

Phenological and Morphological Traits of Important Hazelnut Cultivars in North West Bosnia

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Abstract

The paper presents the results of the analysis of phenological and morphological characteristics of 3 hazelnut cultivars present in the production plantation in the north-western Bosnia and Herzegovina. The 'Rimski', 'Istarski dugi' and 'Tonda Gentile Romana' cultivars served as research material. Blooming time ranged from December to March. For all cultivars, the occurrence of dichogamy, precisely protandry, was observed. The longest flowering period of both male and female flowers was found in the 'Tonda Gentile Romana' cultivar. The 'Rimski' cultivar had the highest fruit weight (3.04 g). 'Tonda Gentile Romana' had the highest kernel weight (1.50 g). The highest kernel percentage (49%) was found in 'Istarski dugi'. The length of male catkins ranged from 21.73 cm to 29.76 cm. Statistically significant differences among cultivars were found for the following traits: the length of male catkins, the number of female flowers in glomeruli, and the number of nuts on a fruiting shoot. The 'Istarski' cultivar had the highest average length of male catkins (29.76) and the highest number of female flowers in the glomeruli (7.32). 'Tonda Gentile Romana' had the highest number of fruits (20.93) on the shoots. All three cultivars have proven to be good varieties in terms of phenological and morphological characteristics, so they can be recommended for intensive production of this nut crop.

Key words: hazelnut cultivars, flowering, nut traits

Introduction

Hazelnut is one of the most important and widespread types of nuts commercially grown in places with mild, humid winters and hot summers, such as the Mediterranean, Black Sea coasts, as well as the Pacific and Atlantic coasts. (Mehlenbacher, 1991). The study INC (2010), lists the major hazelnut producing countries in the world: Turkey, Italy, USA, Azerbaijan, Georgia, Spain, France, China, Iran and Russia.

The economic importance of the hazelnut is that its cultivation is not complicated, it is not attacked by many diseases and pests, and it is not demanding for growing. Its production can be mechanized as much as possible, which is a great advantage over other fruit species. Fruit quality has become a strategic objective for the processing industry as companies search for ways to distinguish their products from those of competitors in an increasingly competitive market, in which wealthy consumers are willing to pay high prices for high quality products (Farinelli et al., 2001). According to the Vujevic et al. (2017), successful adaptation to the climate is required for successful production of a new crop before its introduction into production. They also believe that long-term testing is needed to evaluate the response to specific breeding conditions in terms of phenology, growth, and yield potential. According to the same research, market orientation is also significantly influenced by the choice of variety. Also, the same research shows that confectionery factories prefer varieties that produce small to medium-sized hazelnuts with a crispy kernel, while large and attractive hazelnuts are considered the best for the hazelnut market in the shell.

In a study performed by Solar & Štampar (2011), hazelnuts are monogenic, meaning that their male and female flowers are separate and require different temperature conditions for their development. The main factor influencing the onset of anthesis is related to the special requirements of cold of cultivars to break dormancy of the catkins and female flowers.

In the cultivation of fruit species and cultivars, it is very important to know their phenological characteristics and especially flowering phenophases (Dervić et al., 2011, Aliman et al., 2013, Aliman et al., 2014, Hasanbegović et al., 2017). Pollination and fertilization are essential for nut set in hazelnuts. Male and female flowers bloom at different times. Blossoming varies depending on the ecology, cultivar, and years of the same cultivar. Blooming starts early in regions with warm climate winters. High temperatures in autumn and winter in recent years cause male flowers to bloom earlier than female flowers and dichogamy degrees of some cultivars are increasing (Balik and Beyhan, 2019).

According to German (1994), hazelnut is self-incompatible and inter-incompatible and often occurs between species and cultivars, except for some rare cultivars. This incompatibility occurs as sporophytically and depends on a series of alleles controlling the incompatible locus S. The change occurs at the level of the point where in the pistil, alleles exhibit independent action, whereas in pollen alleles, dominance and codominance are expressed. Also, this study states that dominance is linear and that at the time of pollination, the ovary does not form and grow only if the flower is pollinated. The process of ovule formation begins in March, and fertilization occurs in late May or during the first three weeks of June, 4 to 5 months after pollination, when the diameter of the hazelnut fruit is 7-10 mm. Maturation begins three months later in September or October. A high level of flower cluster drop may be observed before fertilization, in late April or May. This drop is dependent on the apical dominance which exists along one-year-old shoots and along the peduncle of catkins (Germain, 1994). In Davidović (2015), there is no official data on new hazelnut plantations in BiH, while the demand for seedlings has increased, which means that interest in cultivation this species has increased. Ilić et al. (2017), in a study reported that the high price of hazelnuts has increased the interest of farmers in the Balkans in cultivation this crop. The introduction of new varieties of hazelnuts into the agro-ecological conditions of BiH did not result in an increase in the area under hazelnuts in BiH.

There are favourable agro-ecological conditions for the cultivation of hazelnut. Therefore, the aim of this paper is to examine the main phenological and morphological traits of modern cultivars of hazelnuts cultivated in this area. The results of this study will be useful for increasing the production of hazelnuts in the north-western part of Bosnia and Herzegovina.

Materials and Methods

The study was carried out on a hazelnut plantation in Velika Kladuša, locality Marjanovac. At present, the hazelnuts are located at 380 m above sea level, latitude 45°7'22.94 " N, and longitude 15°52'33.1 " E. The area has a moderate continental climate with cold and humid winters and long warm summers. The average annual temperature is 11 °C and the rainfall ranges from 880 to 1330 L / m². The plantation was established in 2013 and the spacing is 3 x 3 with a spacing of 3 x 3 m. The tree form is a free vase with 3 to 5 scaffold branches. All standard cultural practices are regularly implemented. Four irrigations were applied from April to August with a total of 240 L of water per tree. The length of the pilot plot is 120 m and the width is 50 m, with a total of 28 rows. There are 21 shrubs in each row.

The survey was conducted in 2016/17 year. Plants of the 'Rimski', 'Istarski dugi' and 'Tonda Gentile Romana' served as the research material. The following morphological traits were investigated: nut length, nut width, nut mass, kernel mass, kernel yield, length of male catkins, number of female flowers in glomeruli, and number of fruits per fruiting shoot. These measurements were performed in the laboratory of the Biotechnical Faculty in Bihać, and according to literature sources (Ilić et al., 2017). Also, the following phenological traits were investigated: the beginning of flowering of male and female flowers, full flowering, end of flowering, occurrence of dichogamy and homogamy, duration of flowering of male and female flowers. Phenological studies have been performed according to the previous research (Solar & Štampar, 1997; Sylana, 2001; Bostan, 2009). According to Germain and Sarraquigne (2004), female flowers were observed 2-3 times a week from early February to mid-May. Phenological data in this study were recorded based on the protocol presented in Germain and Sarraquigne (2004).

Based on study by Taghavi et al. (2018), Catkin's phenological phases marked in an order: zero phases 0 (catkin brackets are closely interlinked), first phase 1 (rapid elongation of catkins and separation of brackets), and second phase 2 (anthers well-differentiated and yellow pollen appear), third phase 3 (yellow anthers exploded pollen), fourth phase 4 (full bloom anther dehiscence pollen), fifth phase 5 (finish shedding pollen), sixth phase 6 (drying of catkins and not much pollen) and seventh phase 7 (catkins falling on the ground). According to the same study Taghavi et al. (2018), it can be noticed phenological studies for female flowers were recorded as phases: zero phases 0 (vegetative bud break), first phase 1 (red tip of stigmas appears), and second phase 2 (start - 5% of flowers are open and have extended stigmas), third phase 3 (peak - 50% of flowers are open) and fourth phase 4 (end - last flowers are open).

There were 10 shrubs of each variety in the experiment. The morphological data were analysed by general linear modelling in statistical software package SPSS 22 (IBM 2013). Post-hoc analysis of variance (ANOVA) in cases of statistically significant differences ($p < 0.05$) was carried out by the Tukey's test ($p < 0.05$). All data were presented as mean values.

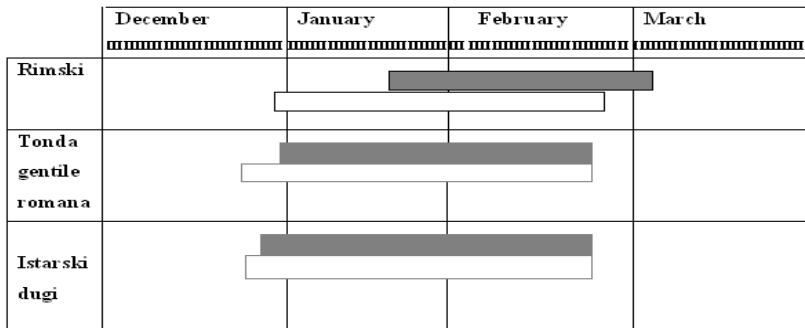
Results and Discussion

Phenological characteristics

The phenological traits of the hazelnut cultivars in the north-western Bosnia (Marjanovac locality, Velika Kladiša) were analysed by monitoring the

date of flowering onset, full flowering, end of flowering, flowering duration in days, and recording the occurrence of dichogamy and homogamy (Graph 1).

The flowering of hazelnut cultivars in the north-western Bosnia started at the end of December and lasted until the beginning of March. According to the data in Graph 1, it can be stated that the occurrence of dichogamy, i.e. protandry, was recorded for all cultivars. Thus, in all three cultivars, male flowers began to bloom first, and female flowers slightly later. This phenomenon is particularly emphasized in the 'Rimski' cultivar. Similar results were obtained by Santos & Silva (1994), Turcu & Botu, (2001) and Vujević et al. (2017).



Graph 1. Flowering phenogram of hazelnut cultivars
Фенограм цвјетања култивара лијеске

The longest flowering period of both male and female flowers was found in the 'Tonda Gentile Romana' cultivar. The flowering of male flowers for all three cultivars lasted approximately the same time, from 59 to 63 days. Greater variability in the duration of flowering was observed in the flowering of female flowers. The shortest flowering period for female flowers was found in the 'Rimski' cultivar (44 days) and the longest was found in the 'Tonda Gentile Romana' cultivar (66 days). The female flowers of all three varieties began to bloom later than the male ones. The beginning of flowering of female flowers took place in the last decade of December and the first half of January, and ended in the last decade of February, until March 4. Similar results have been reported by Solar and Štampar (1997) in their study of hazel bloom phenology in Slovenia, as well as by Vujević et al. (2014) and Vujević et al. (2017) in the agroecological conditions of continental Croatia. According to Bulatovic (1984), American varieties are protogynic and European protandric.

Such tendencies can be altered by environmental conditions, especially temperature. A mild pre-flowering temperature enhances protandry, while low temperatures enhance homogamy and protogyny.

Morphological characteristics

The results of these analyses are shown in Table 1. The 'Rimski' cultivar had the highest nut weight (3.04 g), while the 'Tonda Gentile Romana' cultivar had a very similar result (3.03 g).

Tab. 1. Average values of hazelnut morphological characteristics with the results of statistical analysis

Просјечне вриједности морфолошких особина лијеске са резултатима статистичке анализе

Parameter / Variety	Rimski	Tonda Gentile Romana	Istarski dugi	F
Nut length (mm) <i>Дужина плода</i>	21.10 ^a ± 0.10	19.40 ^b ± 0.04	26.10 ^c ± 0.28	54.75**
Nut width (mm) <i>Ширина плода</i>	21.90 ^a ± 0.12	20.00 ^b ± 0.03	16.50 ^c ± 0.22	138.6**
Nut mass (g) <i>Маса плода</i>	3.04 ^a ± 0.20	3.03 ^a ± 0.05	2.41 ^b ± 0.17	383.66**
Kernel mass (g) <i>Маса језгре</i>	1.27 ^a ± 0.03	1.60 ^b ± 0.20	1.19 ^a ± 0.09	7.69**
Kernel percentage (%) <i>Удио језгре</i>	42	46	49	-
Length of male catkins (cm) <i>Дужина реса</i>	21.73 ^a ± 0.12	26.78 ^b ± 0.23	29.76 ^c ± 0.08	24.35**
Number of female flowers in glomeruli (n) <i>Број женских цвјетова у гломерули</i>	4.11 ^a ± 0.15	5.81 ^b ± 0.18	7.32 ^c ± 0.33	65.21**
Number of fruits on a fruiting shoot (n) <i>Број плодова на родној граници</i>	8.72 ^a ± 0.13	20.93 ^b ± 0.23	18.03 ^c ± 0.13	16.33**

*Note: Different letters in a row indicate significant differences between means at $P \leq 0.05$ by the Tukey test / *Различита слова у реду показују значајне разлике између средњих вриједности при $P \leq 0,05$ према Такејевом тесту*

The 'Istarski dugi' cultivar statistically significantly differs from the other two cultivars, and has much lower fruit weight (2.41 g).

Ilic et al. (2017) investigated the pomological properties of 13 cultivars of hazelnut in the Banja Luka area, Bosnia and Herzegovina. In their research, the 'Rimski' cultivar had a fruit weight of 2.89 g, 'Tonda Gentile Romana' 2.62 g, and the 'Istarski dugi' cultivar 4.28 g. Apart from the mass of the nut, a very important agronomic feature is the mass of the kernel and the percentage of the kernel, since it is the edible part of the hazelnut fruit.

The highest kernel mass was found in 'Tonda Gentile Romana' (Table 1) and was 1.50 g. Comparing these results with the results of Ilic et al. (2017), it can be stated that in their studies the cultivars 'Tonda Gentile Romana' (1.19 g) and 'Rimski' (1.15 g) had a lower value for the mass of the kernel, and the 'Istarski dugi' cultivar had a significantly higher kernel mass (1.53 g). The percentage of the kernel is an important feature of the hazelnut fruit. The higher this percentage, the greater the utilization of the fruit.

Therefore, when selecting cultivars in plantations, preference should be given to those varieties that have a higher percentage of kernel. In this study, the highest percentage of the kernel was found in the 'Istarski dugi' cultivar (49%) compared to the other two varieties ('Tonda Gentile Romana' 46%; 'Rimski' 42%). According to Ilic et al. (2017), the 'Tonda Gentile Romana' cultivar had a higher percentage of kernel (46%) than 'Rimski' (39.58%) and 'Istarski dugi' (35.59%). The length of the male inflorescence ranged from 21.73 cm to 29.76 cm. All three cultivars differ statistically significantly for traits: length of male catkins, number of female flowers in glomeruli, and number of nuts on a fruiting shoot (Table 1).

The 'Istarski dugi' variety had the highest average length of male catkins (29.76) and the highest number of female flowers in the glomeruli (7.32). 'Tonda Gentile Romana' (20.93) had the highest number of fruits on the fruiting shoot.

Conclusion

The results confirm that all three cultivars overlap well in flowering, regardless of the occurrence of dichogamy. The 'Rimski', 'Istarski dugi' and 'Tonda Gentile Romana' cultivars complement each other well in bloom, and can be recommended as a good combination in the pollination and fertilization process. With regard to agronomically important morphological characteristics, the 'Rimski' cultivar is recommended for production due to the high value of the fruit weight. The 'Tonda Gentile Romana' cultivar can be a main cultivar in new hazelnut plantations, as it has large fruits and kernel mass.

The 'Istarski dugi' cultivar is worthy of attention because of the high percentage of the kernel. So, all three varieties have proven to be good cultivars in terms of phenological and morphological characteristics, so they can be recommended for intensive production of this nut crop.

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Фенолошка и морфолошка својства важних сорти лијеске у сјеверозападној Босни

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Сажетак

Рад представља резултате анализе фенолошко – морфолошких карактеристика 3 култивара лијеске који се плантажно узгајају на подручју сјеверозападне Босне и Херцеговине. Као материјал за истраживање послужиле су биљке лијеске сорти: 'Римски', 'Истарски дуги' и '*Tonda Gentile Romana*'. Цвјетање сорти лијеске на подручју сјеверозападне Босне почиње у децембру и траје све до марта. За све сорте је забиљежена појава диогогамије, односно протандрије. Најдужи период цвјетања и мушких и женских цвјетова имала је сорта '*Tonda Gentile Romana*'. Сорта 'Римски' имала највећу масу плода (3,04 g). Највећу масу језгре имала је сорта '*Tonda Gentile Romana*' и износила је 1,50 g. Највећи удио језгре имала је сорта 'Истарски дуги' (49%). Дужина мушке цвасти (ресе) кретала се од 21,73 cm до 29,76 cm. Све три сорте се статистички значајно разликују за особине: дужина ресе, број женских цвјетова у гломерули и број плодова у рачвици. Сорта 'Истарски дуги' имала је највећу просјечну дужину ресе (29,76) и највећи број женских цвјетова у гломерули (7,32). Највише плодова на родној гранчици имала је сорта '*Tonda Gentile Romana*' (20,93). Све три сорте су се показале као добре сорте по питању фенолошких и морфолошких својстава, па се могу препоручити за интензивну производњу овог дефицитарног и скупог воћа.

Кључне ријечи: сорте лијеске, цвјетање, карактеристике језгре

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