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CERCETĂRI PRIVIND BIOLOGIA FLORALĂ LA ALUN
RESEARCH REGARDING FLORAL BIOLOGY OF HAZELNUT

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Abstract

Hazelnut (*Corylus avellana* L.) is a monoecious, dichogamous species flowering in winter and early spring. The purpose of this study was to study the floral biology of 14 hazelnut genotypes ('Fertile de Coutard', 'Tonda Biglini', 'Izvor', 'Tonda di Giffoni', 'Tonda Francescana', 'Mortarella', 'Jefferson', 'Romavel', 'Nocchione', 'Tonda Romana', 'Tonda Gentile delle Langhe' ('TGDL') and its clones - 'PD 6', 'AD 17', 'MT 5') in order to identify the potential genitors for breeding work and to recommend the cultivars for new orchards. The research was carried during the period 2023-2024 in the hazelnut collection at the Research Institute for Fruit Growing Pitești, Romania. Phenological observations were carried out from the onset to the end of the flowering phase using the BBCH scale, as well as microscopic observations regarding pollen viability in carmine acetic and pollen germination capacity on solid medium with sucrose and agars. Regarding the dichogamy phenomenon, 57% of the genotypes studied are protandrous and 43% are protogynous. The flowering time of the male flowers show that the earliest was 'TGDL clone PD 6' and 'TGDL clone AD 17' (end of December 2023), and the latest were 'Nocchione', 'Tonda Francescana' and 'Tonda Romana' (early February). The flowering time of female flowers shows that the earliest was 'TGDL clone MT 5' and 'Tonda di Giffoni' (early January), and the latest were 'TGDL clone PD 6', 'TGDL clone AD 17' (early February) and 'Jefferson' (third decade of February). The average value of pollen viability was 58.56%, ranging between 40.56% at 'Tonda Francescana' cv. and 70.84% at 'Romavel' cv. The average value of the pollen germination capacity was slightly lower than the pollen viability, being of 24.35%, ranging between 19.87% at 'Jefferson' cv. and 30.46% at 'Nocchione' cv. Besides the old cultivars already spread in the commercial orchards it can recommended as pollinators and genitors 'Romavel' and 'Nocchione' cultivars that have been noted for the late flowering, high catkins quantity and pollen with very good viability and germination capacity.

Cuvinte cheie: alun, fenologie, scara BBCH, polen, viabilitate, germinare.
Key words: hazelnut, phenology, BBCH scale, pollen, viability, germination.

1. Introduction

Hazelnut (*Corylus avellana* L.) is one of the most important fruit tree crop worldwide (Novara et al., 2016; Brandoli et al., 2024).

According to the latest FAOSTAT reports (2024), global hazelnut area was 1,061,120 hectares and production was 1,195,732 tons, on the first place being Asia (863,693 ha, and 918,273 t), followed by America (63,912 ha, and 132,867 t) and Europe (133,315 ha, with 144,379 t). In Romania, the area cultivated with hazelnut in 2022 was 840 ha, which ensured a production of 910 tons, but in the last three years the hazelnut surfaces increased intensively due to National Plan for Rural Development which issued a special measure for investments in fruit growing sector.

Hazelnut is a monoecious, dichogamous plant species that flowering in winter and early spring (Germain, 1994; Turcu et. al., 2001; Guo et al., 2009; Falistocco and Marconi, 2013).

The specific climatic conditions from geographic areas affect the annual cycle of hazelnut cultivars, the floral induction, the flowering period and the time of pollination, fecundation and fruits set (Trotter, 1951; Turcu et al., 2001; Taghavi et al., 2020).

Knowledge of the time of blooming is important in the establishment of hazelnut orchards in new areas (Turcu et al., 2001). In traditional growing regions, hazelnut cultivars generally express protandry, respectively blooming of male flowers before the female flowers. In Romania, usually, male flowering is in December – January, and female flowering is in January – March (Turcu et al., 2001).

Each catkin contains 150–200 flowers and produces 5 - 8 million pollen grains in late winter (Trotter, 1930; Soltesz and Nyeki, 2000; Piotrowska, 2008).

The female flowers are generally receptive to pollen for several weeks or more (Molnar, 2011) and, if pollination does not occur, the stigma may remain receptive for up to 3 months (Olsen, 2013; Balik et al., 2023).

The pollen grain of the hazelnut is very small and pollination is anemophilous (wind pollinated) (Olsen, 2013; Taghavi et al., 2020).

Cultivars that produce high levels of sterile pollen are not suitable as pollinators in orchards (e.g. 'Tonda Gentile delle Langhe' cv. with the S_2S_7 allele genes produces many irregular pollen grains that are sterile or with weak pollen tubes) (Riera, 1958, Romisondo, 1963, Olsen et al., 2000).

The aim of this paper was to study the floral biology of 14 hazelnut genotypes ('Fertile de Coutard', 'Tonda Biglini', 'Izvor', 'Tonda di Giffoni', 'Tonda Francescana', 'Mortarella', 'Jefferson', 'Romavel', 'Nocchione', 'Tonda Romana', 'Tonda Gentile delle Langhe' and its clones - 'PD 6', 'AD 17', 'MT 5' in order to identify the potential genitors for breeding work and to recommend the cultivars for new orchards.

2. Material and methods

Field trial, plant material and climatic conditions

The study was conducted in the hazelnut collection established in 2020 at the Research Institute for Fruit Growing Pitesti, Romania. 14 hazelnut genotypes were studied: 'Fertile de Coutard', 'Tonda Biglini', 'Izvor', 'Tonda di Giffoni', 'Tonda Francescana', 'Mortarella', 'Jefferson', 'Romavel', 'Nocchione', 'Tonda Romana', 'Tonda Gentile delle Langhe' ('TGDL') and its clones - 'PD 6', 'AD 17', 'MT 5'. The plants are planted at a distance of 4 m between rows and 3 m between plants per row, and managed as a bush.

The average multi-annual temperature was 10.1°C, the maximum temperature 38.8°C, whereas the minimum temperature –24.4°C; total annual rainfalls recorded was 673.2 mm. Regarding precipitation, there is a rainfall exceeding in winter (119 mm) and a rainfall deficit in summer (156 mm). Compared to the baseline for 55 years period, the agricultural year, 2023-2024, was the hottest in the last 55 years, with 3.1ºC over normal (13.2ºC compared to 10.1ºC as normal), but also much poorer in precipitation, with 193.2 mm below normal (480.0 mm compared to 673.2 mm as it represents the normal interval October - September).

Measurements

In 2023-2024 periods, phenological observations were carried out from the onset to the end of the flowering phase using the BBCH scale (Paradinas et al., 2022; Taghavi et al., 2022; Toillon et al. 2023).

The following phenological stages were taken into account:

- for the development stages of the male flowers: R01 – catkins emerge, R02 - catkins fully developed, R03 - some catkins begin to mature, R04 - catkins in full bloom, pollen is released, R05 – catkins withering;

- for the development stages of female flower: R07 - beginning of female flowering, R08 - inflorescence in full bloom, R09 - end of the female flowering, R10 - enlargement of ovaries, R11 - beginning of fruiting, small fruits, R12 - immature fruits, R13 – fruit maturation, R14 – fruit dropping, R15- all nuts dropped.

To determine the pollen viability, microscopic observations were made in acetic carmine. Fertile pollen turns red, sterile pollen turns pink or remains colorless.

The pollen germination capacity was determined *in vitro* by cultivating on solid medium (15% sucrose, 1.5 g agars, 0.01 g boric acid in 100 ml distilled water), under laboratory conditions (temperature 18 - 20ºC and relative humidity of 70 - 90%).

In addition, evaluation of flowering time, pollen viability and pollen germination was made according UPOV Descriptors (Table 1).

Statistical analysis

The data were included in an Excel database and statistically interpreted with some statistic indices: average, standard deviations and variability coefficient (%).

3. Results and discussions

Flowering time

The hazelnut cultivars bloomed at different times. The flowering period is influenced by the climatic conditions and the flowering type of cultivars (Turcu et al., 2001). In the Maracineni area, flowering extends on three month (January to March).

The dichogamy phenomenon is present in hazelnut and was noted in our study. Generally, male flowers bloom before female flowers, manifesting a tendency to protandry. However, at six genotypes ('Fertile de Coutard', 'Tonda di Giffoni', 'Tonda Francescana', 'Tonda Gentile Romana', 'Nocchione' and 'Romavel'), the male flowers bloomed a few days later than the females, showed a tendency toward protogyny. Thus, between 2023-2024 periods, 57% of the cultivars are protandrous and 43% are protogynous (Table 2). Regarding the dichogamy phenomenon, Turcu et al. (2001) reported 'Romavel' and 'Tonda Gentile delle Langhe' as homogamous cultivars. In our study 'Romavel' cv. is protogynous and 'Tonda Gentile delle Langhe' cv. is protandrous. Also, our result regarding the nature of dichogamy of 'Tonda Romana' cv. is similar with results of Turcu et al. (2001) and Soltesz and Nyeki (2000). Soltesz

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and Nyeki (2000) describe the 'Tonda Gentile delle Langhe' cv. with a highly protandry. The different climatic conditions from year and growing area led to a change of dichogamy type for some hazelnut cultivars (Soltesz and Nyeki, 2000; Turcu et al., 2001; Taghavi et al., 2020). For example, the warm temperatures in December - February stimulate first of all the bloom of the male flowers (catkins) and the cool weather may delay or prolong the bloom of male flowers. Therefore, the association of cultivars in orchards will be made according to the type of dicogamy, as well as the climatic conditions of the culture area.

Regarding the flowering of the male flowers, the earliest was 'TGDL clone PD 6' and 'TGDL clone AD 17' (the end of December 2023), and the latest were 'Nocchione', 'Tonda Francescana' and 'Tonda Romana' (early February). Regarding the flowering of female flowers, the earliest was 'TGDL clone MT 5' and 'Tonda di Giffoni' (early January), and the latest were 'TGDL clone PD 6', 'TGDL clone AD 17' (early February) and 'Jefferson' (third decade of February) (Table 2). The same results regarding flowering time for 'Tonda di Giffoni' and 'Jefferson' cvs. were reported by Taghavi et al. in 2020.

Based on their flowering times, cultivars studied were placed into three classes: early flowering (December 28 – January 10), midseason flowering (January 10 – February 1) and late flowering (after February 1).

The longest flowering period had 'TGDL clone MT 5' (64 days in the case of female flowers, respectively 48 days in the case of male flowers). The lowest flowering period was recorded at the 'Jefferson' cv. (37 days in female flowers) and 'Tonda Romana' (20 days in male flowers) (Table 3).

Regarding the amount of catkins, most of the genotypes studied have a high quantity of catkins uniformly distributed. Exception makes the 'Nocchione' cv. where the catkins are apically distributed (Table 3). Our results are similar with results reported by Brandoli et al. (2023) for 'Tonda Gentile delle Langhe' and 'Nocchione' cvs. On the other hand, Ascari et al. (2020), reports the uniform distribution of catkins at the 'Nocchione' cv.

Pollen viability and germination

The pollen yield of hazelnut is very abundant, about 5 – 8 million grains are produced per catkin (Trotter, 1930; Soltesz and Nyeki, 2000; Piotrowska, 2008). Other authors have calculated between 15-35 million pollen grains, considering that one catkin contains 150-200 flowers and that each flower has 8 stamina (Pisani and Giulivio, 1968; Barbeau, 1972; Romisando, 1977; Szentivanyi, 1980). Pollen quality is an important varietal character, but the quantity is also decisive (Soltesz and Nyeki, 2000). It is known that some cultivars have sterile pollen grains, with irregular forms or with very weak tubes (Olsen et al., 2000).

The average value of pollen viability was 58.56%, ranging between 40.56% at 'Tonda Francescana' cv. and 70.84% at 'Romavel' cv. (Table 4). With the exception of the 'Tonda Francecana' and 'Tonda di Giffoni' cvs., all the genotypes studied had values over 50% of the pollen viability. Our results are similar to those obtained by Brandioli et al. (2023) for 'Tonda Gentile delle Langhe' and 'Nocchione' cvs. Ascari et al. (2020) report the same results of pollen viability for the 'Tonda Romana' cv., but smaller for the 'Tonda di Giffoni' cv. Regarding 'Tonda Gentile delle Langhe' cv. some authors reported a high quantity of sterile pollen (Riera, 1958, Romisondo, 1963, Olsen et al., 2000), but in our study this cultivar had about 60% pollen viable.

From the point of view of the pollen viability, the genotypes were grouped into 3 classes:

- class 3 – low pollen viability (37-50%): 'Tonda di Giffoni' and 'Tonda Francescana';
- class 5 – medium pollen viability (51-64%): 'Tonda Gentile delle Langhe' and 'TGDL clone PD 6', 'TGDL clone MT 5', 'Tonda Biglini', 'Tonda Romana', 'Nocchione', 'Izvor' and 'Jefferson';
- class 7 – high pollen viability (65-78%): 'TGDL clone AD 17', 'Mortarella', 'Fertile de Coutard' and 'Romavel'.

The average value of the pollen germination capacity was slightly lower than the pollen viability, being of 24.35%, ranging between 19.87% at 'Jefferson' cv. and 30.46% at 'Nocchione' cv. (Table 4). The pollen germination rates determinate in our research were similar to the literature. Balik et al. (2023) reported pollen germination between 15-78% at some Turkish hazelnut genotypes. Beyhan and Odabaș (1997) reported pollen germination capacity between 27-76% also at some Turkish cultivars. Fatahi et al. (2014) determined above 60% pollen germination capacity of some hazelnut cultivars. There is a strong relationship between pollen viability and germination rate (Novara et al., 2017).

According the pollen germination capacity, the genotypes were grouped into 2 classes:

- class 1 – very low pollen germination (<25%): 'Tonda Gentile delle Langhe', 'TGDL clone PD 6', 'TGDL clone MT 5', 'Tonda Biglini', 'Tonda Romana', 'Tonda di Giffoni', 'Tonda Francescana', 'Mortarella', 'Izvor', 'Jefferson', 'Fertile de Coutard';
- class 3 – low pollen germination (28-41%): 'TGDL clone AD 17', 'Nocchione' and 'Romavel'.

4. Conclusions

The results regarding the floral biology provide information on the possibility to use a cultivar as pollinator in orchards or as genitors in breeding work. Pollinators should produce a large number of catkins, and pollen viability and germination should be high.

The dichogamy phenomenon is present in hazelnut and was noted in our study. Generally, male flowers bloom before female flowers, manifesting a tendency to protandry. However, at six genotypes ('Fertile de Coutard', 'Tonda di Giffoni', 'Tonda Francescana', 'Tonda Romana', 'Nocchione' and 'Romavel'), the male flowers bloomed a few days later than the females, showed a tendency toward protogyny.

Regarding the flowering of the male flowers, the earliest was 'TGDL clone PD 6' and 'TGDL clone AD 17' (the end of December 2023), and the latest were ‘Nocchione’, ‘Tonda Francescana’ and ‘Tonda Romana’ (early February). Regarding the flowering of female flowers, the earliest was 'TGDL clone MT 5' and 'Tonda di Giffoni' (early January), and the latest were 'TGDL clone PD 6', 'TGDL clone AD 17' (early February) and ‘Jefferson’ (third decade of February).

The genotypes formed a high quantity of catkins uniformly distributed, with high level of pollen viability and germination capacity and can be use as pollinators in new orchards.

The average value of pollen viability was 58.56%, ranging between 40.56% at 'Tonda Francescana' cv. and 70.84% at 'Romavel' cv.

The average value of the pollen germination capacity was slightly lower than the pollen viability, being of 24.35%, ranging between 19.87% at 'Jefferson' cv. and 30.46% at 'Nocchione' cv.

In conclusion, besides the old cultivars already spread in the commercial orchards we can recommend the 'Romavel' and 'Nocchione' cultivars that have been noted for the late flowering, high catkins quantity and pollen with very good viability and germination capacity.

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Tables and Figures

Table 1. UPOV Descriptors (TG 71/3; 2022)

Traits	Categories	Categories ranges	Point
Flowering period	Very early Early Medium Late Very late		1 3 5 7 9
Pollen viability (%)	Very high High Medium Low Very low	>79 65-78 51-64 37-50 <36	9 7 5 3 1
Pollen germination (%)	Very high High Medium Low Very low	>66 53-65 41-52 28-40 <27	9 7 5 3 1
Amount of catkins	High Medium Low		5 3 1

Table 2. Flowering time (RIFG Pitești, 2023-2024)

No.	Genotype	Flowering of male flowers		Flowering of female flowers		Nature of dichogamy
		Beginning	Ending	Beginning	Ending	
1	Tonda Gentile delle Langhe (TGDL)	04.01.2024	23.02.2024	17.01.2024	14.03.2024	Protandrous
2	TGDL clone PD 6	28.12.2023	23.02.2024	02.02.2024	14.03.2024	Protandrous
3	TGDL clone MT 5	07.01.2024	23.02.2024	11.01.2024	14.03.2024	Protandrous
4	TGDL clone AD 17	30.12.2023	23.02.2024	02.02.2024	14.03.2024	Protandrous
5	Tonda Biglini	02.01.2024	29.02.2024	17.01.2024	14.03.2024	Protandrous
6	Tonda di Giffoni	26.01.2024	29.02.2024	11.01.2024	23.02.2024	Protogynous
7	Tonda Francescana	06.02.2024	29.02.2024	23.01.2024	14.03.2024	Protogynous
8	Tonda Romana	10.02.2024	29.02.2024	17.01.2024	14.03.2024	Protogynous
9	Nocchione	02.02.2024	29.02.2024	11.01.2024	14.03.2024	Protogynous
10	Mortarella	17.01.2024	29.02.2024	02.02.2024	22.03.2024	Protandrous
11	Fertile de Coutard	23.01.2024	29.02.2024	19.01.2024	20.03.2024	Protogynous
12	Izvor	17.01.2024	23.02.2024	23.01.2024	14.03.2024	Protandrous
13	Jefferson	17.01.2024	14.03.2024	23.02.2024	30.03.2024	Protandrous
14	Romavel	23.01.2024	29.02.2024	17.01.2024	23.02.2024	Protogynous

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Table 3. Duration of flowering, quantity and distribution of catkins (RIFG Pitești, 2023-2024)

No.	Genotype	Duration of flowering (day)		Catkins quantity	Distribution of catkins
		♂	♀		
1	Tonda Gentille delle Langhe (TGDL)	51	58	Abundant	Uniform
2	TGDL clone PD 6	58	42	Abundant	Uniform
3	TGDL cone MT 5	48	64	Abundant	Uniform
4	TGDL clone AD 17	56	42	Abundant	Uniform
5	Tonda Biglini	59	58	High	Uniform
6	Tonda di Giffoni	35	44	Medium	Uniform
7	Tonda Francescana	24	52	Medium	Uniform
8	Tonda Romana	20	58	High	Uniform
9	Nocchione	28	64	Abundant	Apical
10	Mortarella	44	50	High	Uniform
11	Fertile de Coutard	38	62	High	Uniform
12	Izvor	38	52	Medium	Uniform
13	Jefferson	58	37	Medium	Uniform
14	Romavel	38	38	Medium - High	Uniform

Table 4. Pollen viability of hazelnut genotypes studied

No.	Genotype	Pollen viability (%)	Point	Pollen germination (%)	Point
1	Tonda Gentille delle Langhe (TGDL)	60.03	5	25.40	1
2	TGDL clone PD 6	62.76	5	23.56	1
3	TGDL clone MT 5	53.33	5	22.69	1
4	TGDL clone AD 17	70.12	7	29.20	3
5	Tonda Biglini	58.09	5	26.35	1
6	Tonda di Giffoni	41.85	3	22.10	1
7	Tonda Francescana	40.56	3	20.46	1
8	Tonda Romana	52.28	5	24.82	1
9	Nocchione	57.14	5	30.46	3
10	Mortarella	68.28	7	22.50	1
11	Fertile de Coutard	69.57	7	24.60	1
12	Izvor	60.36	5	20.12	1
13	Jefferson	54.62	5	19.87	1
14	Romavel	70.84	7	28.84	3
	Average	**58,56**		**24,35**	
	Standard deviation	**9,65**		**3,41**	
	Variability coefficient (%)	**16,48**		**14,01**	

Fig. 1. The beginning and end of blooming of male and female flowers - 'Tonda Gentile delle Langhe MT5'

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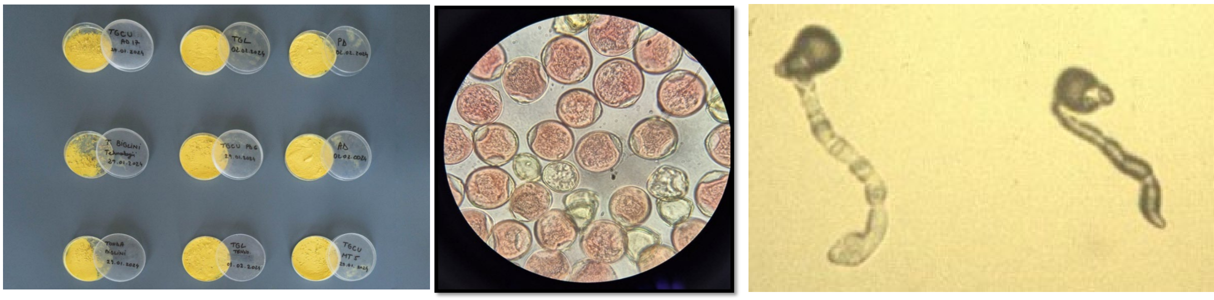

Fig. 2. Amount of pollen, pollen viability and pollen germination