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ANALYSIS OF THE INFLUENCE OF CLIMATE CONDITIONS ON HAZELNUT FLOWERING AND POLLINATION

SUMMARY

In the hazelnut orchards in Bosnia and Herzegovina, continental cultivars are predominantly cultivated, though Mediterranean cultivars have been increasingly grown in recent years. Hazelnut yield in orchards is quite variable between years and depends on the influence of weather conditions on reproductive biology during the entire organogenesis cycle, and especially during the flowering and pollination periods. As a result of adverse weather conditions, uneven flowering times of male and female inflorescences of dominant cultivars and pollinator cultivars are registered, accelerated and shortened pollen shedding time, freezing of catkins that are in the elongation and pollen shedding phase and lack of pollination of late-flowering hazelnut cultivars.

An analysis of the influence of climatic factors on the hazelnut flowering process and the compatibility of cultivars for cross-pollination was conducted out in the area of northwestern Bosnia and Herzegovina in the period from 2017 to 2020. The following cultivars were analyzed: Romai, Istarski Dugi, Hall's Giant, Tonda Gentile Romana and Tonda Gentile delle Langhe.The results of the study show that during certain years there is a significant influence of weather conditions on the flowering and pollination of hazelnut, where early and accelerated pollination and uneven flowering time of the observed cultivars is registered.

Keywords: pollen shedding, stigmatic styles, climate change

INTRODUCTION

The hazelnut (*Corylus avellana* L.) is an anemophilous (wind-pollinated), monoecious fruit species that blooms in the winter period (Germain, 1994) when other fruit species are in the dormancy phase. In the Northern Hemisphere, under moderately continental and Mediterranean climates, hazelnut flowering occurs from early December to late March, depending on cultivar characteristics,

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weather conditions, altitude, and terrain exposure (Solar and Štampar, 2011; Ilić *et al.,* 2018). The flowering type can vary depending on weather conditions, with cultivated hazelnut cultivars most commonly exhibiting protandry (Piskornik *et al.,* 2001). The duration of male flowering ranges from 3 to 75 days, while female flowers take from 5 to 105 days (Modic, 1969; Santos and Silva, 1994; Ilić *et al*., 2018). Over the past two decades, the Balkan Peninsula has experienced rising average temperatures and a significant reduction in snow days in lower-altitude regions (Trbić *et al.,* 2017). Winters are increasingly characterized by warm spells and frequent temperature fluctuations, from –10 to +20 ºC, which directly affect hazelnut flowering and pollination (Ilić *et al.,* 2021). Indicative changes in flowering dynamics are manifested in the following: a reduction in the flowering period of catkins and pollen shedding by up to 25.6 percent on a multi-year level (Črepinšek *et al.,* 2011; Mercuri *et al.,* 2016); uneven flowering times between catkins of pollinator cultivars and female flowers of dominant cultivars in orchards (Ilić *et al*., 2018; Benewitz *et al.,* 2019) and the absence of pollination in late-flowering cultivars (Baldwin, 2009). The occurrence of low temperatures after a warm period can affect the functionality of the male gametophyte, which is found in different micro-phenophases of development (Mićić *et al*., 2022). Hazelnut cultivars are characterized by varying degrees of resistance to low temperatures. At the time of pollen shedding, catkins freeze at temperatures of –5 to –7 ºC (Miljković, 2018, cited by Romisondo, 1978), while at temperatures of –2 to –5 ºC, degeneration of male gamets occurs reducing the possibility of fertilization (Šoškić, 2005 citing Milošević, 1997). On the other hand, female inflorescences exhibit greater resistance to low temperatures during the flowering time. Krpina *et al.* (1994) and Vujević *et al.* (2014) note that the continental cultivars Romai, Istarski Dugi and Hall's Giant did not suffer significant damage in terms of yield in those years when temperatures during flowering ranged from –5 to –19.5 ºC.

The aim of this research is to analyze the influence of climatic conditions on flowering phenology and the possibility of cross-pollination of cultivated hazelnut cultivars in the territory of Bosnia and Herzegovina. The results of the research should create the possibility for the application of biological fertility control and solving the problem of low and irregular fruiting of hazelnuts.

MATERIAL AND METHODS

Monitoring the influence of climatic factors on the flowering phenology and pollination synchrony of cultivated hazelnut cultivars was conducted in a hazelnut orchard located in the Laktaši municipality (Šušnjari), Bosnia and Herzegovina, at an altitude of 200-250 m, coordinates N 44°50'43.3" 17°17'12.7"E. The orchard was established in 2012. year, covering an area of 6 ha with planting distance 5×3 m. The hazelnuts were grown on their own roots with a bush training system. The research was conducted during the flowering season 2017/2018, 2018/2019, and 2019/2020 and included the following hazelnut cultivars: Romai, Istarski Dugi, Hall's Giant, Tonda Gentile Romana (TGR) and Tonda Gentile delle Langhe (TGDL). Hazelnut flowering phenology was studied

from November to March, focusing on different micro-phenophases of development depending on the type of inflorescence:

a) male inflorescences (start of flowering - elongation of the catkins and pollen shedding in <10 percent of catkins; full flowering - pollen shedding in >10 percent of catkins; end of flowering - drying of >90 percent of catkins).

b) female inflorescences (start of flowering - appearance of red stigmatic tips in >10 percent of female inflorescences; full flowering – red stigmatic tips present in >10 percent of inflorescences; end of flowering - drying of >90 percent of the stigmatic tips which turn dark).

Field activities and monitoring of the flowering phenophase were conducted visually on a weekly basis. In the event of high air temperatures, the observation were conducted two to three times per week, depending on the weather conditions. For the analysis, the northwestern side of the orchard was selected, covering an area of 0.3 ha, where five uniformly vigorous bushes of each cultivar were monitored. Due to the pronounced influence of weather conditions on the flowering dynamics of male and female inflorescences, as well as the simultaneous occurrence of different micro-phenophases of flowering depending on the position of the inflorescences on the plant (Figure 1), all micro-phenophases were represented in the phenogram as full flowering phases. During the research, the occurrence of dichogamy, the influence of air temperature on the phase of pollen shedding and the flowering synchrony of cultivars for mutual cross-pollination were recorded, which was analyzed subsequently. The meteorological station of the Hydrometeorological Institute of the Republic of Srpska, which provided the air temperature data, is located 8 km away from the hazel orchard in a straight line and is located at an altitude of 163 meters above sea level. The chi-square test was used to test differences in flowering length of male and female inflorescences between years and between male and female inflorescences within a year.

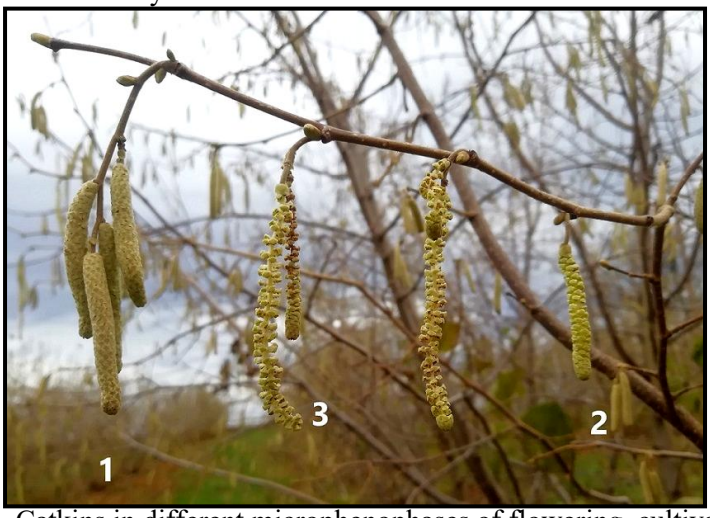


Figure 1. Catkins in different microphenophases of flowering, cultivar TGDL (phase 1 - catkins are completely dormant; phase 2 - elongation of catkins before the start of pollination; phase 3 –dried catkins that have finished pollination)

RESULTS AND DISCUSSION

The results of the research on flowering phenology of male and female hazelnut inflorescences during the 2017/2018 season are presented in Figure 2, while meteorological data with air temperatures are shown in Graph 1.

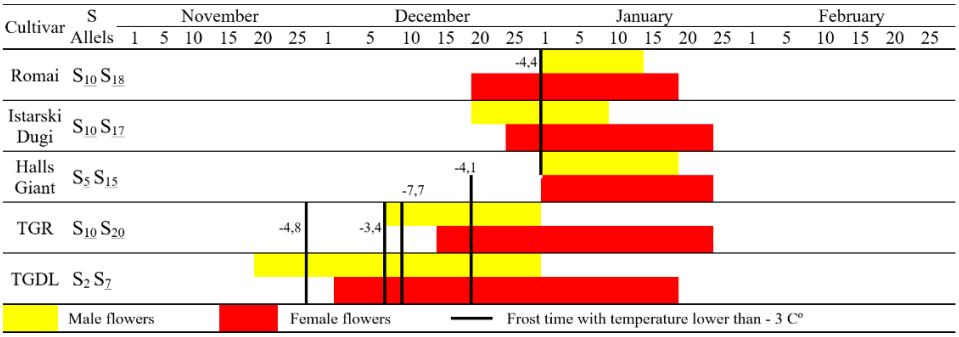
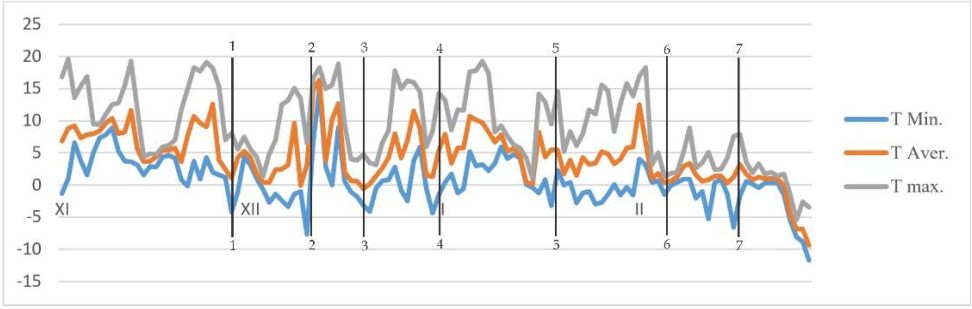


Figure 2. Total flowering phenophases of hazelnut during the 2017/2018 season

Flowering of male inflorescences lasted from November 20 to January 20 (totaling 60 days), while female bloomed from December 5 to January 25 (totaling 50 days). The earliest start of flowering was observed in the TGDL cultivar, with male inflorescences on November 20 and female inflorescences on December 5. The latest flowering start was recorded in the Hall's Giant cultivar, at the beginning of January for both male and female inflorescences. The warm weather conditions during November, December and January (Graph 1) with maximum daily temperatures reaching up to 20 ºC, accelerated the hazelnut flowering process, particularly pollen shedding, which concluded by mid-January for most cultivars.



Graph 1. Minimal, average and maximal daily air temperatures, November 2017 - March 2018 (Republic Hydrometeorological Institute of the Republic of Srpska, 2024).

In early-flowering cultivars TGDL and TGR, pollen shedding ended on December 25, at a time when female flowering in other cultivars had not yet begun. These two cultivars were capable of cross-pollinating each other and could also pollinate the Romai cultivar at the onset of its flowering. The Romai and Istarski Dugi cultivars flowered uniformly and were able to pollinate the late-

flowering cultivar Hall's Giant, which in turn could pollinate unpollinated female flowers across all cultivars in the orchard. Due to the presence of the S10 allele in pollen of TGR, Romai and Istarski Dugi, their mutual cross-compatibility is questionable. During the pollen shedding period, several temperature fluctuations (from –8 to +20 ºC) were recorded on 6 occasions, which affecting initiation of flowering and the freezing of pollen in the catkins.

During the second year of measurement, significant differences in flowering timing were observed among the studied cultivars (Figure 3).

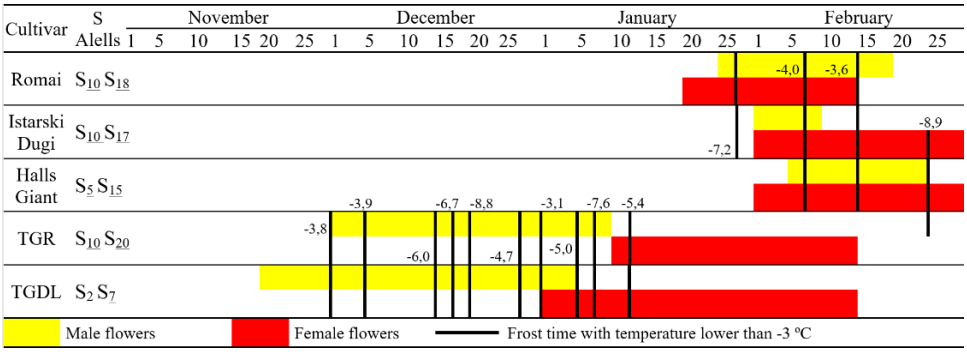
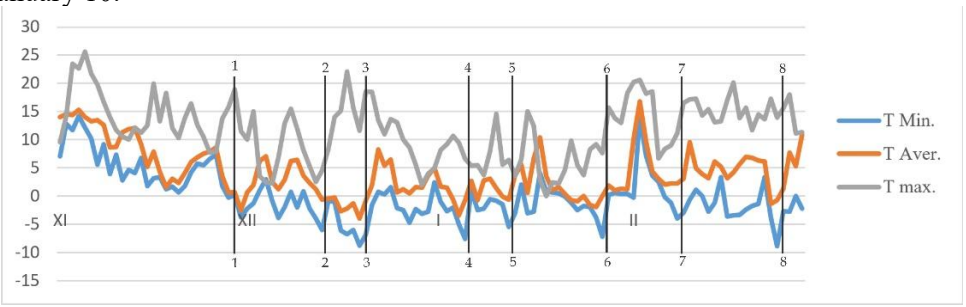


Figure 3. Total flowering phenophase of hazelnut during the 2018/2019 season.

Flowering of male inflorescences lasted from November 17 to February 25 (totaling 97 days), while flowering of female inflorecences lasted from December 1 to March 1 (totaling 90 days). The earliest start of pollen shedding was observed in the TGDL cultivar (November 17) and the Hall's Giant cultivar had the latest (February 5). Similarly, the earliest female flowering initiation was recorded in TGDL, with the latest flowering observed in Istarski Dugi and Hall's Giant (February 1). The warm November weather, featuring a maximum temperature of 26.2 ºC (Graph 2), promoted earlier male flowering and pollen shedding in TGDL and TGR cultivars, which completed their flowering cycle by January 10.



Graph 2. Minimal, average and maximal daily air temperatures, November 2018 - March 2019 (Republic Hydrometeorological Institute of the Republic of Srpska, 2024).

The TGR and TGDL cultivars could not pollinate other cultivars in the orchard because the female flowers of the other cultivars bloomed much later.

However, in the final phase of male flowering, the TGR cultivar was able to pollinate the female flowers of TGDL that had just begun flowering. The flowering of Romai, Istarski Dugi and Hall's Giant cultivars was synchronized, allowing for mutual cross-pollination among them. These cultivars could also pollinate the female flowers of TGR and TGDL, assuming compatibility issues are disregarded. During the entire flowering period, temperature fluctuations were recorded on 8 occasions with morning frosts as low as –8.9 ºC and daytime temperatures up to 22.2 ºC.

During the third year of observation, flowering began the earliest (Figure 4).

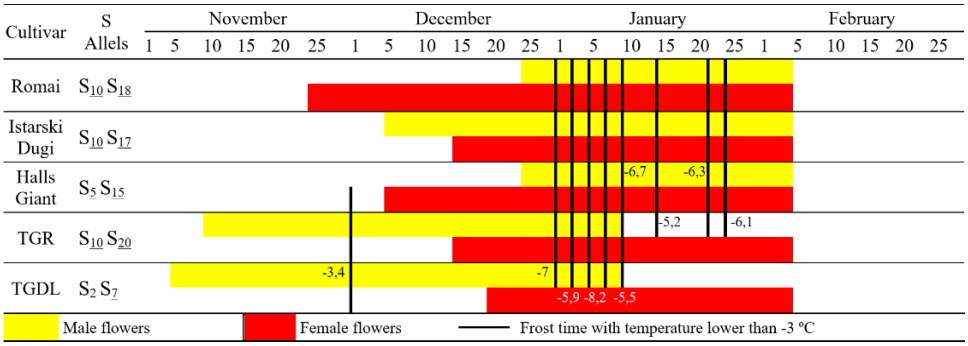
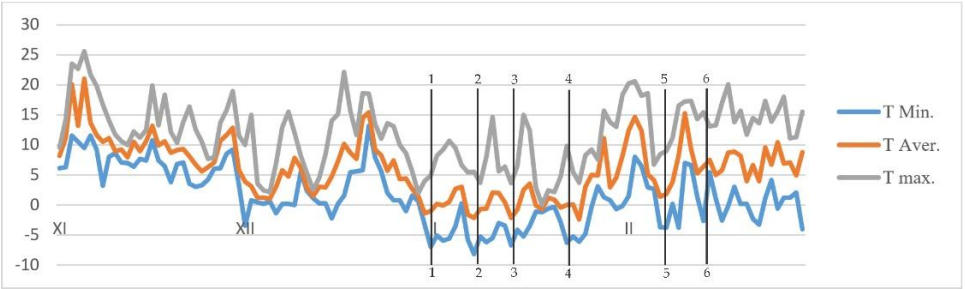


Figure 4. Total flowering phenophase of hazelnut during the 2019/2020 season

The flowering of catkins lasted from November 6 to February 5 (totaling 92 days), while the flowering of female flowers lasted from November 25 to February 5 (totaling 72 days). In the early-flowering cultivar TGDL, flowering started on November 6, whereas it lasted in the Romai and Istarski Dugi cultivars, beginning in early January. The earliest start of female catkin flowering was in the mid-flowering cultivar Romai on November 25, and the latest was in the early-flowering cultivar TGDL on December 20, which was completely opposite of what was expected.



Graph 3. Minimal, average and maximal daily temperatures, November 2019. - March 2020., Republic Hydrometeorological Institute of the Republic of Srpska, 2024).

Higher air temperatures in November and December, along with milder temperatures in January, led to earlier and more uniform flowering across all cultivars without significant differences, as observed in previous years. Extremely

early pollen shedding was recorded at the beginning of November, when approximately 50 percent of the catkins from the TGDL and TGR cultivars released pollen due to unusually high night and daytime temperatures reaching up to 26 ºC. Colder weather in December and January showed pollen release from the remaining catkins in the orchard, extending the process over the next 50 to 60 days. However, a sudden rise in temperatures in early February accelerated and shortened the flowering period, causing it to end within just a several days. The flowering synchronization was quite uniform, increasing the chances of successful cross-pollination of the cultivar, although temperature fluctuations were recorded on several occasions.

The flowering of male inflorescences was the shortest in the TGR cultivar, 19 days during the 2017/2018 year, and the longest in the TGDL cultivar, 66 days during the 2019/2020 year (Table 1).

Table 1. Testing the difference in the flowering time of male and female inflorescences with the Chi-square test and the occurrence of dichogamy.

Cultivar	Year	Σ number of days of flowering male and female inflorescences						Type of dichogamy
		♂	$\chi^2_{0,05}$	♀	$\chi^2_{0,05}$	♂ $\chi^2_{0,05}$	♀ $\chi^2_{0,05}$	
Romai	2017/18	21	15.30**	31	38.20**	0.05^{ns}	0.45^{ns}	Protogyny
	2018/19	24		30		0.80^{ns}	1.51^{ns}	Protogyny
	2019/20	37		71		14.45**	37.02**	Protogyn.
Istarski Dugi	2017/18	22	19.65**	32	14.11**	0.20^{ns}	0.25^{ns}	Protandry
	2018/19	37		49		14.45**	5.60*	Protandry
	2019/20	30		52		5.00*	8.25**	Protandry
Hall's Giant	2017/18	20	14.65**	27	23.67**	0.00^{ns}	1.82^{ns}	Homogamy
	2018/19	22		29		0.20^{ns}	1.02^{ns}	Protogyny
	2019/20	37		62		14.45**	20.82**	Protogyny
TGR	2017/18	19	1699.1**	41	2.31^{ns}	0.05^{ns}	1.02^{ns}	Protandry
	2018/19	39		38		18.05**	0.25^{ns}	Protandry
	2019/20	61		41		84.05**	1.02^{ns}	Protandry
TGDL	2017/18	35	153.50**	42	10.45**	11.25**	1.20^{ns}	Protandry
	2018/19	47		46		36.45**	3.45^{ns}	Protandry
	2019/20	66		49		102.05**	5.60*	Protandry

The flowering of female inflorescences was the shortest with the cultivar Hall's Giant 27 days during 2017/2018, and the longest with the cultivar Romai 71 days during the year 2019/2020. Testing the difference in the flowering of male and female inflorescences between years shows highly significant differences in all cultivars, except for the female inflorescences of the cultivar TGR, which had no significant differences. Testing the difference between male and female inflorescences within years, shows highly significant differences during the 2019/2020 year in male inflorescences in all observed cultivars, as well as in the TGDL cultivar during all observed years. In the flowering of female inflorescences, highly significant differences were manifested in certain years only in the cultivars Romai and Hall's Giant. All cultivars exhibited different types of dichogamy depending on the year and weather conditions. Throughout

all years of observation, the TGDL, TGR and Istarski Dugi cultivars showed protandry, while Romai showed protogyny. Hall's Giant cultivar alternated between protogyny and homogamy depending on the year.

According to the available research results in the field of hazel flowering phenology indicate different research results depending on the region and the influence of climate conditions. The flowering of male and female hazel inflorescences in our study was much earlier and shorter compared to other studies conducted in BiH (Skender *et al.,* 2019; Ilić *et al.,* 2021). Similar results were recorded in relation to the area of Croatia (Vujović *et al.,* 2014), Slovenia (Solar and Štampar, 1997; Solar and Štampar, 2011) and Poland (Piskornik, 2001) where the observed cultivars bloomed for an average of two to three months, from January to the end of March. Cristofori *et al*. (2018) states that in the area of central Italy, the cultivar TGDL showed early flowering of male inflorescences during November, in accordance with our research, and much later pollination of the cultivar TGR, which is contrary to our measurements. The non-coordinated synchronization of flowering of cultivars, which was recorded in our research during 2018/2019, is stated by Bennewitz *et al.* (2019) in the territory of Chile in different locations with dominant and pollinator cultivars as well as Baldwin (2009) in the territory of Australia for late flowering cultivars. Mićić *et al.* (2024) claim that the essence of a successful cultivar composition implies that the microphenophases of anther shedding of pollen and the ability of the pistil to accept pollen of compatible cultivars coincide in at least 50 percent of the flowering time during two of the five observed years.

The dynamics and synchronization of the flowering in our research indicates unevenness between the shedding of pollen of Mediterranean cultivars and flowering of female inflorescences of the other observed cultivars, whereby they do not coincide in the flowering period which is greater than 50 percent. The flowering time of male hazelnut flowers in Italy is shortened by up to 25 percent due to the influence of climatic factors (Mercuri *et al.,* 2016) as well as in Slovenia (Črepinšek *et al.,* 2011), which is in accordance with our research that was recorded during 2017/2018 and 2018/2019 in cultivars Romai, Istarski Dugi and Hall's Giant. Regarding the occurrence of dichogamy in hazelnut, Piskornik *et al.* (2001) and Turcu *et al.* (2001) state that the type of manifestation of dichogamy depends on the weather conditions during the flowering period, whereby cultivars that are considered exclusively protandric cultivars can also exhibit a protogynous type of flowering. In research in the region, Skender *et al.* (2019) state the occurrence of protandry in cultivars Romai, Istarski Dugi and Hall's Giant in BiH, which is in agreement with our research, except for Romai cultivar. While Krpina et al. (1994) and Vujević *et al.* (2014) in Croatia report variability and protogyny in Romai, Istarski Dugi and Hall's Giant cultivars, which is in agreement with our research, with the exception of the Istarski Dugi cultivar which was protandric in our research.

CONCLUSIONS

The analysis of the influence of climatic conditions on the phenology of hazelnut flowering in the Banja Luka region shows a strong influence of air

temperatures on the dynamics and duration of flowering of male and female inflorescences in all observed cultivars. During some years, extremely early pollen shedding of Mediterranean cultivars was recorded, uneven flowering of male and female inflorescences and shortened and accelerated flowering of temperate continental cultivars. Temperature fluctuations started and stopped the flowering process on several occasions, with cold snaps of –9 Cº interrupting the flowering of male inflorescences at different stages of development. In order to avoid the problems noted in this study it is necessary to take into account the choice of dominant cultivars and pollinator cultivars when establihing new hazelnut orchard. For each dominant cultivar, it is necessary to use two or three compatible pollinators with synchronized shedding of catkins that cover the entire complete stage of flowering of female inflorescences of dominant cultivar in orchard. Also, it is necessary to conduct regular biological control of flowering and the functionality of the male gametophyte, and based on this implement adequate measures of early pollen collection and supplementary artificial pollination.

REFERENCES

Baldwin, B. (2009). Field and controlled temperature studies on the flowering of hazelnut in Australia. Acta Horticulturae, 845, 213–218.

Bennewitz, E., Ramirez, C., Munoz, D., Cazanga, R., Lošak, T., Alba-Mejia, J. & Maureira-Butler I. (2019). Phenology, pollen synchronization and fruit characteristics of European hazelnut (*Corylus avellana* L.) CV. "Tonda di Giffoni" in three sites of central Chile. Revista de la Facultad de Ciencias Agrarias. Tomos, 51. N. 2. 55-67.

Črepinšek, Z., Štampar, F., Kajfež-Bogataj, L. & Solar, A. (2011). The response of *Corylus avellana* L. phenology to rising temperature in north-east Slovenia, Int. J. Biometeorol., 56, 681-694.

Cristofori, V., Pica, A. L., Silvestri, C., & Bizzarri, S. (2018). Phenology and yield evaluation of hazelnut cultivars in the Latium region. Acta Horticulturae, 1226, 123–130.

Germain, E. (1994). The reproduction of hazelnut (*Corylus avellana* L.): a review. Acta Horticulturae, 351, 195–210.

Ilić, P., Đurić, G., & Mićić, N. (2021). Flourish of hazel cultivars (*Corylus avellana* L.) in the Banja Luka region (Bosnia and Herzegovina) and justifiability of using artificial pollination. Acta Horticulturae, 1308, 333–338.

Ilić, P., Đurić, G., Mićić, N. & Flachowsky, H. (2018). Dynamics of flowering of male and female inflorescence and pollen germination of hazel in the conditions of the Banja Luka region. Acta Horticulturae, 1229, 313-318.

Krpina, I., Cvrlje, M. & Vujevic, P. (1994). Influence of extremely low winter temperature on some hazelnut cultivars. Acta Horticulturae, 351, 329-334.

Mercuri, A. M., Torri, P., Fornaciari, R., & Florenzano, A. (2016). Plant responses to climate change: The case study of Betulaceae and Poaceae pollen seasons (Northern Italy, Vignola, Emilia-Romagna). Plants, 5(4), 42.

Mićić N., Đurić G., Pašalić B. (2022). Gajena leska, Partenon Beograd.

Mićić N., Đurić G., Pašalić B. (2024). Voćarstvo (Morfologija organa rasta i plodnošenja), Partenon Beograd.

Miljković I. (2018). Lijeska. Hrvatska voćarska zajednica Zagreb.

Modic, D. (1969). Prilog poznavanju cvatnje i oplodnje nekih sorti lijeske, Zagreb, Croatia: Poljoprivredni fakultet, Sveučilišta u Zagrebu (PhD thesis).

Piskornik, Z., Wyżgolik, G., & Piskornik, M. (2001). Flowering of hazelnut cultivars from different regions under the climatic conditions of southern Poland. Acta Horticulturae, 556, 529–536.

Republic Hydrometeorological Institute of the Republic of Srpska, Ministry of agriculture, forestry and water management of the Republike of Srpske, 2024.

Santos, A. & Silva, A. (1994). Dichogamy and flowering periods of eleven hazelnut varieties in northern Portugal – eight years of observation. Acta Horticulturae, 351, 211-214.

Skender, A., Hadžiabulić, S., Aliman, J., & Hasanbegović, J. (2019). Phenological and morphological traits of important hazelnut cultivars in north west Bosnia. Agroznanje - Agro-knowledge Journal, 20 (4).

Solar, A., & Štampar, F. (1997). First experiences with some foreign hazelnut cultivars (*Corylus avellana* L.) in Slovenia. Acta Horticulturae, 445, 83–90.

Solar, A., & Štampar, F. (2011). Characterisation of selected hazelnut cultivars: phenology, growing and yielding capacity, market quality and nutraceutical value. Journal of the Science of Food and Agriculture, 91(7), 1205–1212.

Šoškić, M. (2005). Leska i orah. Beograd, Partenon.

Trbić G., Popov T. & Gnjato S. (2017). Analysis of air temperature trends in Bosnia and Herzegovina, Geographica Pannonica, Volume 21, Issue 2, 68-84.

Turcu, E., Turcu, I., & Botu, M. (2001). Flowering of hazelnut cultivars in Oltenia, Romania. Acta Horticulturae, 556, 365–370.

Vujević P., Milinović V., Poljak M. & Čmelik Z. (2014). Period cvatnje sorti lijeske i pojava dihogamije u agroekološkim uvjetima kontinentalne Hrvatske. Pomologia Croatica, 20 (1-4), 3-10.