Flourish of hazel cultivars (*Corylus avellana* L.) in the Banja Luka region (Bosnia and Herzegovina) and justifiability of using artificial pollination

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Abstract

In the world production of hazels, there is no a generally accepted hazel cultivar as a universal pollinator, but cultivar composition is rather determined based on cultivar characteristics, which are manifested in given growing conditions. One of the most important parameters that determines the cultivar composition of hazel is the knowledge of reproductive biology of cultivars, which have numerous specificities such as allogenic fertilization and incompatibility. Besides the above, the process of pollination and fertilization of hazel is further complicated by the different dynamics of cultivar flowering and discrepancies in terms of the period of flowering. All these factors influence the cultivars in orchard to have a low level of fruit set and yields are below expectations. As a contribution to the knowledge of phenology of hazel flowering the flowering of several hazel cultivars was observed in the area of Banja Luka region. The observation was carried out over the period of two years at the site of Jošavka (Čelinac) on 'Romai', and 'Tonda Gentile Romana' cultivars and on two clone cultivars of 'Istrian Long' with different phenological characteristics. All cultivars were grafted onto the *Corylus colurna* L. rootstocks. The results of research show that temperature fluctuations during the phenophase of flowering, significantly affect the initiation and length of hazel flowering, as well as the inter-pollination of cultivars in the orchard.

Keywords: cultivar composition, temperature changes, pollen freezing, fertility control

INTRODUCTION

Selection of the cultivar composition and organization of successful production of hazel depends to a large extent on the knowledge of the flowering biology of cultivars and their agrobiological characteristics in a given area. The natural habitats in which hazel is most cultivated and showing the best results are areas characterized by warm Mediterranean climates and mild winters such as the area from Spain to Iran, and in the state of Oregon in the USA (Fideghelli and De Salvador, 2009). In warmer areas where low temperatures do not occur, the bloom of hazel occurs undisturbed between December and March and, depending on whether male or female inflorescences open first, or simultaneously, it lasts from 35 to 90 days (Santos and Silva, 1994; Bostan, 2009).

In recent years, hazel has been increasingly cultivated in Chile (Ellena et al., 2014) and in areas with moderately continental climates and relatively low spring temperatures (western Balkans, Poland, Russia, China) (Food and Agriculture Organisation of the United Nations, 2017). Such temperatures can be a limiting factor for the cultivation of susceptible and early flowering cultivars of hazel as they cause freezing and damage reproductive organs that are in the flowering and pollination phase. Among the grown cultivars, some hazel cultivars show tolerance to low temperatures. Thus, Krpina et al. (1994) state that the cultivars 'Romai', 'Hall's Giant' and 'Istrian Long' in Slavonia, Croatia had high yields, although they were exposed to temperatures of -19°C during the period of full bloom. Due to the evident climate change in recent years, hazel freezing has also occurred in the territory of Turkey,

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which resulted in a drastic decrease in yield and an increase in the price of hazelnuts on the world market (Ustaoğlu, 2012; Ustaoglu and Karaca, 2014).

Temperature changes in winter are particularly pronounced in the continental part of the Balkan Peninsula due to the penetration of warm air from the Mediterranean and cold air from the north and east of Europe. Extreme data related to temperature fluctuations were recorded in the Banja Luka region, where during December 2009 the temperature change in the range of -28.7 to +23.8°C was observed in Trebovljani (Gradiška) during the period of 72 h (Republički hidrometeorološki zavod Republike Srpske, Ministarstvo Poljoprivrede, Šumarstva i Vodoprivrede, Meteorološka Stanica Banja Luka, 2017). In the western Balkans, most hazel cultivars bloom from January to March, except for the very early cultivars that start flowering in December (Solar and Štampar, 1997, 2011; Vujević et al., 2014; Ilić et al., 2018).

In areas with higher altitudes and pre-mountain climates, the bloom of the hazel is quite different. Kurtović and Mićić (1987) state that in the agro-ecological conditions of Sarajevo (BiH) female inflorescences of some cultivars began their flowering in late November, depending of cultivar, while flowering of female inflorescences in early flowering cultivars lasts 107 days, and in late flowering cultivars lasts 36 days. This phenomenon can certainly be related to the weather conditions recorded in the observed locations in those years.

Temperature fluctuations that are more or less pronounced in some years lead to damage to the male reproductive organs of hazel, shortening the time required for an even pollen dusting, and uneven flowering of male and female inflorescences in mutually compatible cultivars. In these conditions, female inflorescences remain poorly pollinated, and the fruiting of the hazel for many years assumes the character of an alternative type with yields that have no economic justification.

Solving the problem of hazel pollination and achieving high yields should be sought in the control of the fertility rate of hazel through the use of artificial pollination as a regular pomotechnical measure in the production of hazelnuts (Ilić et al., 2018). In this way, the problems arising during winter are avoided, which are related to the mismatch of flowering time of compatible cultivars, freezing of pollen, the adverse impact of rainfall followed by strong winds, lack of pollen, poor cultivar composition in the orchards and other factors. The application of this pomotechnical measure allows the application of pollen only to those cultivars that give the best results, since it has been found that there is a significant difference in pollination by compatible pollinators, regarding the weight of the fruit and the number of empty hazelnuts (Rahemi and Mojadad, 2001). Research in this area and positive results were achieved in Chile, where the application of artificial pollination resulted in a decrease in the number of empty fruits and an increase in yield by 37.3% (Ellena et al., 2014).

The purpose of this study was to study the phenology of flowering of the hazel cultivars most commonly present in orchards in BiH and to analyse the justification for the application of artificial pollination in case of weaker pollination.

MATERIALS AND METHODS

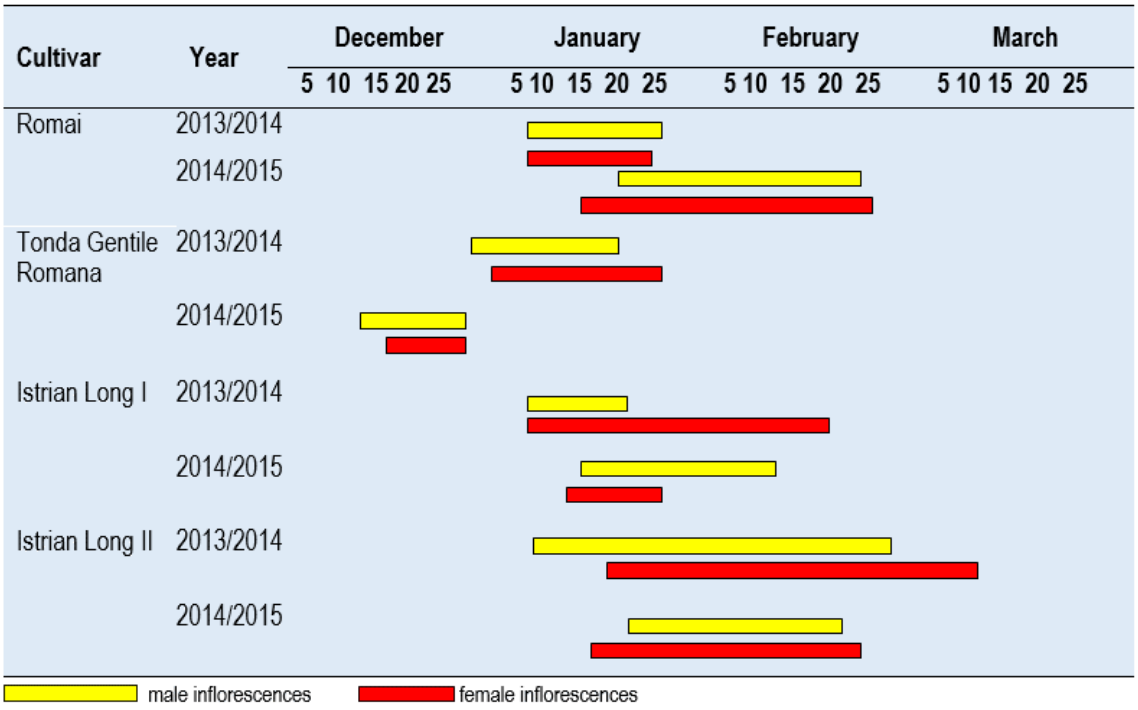
The research was conducted during 2013/2014 and 2014/2015 between December and April. The hazel plantation was located in the municipality of Čelinac, at the location of Donja Jošavka (44°43'59.99"N; 17°23'59.99"E) 250-300 m a.s.l. The plantation was raised in 2009 on a surface of 1.2 ha with a tree distance of 4.5×3 m. The plants were grafted on the rootstock of the Turkish tree hazel (*Corylus colurna* L.) and cultivated as a tree in a form of a vase. In the orchard, regular agrotechnical measures were carried out. The most common cultivar being 'Romai', while the pollinators include 'Tonda Gentile Romana' and two clones of 'Istrian Long'. Clones of 'Istrian Long' are referred to below as 'Istrian Long I' (early-flowering clone) and 'Istrian Long II' (late-flowering clone). Flowering dynamics were monitored every 2 to 5 days depending on weather conditions. During the observation, the beginning of flowering, the length of full flowering, the end of flowering and the occurrence of dichogamy and homogamy were monitored. Flowering of male and female inflorescences was performed from the moment of beginning of elongation of the fringe for male inflorescences and the opening of female inflorescences, i.e., the appearance of stigmatic columns. Also, the observation of the stigmatic column of female inflorescences after completing the dusting of

male inflorescences to record the degree of pollination of female flowers.

RESULTS AND DISCUSSION

The results of the investigations show differences in the beginning and the length of flowering in the observed cultivars of hazel. Flowering of hazel cultivars during two years of observation is shown in Table 1. During the first year of flowering phenology monitoring, the flowering was fairly uniform between observed cultivars and took place during January and February. The earliest flowering was recorded with 'Tonda Gentile Romana' during the first decade of January, while the latest bloom was in 'Istrian Long II'.

Table 1. Flowering of hazel cultivars during 2013/2014 and 2014/2015.



During the flowering phenophase, a cooling period was observed followed by heavy snowfall in the period from January 23 to February 5 which stopped the process of flowering and pollination (Figure 1).

Due to this, the flowering of the hazel cultivars of can be divided into two parts:

- the period until January 23 when 'Tonda Gentile Romana' and 'Romai' have finished flowering and the flowering of clones 'Istrian Long' has ceased;
- the period after February 5 when the subsequent flowering of female inflorescences with the cultivar 'Istrian Long I' and the flowering of male and female inflorescences with 'Istrian Long II' occurred.

In the first year of observation it can be said that the biggest problem was the freezing of male flowers that were in full bloom at the time of cooling, as well as the absence of pollination of female flowers with the late flowering cultivar 'Istrian Long II'.

During the second year of flowering phenology monitoring, the flowering took place between early December and late February. The earliest blooms were recorded with 'Tonda Gentile Romana' during the first decade of December, while the other cultivars bloomed much later, between the second decade of January and the last decade of February. A significant difference in the period of flowering was manifested by the occurrence of cooling followed by the occurrence of snowfall and low temperatures locally up to -20°C between December 25 and January 8 (Figure 2).

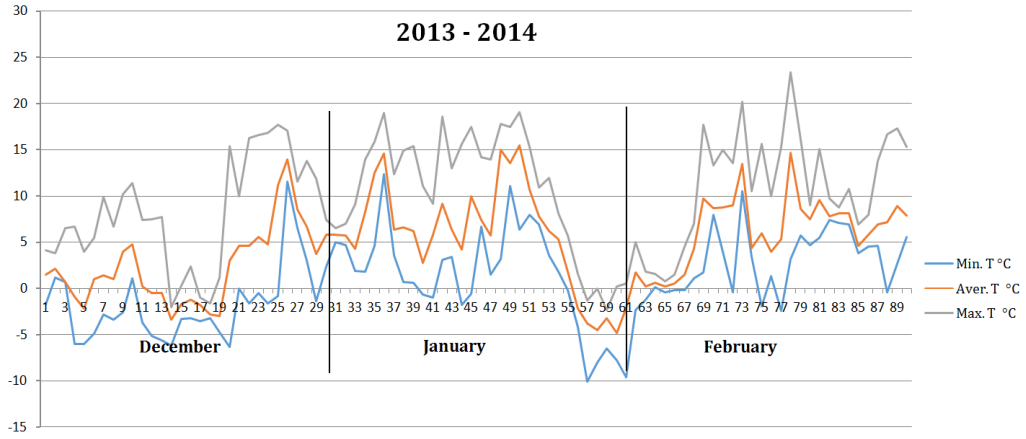


Figure 1. Temperature diagram of minimum, average and maximum daily air temperatures during the flowering of hazel in the period from December 2013 to March 2014 (Hydrometeorological Institute of the Republic of Srpska).

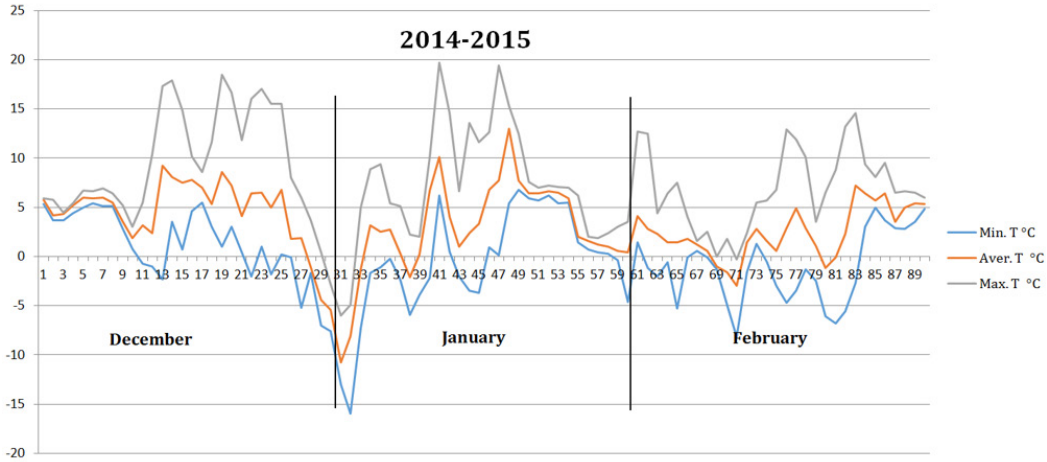


Figure 2. Temperature diagram of minimum, average and maximum daily air temperatures during the flowering of hazel in the period from December 2014 to March 2015 (Republički hidrometeorološki zavod Republike Srpske, Ministarstvo Poljoprivrede, Šumarstva i Vodoprivrede, Meteorološka Stanica Banja Luka, 2017).

Low temperatures led to freezing male and female inflorescences in full bloom with 'Tonda Gentile Romana', which is the most prevalent pollinator in the orchard. However, the other cultivars in the plantation did not freeze but the flowering onset was significantly delayed until later. Table 2 presents the duration of flowering of male and female inflorescences in days during both years of research.

Table 2. Duration of flowering of male and female inflorescences in days.

Cultivar	2013/2014		2014/2015	
	Male inflorescences	Female inflorescences	Male inflorescences	Female inflorescences
Romai	19	17	35	42
Tonda Gentile Romana	21	24	15	12
Istrian Long I	12	43	28	14
Istrian Long II	51	52	30	39

Pollen dusting of male inflorescences was the shortest in 'Istrian Long I' cultivar: 12 days during 2013/2014, and the longest in 'Istrian Long II' 51 days during 2014/2015. Female inflorescences bloomed the shortest for 'Tonda Gentile Romana' for 12 days during 2014/2015, and the longest for 'Istrian Long II' for 52 days during 2013-2014. Vujević et al. (2014) found the flowering of 'Romai' and 'Istrian Long' in the first two years was approximately uniform and significantly shorter during the other two years. The cultivars of hazel in this study exhibited different types of dichogamous flowering. 'Tonda Gentile Romana' had a protandric flowering, 'Romai' and 'Istrian Long I' a homogamous one with a tendency towards protoginia, while 'Istrian Long II' had a protandric flowering in the first year and in the second protogynical. The occurrence of a change in the type of dichogamy in certain cultivars of hazel, depending on the weather conditions, has been reported in other studies in the cultivars of 'Hall's Giant', 'Romavel' and 'Du Chilliy' (Turcu et al., 2001), 'Hall's Giant', 'Istrian Long' and 'Romai' in Slavonia (Croatia) (Vujević et al., 2014), while in the study of Piskornik et al. (2001) cultivars that excluded the protandric as 'Ennis' and 'Tonda Gentile delle Langhe' exhibited protogyny characteristics.

During both years of observation, the occurrence of female inflorescences with red stigmatic columns after the flowering was completed with 'Istrian Long II' resulting in the lack of pollination. Also, the occurrence of freezing of male inflorescences in 'Tonda Gentile Romana', which was the most important pollinator in the plantation before the flowering of female inflorescences of other cultivars, was recorded.

CONCLUSIONS

- There are differences in flowering dynamics of four hazel cultivars in the Banja Luka region in two years due to the influence of temperature fluctuations at flowering time;
- During the first year of observation, the occurrence of non-functional male inflorescences was registered in a large number of trees of 'Romai', which is the most represented cultivar in the plantation. This cultivar is sensitive to high temperatures, so it is possible that due to physiological stress during the summer when the process of microsporogenesis occurs, the development of male inflorescences did not occur or was subsequently rejected;
- During the second year of observation, the freezing of male inflorescences was recorded with the main pollinator of 'Tonda Gentile Romana', before the female inflorescences of other cultivars had flowered;
- There were a number of open issues in the process of hazel pollination in the agro-ecological conditions of BiH, which during vegetation are manifested by the appearance of low and alternative fertility and the appearance of empty nuts. This can be solved by controlling fertility and using artificial pollination as a regular cultural practice.

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