs. 'Story Inored' and 'Galiwa' presented similar values (164-168 cm) in 2015, while stronger vigor of cv. 'Story Inored' resulted in higher trees in the later years (***Figure 4***). Cultivar 'Story Inored' reached the desirable height (3.1 m) in the four-year-old trees, but height of cv. 'Galiwa' trees remained under 2.7 m even at the age of five. The smaller cropping surface can be obviously related with weaker generative performance during the time of turning to bearing.

During the assessed period, in 2016 spring frost caused total yield loss in both cultivar, while in 2019 cv. 'Galiwa' suffered 100% damage due to late frost (***Table 1***). In the experimental site the ripening time of cv. 'Galiwa' was the first week of September (07/09 and 05/09), as cv. 'Story Inored' was harvested in the first decade of October (10/10, 02/10 and 07/10).

Two years after planting (2017), cv. 'Galiwa' presented 5.3 kg/tree (25 fruit/tree), as cv. 'Story Inored' produced 7.7 kg/tree (50 fruit/tree). Crop load (fruit amount per trunk unit area) was 0.59 kg/cm^2 for cv. 'Galiwa' and 0.49 kg/cm^2 for cv. 'Story Inored'. Fruit number per trunk unit area was higher with cv. 'Story Inored' (3.1 number/cm^2). Cultivar 'Galiwa' presented 28.4 t/ha calculated average yield, as 'Story Inored' showed 41.3 t/ha.

In 2018, differences of the cultivars became more evident. Cultivar 'Galiwa' showed 6.1 kg/tree (49 fruit/tree), while cv. 'Story Inored' reached much higher values, 19.2 kg/tree (137 fruit/tree). Tree crop load confirms also this tendency, as fruit amount per TCSA doubled with cv. 'Story Inored' (1.02 kg/cm^2) compared to the previous year (0.49 kg/cm^2). Meanwhile cv. 'Galiwa' displayed the same crop load compared to the previous year (0.59 kg/cm^2). Calculated yield per hectare was 32.6 tons for cv. 'Galiwa', while cv. 'Story Inored' achieved outstanding 102.7 t/ha in the four-year-old trees.

In 2019, only cv. 'Story Inored' produced yields, but its fruit amount was also affected negatively by the spring frost. Yield (14.4 kg/tree) and crop load (0.6 kg/cm^2) was also lower than in the previous year, while average yield was 77.4 t/ha.

Cultivar 'Galiwa' reached the required 70 mm fruit size in both bearing years (***Table 2***). In 2018 fruit diameter and weight were larger (79.1 mm, 220 gram), as in 2019 values were smaller (72.7 mm, 166 gram) due to the higher number of fruits per tree. Shape of the apples was rather flat, than globular (0.83-0.84 shape index). Fruit surface color remained under 50% in both years (43-49%), while red skin color intensity was 4.4-4.6.

Based on the three-year data, cv. 'Story Inored' can be characterized by smaller fruit size and weight. Fruit diameter was between 66.9 mm and 69.2 mm, as weight varied up 150 g to 165 g. Shape of the apples was elongated (0.95-1.00 shape index). Fruits reached high percentage of surface color (87-93%) and dark red color with high intensity (4.8-5.0).

Fruit color index, as a complex indicator of the coloration peculiarities, showed obvious difference between the cultivars. Cultivar. 'Galiwa' reached value of 38-45, while cv. 'Story Inored' displayed value of 85-93, as attractive appearance of cv. 'Story Inored' fruits was also proved.

Discussions

In this research, we evaluated some vegetative and generative features of two resistant apple cultivars in multi-row training system for young trees. Results were influenced by extreme weather events, but main characteristics of the cultivars were well manifested. The given data of our research mainly confirms the descriptions of cultivars published in previous studies, despite the fact that trees for research and for also commercial purposes are worldwide planted mostly in single row system.

Cultivar 'Galiwa'

Cultivar 'Galiwa' is distinguished by its large orange-red fruit, high fruit sugar content and resistance to scab (Kellerhals, 2012). In our study cv. 'Galiwa' presented 28.4-32.6 ton/ha average yield in the three- and four-year-old trees, as the cultivar proved to be frost sensitive in spring. According to Franck & Kellerhals (2010) cv. 'Galiwa' is characterized by early yields and produce medium-good fruit quantity, not sensitive to cold, but susceptible to biannual bearing.

A previous study by Kellerhals (2012) showed that cv. 'Galiwa' produce large fruits (78 mm), which is confirmed by also Höller et al. (2017) publishing fruit weight of 218 g, but Gregori et al. (2015) emphasised that the fruit size can be heterogeneous. Our research confirmed this statement, as fruit weight was 166-200 g and fruit diameter was 72.7-79.1 mm in the bearing years.

Fruit surface color remained under 50% each year (43-49%), while red skin color intensity was also lower (4.4-4.6). Gregori et al. (2015) reported that fruits of cv. 'Galiwa' had less intense color than other prospective Gala clones. Study of Rühmer (2013) found that about 50% of the harvested fruit had less than 50% fruit surface color. Denzel (2014) noted that the coloring is weak, and the maturity is staggered in warm years and production sites.

Fruit shape of cv. 'Galiwa' is spherical, slightly conical (Franck & Kellerhals, 2010), while in our research fruit shape was rather flat (0.83-0.84 shape index).

Cultivar 'Story Inored'

Cultivar 'Story Inored' is notable for its resistance to scab and high quality fruit with attractive appearance. It is characterized by deep red overcolor on the whole surface and excellent flavour (Pitiot & Laurens, 2012; Gregori et al., 2015; Kiem, 2021). The cultivar is suitable for hot fruit-growing regions, due to the favorable color development (Guerra, 2014).

In our study cv. 'Story Inored' reached the optimal tree height (3.1 m) during four vegetation period, as tree vigor ensures the optimal cropping surface for the early yields. Pitiot & Laurens (2012) reported also that the tree vigour is average, although Alins et al. (2016) complements that its vigour is clearly inferior to Golden or Gala.

The time of turning to bearing is very short, as 19.2 kg fruit was harvested from the three-year-old trees (102.7 t/ha) with multi-row training system. At the age of four, fruit amount was smaller (14.4 kg/tree; 77.4 ton/ha) due to spring frost. Ugo (2014) and Gandubert (2017) stated also that the cultivar 'Story Inored' is very productive, and not susceptible to alternation.

Based on our examinations cv. 'Story Inored' showed medium fruit size, which can be the consequence of the high planting density and high crop load. Fruit diameter was 66.9-69.2 mm, as weight varied up 150 g to 165 g. Previous study of Pitiot & Laurens (2012) reported 75-80 mm fruit size and 200 gram fruit weight for the cultivar. Cullell (2020) confirmed that statement by publishing 75.1-76.7 mm fruit diameter.

Our study showed that cv. 'Story Inored' reached high fruit surface color (87-93%) and excellent color intensity (4.8-5.0), which is in agreement with the studies of Pitiot & Laurens (2012) who reported 75-100% over color.

This study revealed, that shape of the fruits was elongated (0.95-1.00 shape index), which is supported by Guerra (2017) who described the fruits as uniformly cone shaped.

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