# PHENOLOGICAL CHARACTERISTICS OF INTRODUCED ALMOND (*Prunus amygdalus*) CULTIVARS IN HERZEGOVINA

Jasna Hasanbegović[1], Semina Hadžiabulić[1], Mirsad Kurtović[2], Alisa Hadžiabulić[1], Azra Skender[3], Jasmin Grahić[2]

*Original scientific paper*

## Summary

The research aims to determine the phenological characteristics of seven introduced almond cultivars (Ferragnes, Ferraduel, Tuono, Genco, Supernova, Texas, Nonpareil), in Herzegovina, in a private plantation located near the settlement of Gnojnice, Mostar municipality. The area of Herzegovina - Mostar is very favorable for intensive almond cultivation. The phenological observations covered two vegetation years (2017-2018). Phenological observations are considered as sensitive methods for recognizing the plant reactions to climate change. The flowering period is a significant characteristic of almonds because it is important to avoid late frosts that affect the production of almonds with early flowering. Based on the study of the phenological phases of almond flowering, it can be concluded that all introduced almond cultivars belong to the group of medium to late flowering, which shows a satisfactory adaptation to the ecological conditions of Herzegovina. There are significant differences in the time of the beginning of ripening of almond cultivars in 2017 and 2018, which is the result of the agro-ecological conditions. Based on the phenological research that referred to the late flowering, the most promising cultivar for the area of Herzegovina is Supernova, and it can be recommended for wider production. In addition to the late flowering phenophases, Supernova is self-fertile cultivar. In the future, it is necessary to continue and intensively research both the introduction and autochthonous genotypes of almonds in Herzegovina for genetic characteristics and breeding programs.

Key words: *Prunus amygdalus, almond, phenophase, flowering, ripening*.

## INTRODUCTION

Almond (*Prunus dulcis*) is a synonim (*Prunus amygdalus* Batsch) is classified in the family *Rosaceae*. The Prunus genus includes many important fruit crops such as peach (*P. persica* L. Batsch), apricot (*P. armeniaca* L.), cherry (*P. avium* L.), cherry (*P. cersus* L.) and plum. (*P. domestica* L.).
The number of chromosomes of *Prunus dulcis* is 2n = 16, which is the same as other species of the genus Prunus (Kester and Gradziel, 1996). Almonds are one of the

[1] Agromediterranean Faculty, University Džemal Bijedić of Mostar
[2] University of Sarajevo, Faculty of Agriculture and Food Sciences
[3] University of Bihać, Biotechnical faculty
Corresponding author: jasna.hasanbegovic@unmo.ba

oldest stone fruit crops (around 4000 BC), and originate from western Asia and Greece. Almond (*Amygdalus communis* Spach) originates from the highland areas of Central Asia, where many of its wild ancestors are still found today. These are the areas: Tian Chan, Kurdistan, Turkestan, Afghanistan and Iran (Vlašić, 1978). Almonds are grown in the wider Mediterranean rim in Spain, Italy, France and Turkey. More than 30 types of almonds can be found in southern Europe, Asia Minor, southwest and Central Asia. According to the research by Polat *et al*. (2001), it is widespread in the world, but the productivity is limited by the environmental factors. Susceptibility to late spring frosts, that cause significant damage to flowers, affects almond production (Kodad *et al*., 2011). Almonds can grow in a variety of distinctive pedoclimatic conditions and are characterized by the outstanding drought resistance (Laghazali *et al*., 1985). An important phenological characteristic of almonds is their flowering period. The late flowering and self-fertilization are the most important breeding goals of almonds. The aim of this paper is to examine the phenological phases of flowering and ripening of seven introduced almond cultivars in the conditions of the Mediterranean climate.

## MATERIALS AND METHODS

The examination of the phenological characteristics of flowering of seven introduced almond cultivars was performed in the period of 2017 and 2018 at the location "Gnojnice", south of Mostar on a private plantation. The experimental plantation is located at an altitude of about 60 m with coordinates of N 43º17'05" and E 17º51'25". The territory of Herzegovina is characterized as a very suitable area for the commercial production of almonds. The site is characterized by a typical Mediterranean climate.

Tab. 1. Average annual agrometeorological data for the period 2017 and 2018 for the region of Mostar

| | 2017 | 2018 |
|---|---|---|
| Annual precipitation amounts (l/m$^2$) | 1272.4 | 1475.4 |
| Insolation (hours) | 2626.9 | 2322.5 |
| Medium temperatures ($^o$C) | 16.0 | 16.6 |
| Maximum temperatures ($^o$C) | 41.9 | 38.2 |
| Minimum temperatures ($^o$C) | -9.3 | -4.9 |

The plantation was established in 2006 and 2007 and it is in the period of full fruiting. All tested almond cultivars were grafted on the vegetative rootstock GF-677, which showed an exceptional compatibility of grafted almond cultivars, as well as adaptability to soil and agro-ecological conditions. The planting distance in the plantation is 4.5 x 3.5 m, and the entire plantation occupies an area of 3000 m$^2$. The regular agro-technical measures in the plantation included irrigation, nutrition, and

pest and disease control. Phenological tests were performed on three adult and healthy trees (13 years old), and seven introduced almond cultivars: Tuono, Texas, Ferragnes, Nonpareil, Ferraduel, Genco and Supernova.

The phenological characterization of almonds at the phenotypic level has been performed according to the guidelines included in the IBPGRI almond descriptor (Almond descriptor), published by the International Board for Plant Genetic Resources (1981) to describe species of the genus *Prunus amygdalus* L. The analysis of results of the evaluation of phenological characteristics of seven introduced almond cultivars in the territory of Herzegovina has been performed by applying the Principal Component Analysis (PCA) on the basis of the correlation matrix in the statistical program *XLSTAT2020*.

## RESULTS AND DISCUSSION

The phenological studies of the introduced almond cultivars included monitoring the course of flowering and ripening phenophases: beginning of flowering, full flowering and end of flowering, duration of flowering, ripening and the period required for ripening. Flowering phenograms of introduced almond cultivars are presented in the following tables and graphs.

Tab. 2. Phenological research of introduced almond cultivars in the period 2017-2018

| | **Beginning of flowering** | **Full flowering** | **End of flowering** | **Duration of flowering (days)** | **Ripening** | **Ripening period (days)** |
|---|---|---|---|---|---|---|
| **Cultivars** | | | **Year 2017** | | | |
| Texas | 01.03. | 06.03. | 11.03. | 11 | 02.09. | 175 |
| Nonpareil | 05.03. | 11.03. | 13.03. | 9 | **27.08.** | 167 |
| Ferraduel | 08.03. | 13.03. | 17.03. | 10 | 29.08. | 165 |
| Genco | 09.03. | 13.03. | 17.03. | 9 | 29.08. | 165 |
| Ferragnes | 02.03. | 09.03. | 16.03. | 15 | **06.09.** | 174 |
| Supernova | **12.03.** | **15.03.** | **18.03.** | 7 | 05.09. | 171 |
| Tuono | **28.02.** | **04.03.** | **10.03.** | 11 | 30.08. | 173 |
| | | | **Year 2018** | | | |
| Texas | **07.03.** | **12.03**. | **18.03.** | 12 | 10.09. | 176 |
| Nonpareil | 11.03. | 18.03. | 23.03. | 13 | **02.09.** | 163 |
| Ferraduel | 13.03. | 20.03. | 25.03. | 13 | 03.09. | 162 |
| Genco | 14.03. | 19.03. | 26.03. | 13 | 03.09. | 161 |
| Ferragnes | 15.03. | 21.03. | 29.03. | 15 | **15.09.** | 170 |
| Supernova | **17.03**. | **23.03**. | **30.03.** | 14 | **15.09.** | 169 |
| Tuono | 08.03. | 15.03. | 22.03. | 15 | 09.09. | 170 |

Based on the results presented in Table 2 and Graphs 1 and 2, it can be concluded that the earliest beginning of flowering in 2017 was recorded in the Tuono cultivar on February 28, while the latest beginning of flowering was recorded in the Supernova cultivar on March 12. Looking at 2018, it can be stated that the beginning of flowering was recorded somewhat later in the Texas cultivar (March 7), and the latest beginning of flowering was also recorded in the Supernova cultivar (March 17).
Analyzing the full flowering, it can be concluded that it occurred 5 to 7 days in most cultivars in both research years.
The earliest end of flowering in 2017 was recorded in the Tuono cultivar on March 10, and the latest in the Supernova cultivar on March 18.
In 2018, the earliest end of flowering was recorded in the Texas cultivar on March 18, and the latest in the Supernova cultivar on March 30. The duration of flowering phenophases in the examined period 2017-2018 ranged from 7 to 15 days, which can be related to the temperature oscillations in the examined periods. Analyzing the ripening phenophase, it can be stated that the earliest ripening was recorded in the cultivar Nonpareil on August 27, 2017, and the latest was recorded in the cultivars Ferragnes and Supernova on September 15, 2018. The period required to full ripening ranged from 165 days for the Ferraduel and Genco cultivars to 175 days for the 2017 Texas cultivars. In 2018, the lowest number of days to full ripening was recorded in the Ferraduel cultivar 162 days, and the highest number of days 176 to full ripening was recorded in the Texas cultivar.

Based on the results, it can be concluded that these are cultivars of medium late to late flowering and ripening time.

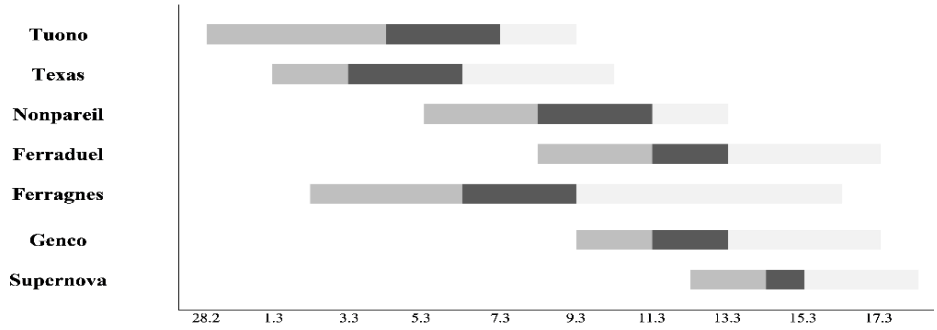



Fig. 1. Flowering phenogram of introduced almond cultivars in 2017

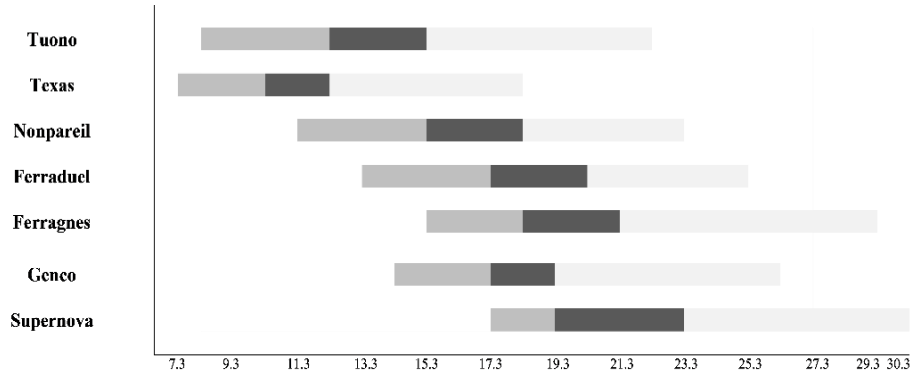



Fig. 2. Flowering phenogram of introduced almond cultivars in 2018

| | |
|---|---|
| | The beginning of flowering |
| | Full flowering |
| | End of flowering |

In the study Miljković (1991), it is stated that the cultivars Texas and Yalta are classified in the group of late flowering cultivars, while the cultivar "Non Pareil" was rated as a medium late flowering cultivar. Another study by Vargas *et al*. (2001) states that the cultivar "Non Pareil" is classified as a medium-early flowering cultivar, while the cultivars "Texas" and "Yalta" have been classified as the late flowering cultivars.

The increased dynamism of flowering in 2018 was influenced by the increased average daily air temperatures that occurred during the period of full flowering, while in 2017 they experienced a decline in that period. In the study by Kester *et al*. (1997), it is stated that the duration of flowering in Genco cultivars was 9 days, which is very similar to the results of this study in 2017 for Genco cultivars. Kaska *et al*. (2007), report that the duration of flowering phenophases for Texas cultivar was 12-15 days, which is very similar to the results of this study for Texas cultivar in which flowering in the period 2017-2018 was 11 -12 days.

Manushev *et al*. (1978), in a paper examining the phenological phases of almond cultivars in Herzegovina, the Buna and Hodbina sites, state that the flowering phenophases of Texas cultivars lasted 16 days in the 1997 research year.

Aliman and Oručević (2018) state that the cultivar Nonpareil in the research period 2013-2014 matured earlier, which is also very similar to this research.

According to Hadžiabulić *et al*. (2011), which included the study of morphological and phenological characteristics of 27 indigenous genotypes of almonds in Herzegovina, they came to the conclusion that the latest onset of flowering is 4.3., and the end of flowering 23.3.2009 was found at the genotype II.

Tab. 3. Eigenvalues, proportion of variance and cumulative variance associated with the first five main components (PCA), estimated from a correlation matrix with 12 variables in 7 introduced almond cultivars

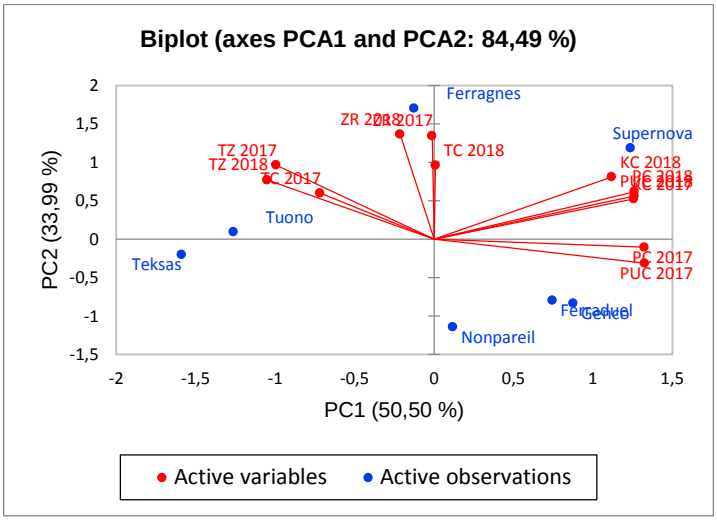
| Variables | PC1 | PC2 | PC3 | PC4 | PC5 |
|---|---|---|---|---|---|
| **Eigenvalue** | 6,060 | 4,078 | 1,243 | 0,564 | 0,034 |
| **Proportion of variance (%)** | 50,502 | 33,985 | 10,356 | 4,701 | 0,282 |
| **Cumulative variance (%)** | 50,502 | 84,487 | 94,843 | 99,544 | 99,827 |

Tab. 4. Analysis of 12 quantitative properties of introduced almond cultivars in a total experimental variability (significant sources of variability are in bold)

| | PCA1 | PCA2 | PCA3 | PCA4 | PCA5 |
|---|---|---|---|---|---|
| **Beginning of flowering - PC 2017** | **0,872** | 0,006 | 0,110 | 0,007 | 0,006 |
| **Full flowering - PUC 2017** | **0,876** | 0,049 | 0,001 | 0,071 | 0,002 |
| **End of flowering - KC 2017** | **0,788** | 0,136 | 0,070 | 0,000 | 0,003 |
| **Ripening - ZR 2017** | 0,000 | **0,899** | 0,060 | 0,040 | 0,001 |
| **Beginning of flowering - PC 2018** | **0,792** | 0,190 | 0,004 | 0,009 | 0,000 |
| **Full flowering - PUC 2018** | **0,791** | 0,156 | 0,035 | 0,000 | 0,011 |
| **End of flowering - KC 2018** | **0,622** | 0,325 | 0,048 | 0,001 | 0,000 |
| **Ripening - ZR 2018** | 0,023 | **0,923** | 0,052 | 0,002 | 0,000 |
| **Flowering duration - TC 2018** | 0,000 | **0,459** | 0,347 | 0,192 | 0,001 |
| **Ripening period - TZ 2018** | **0,549** | 0,295 | 0,154 | 0,000 | 0,000 |
| **Flowering duration - TC 2017** | 0,256 | 0,178 | **0,322** | 0,241 | 0,003 |
| **Ripening period – TZ 2017** | **0,492** | 0,461 | 0,039 | 0,000 | 0,006 |

Analyzing the results of the five main components of the PCA analysis shown in Tables 3 and 4, one can see the contribution of each of the 12 analyzed characteristics in the total variability present in the analyzed set of seven introduced almond cultivars. Each of the 12 observed characteristics is found with a high value of eigenvectors in one of the first five main components. The variables with the highest values of eigenvectors in the first five main components are presented: PCA1 - beginning, full, end of flowering and period required for ripening in 2017, then beginning of flowering, full flowering, end of flowering and period required for ripening in 2018; PCA2 - ripening in 2017 and 2018 and duration of flowering in 2018; PCA3 - duration of flowering in 2017. The analysis of the obtained results shows that through the dominant eigenvectors, they are available in the first main component (PCA), which

amounted to 50.502% of the total variance of the research. The most significant properties of the first component relate to the phenological properties of flowering and ripening. The highest values of eigenvectors had the beginning and full flowering in 2017 (0.872 and 0.876). Lower values of eigenvectors had the characteristics of the beginning and full flowering in 2018 (0.792 and 0.791), end of flowering in 2017 (0.788) and end of flowering in 2018 (0.622), while the lowest eigenvalue of the vector had the periods required for ripening in 2018 and 2017 (0.549 and 0.492). Within the second main component, which accounts for 84.487% of the total variability of the experiment, most of the properties with a high value for the eigenvector are related to the phenophase of ripening and the duration of flowering. Of these, the properties with the highest value of eigenvectors are the phenophases of ripening in 2018 and 2017 (0.923 and 0.899). Due to the visualization of the statistical significance level of the separation of the introduced almond cultivars, the biplot chart also includes an analytical presentation of the original analyzed properties.




*Beginning of flowering - PC 2017, Full flowering - PUC 2017, End of flowering - KC 2017, Ripening - ZR 2017, Beginning of flowering - PC 2018, Full flowering - PUC 2018, End of flowering - KC 2018, Ripening - ZR 2018, Flowering duration - TC 2018, Ripening period - TZ 2018, Flowering duration - TC 2017, Ripening period – TZ 2017*

Fig. 3. Biplot of 7 introduced almond cultivars separated on the basis of phenological characteristics by the principal components analysis. The original properties are shown as vectors where the direction indicates the value for each property and the length to the level of variability

Analyzing the first two components, which contain 84.487% of the total variability of the experiment, it is noticeable that the introduced almond cultivars were not grouped around the center of the coordinate system. From Graph 3, it is evident that there is a

strong positive correlation between the beginning, full and end of flowering in 2018 and the end of flowering in 2017, then between ripening in 2018 and 2017 and the duration of flowering in 2018. The obtained result has a logical explanation that the stated phenological properties are dependent on each other and increase proportionally with the course of phenophases.

The presence of a negative correlation was recorded between the phenological phases of the beginning of flowering in 2017 and full flowering in 2017 due to agro-ecological conditions in a given year. A strong positive correlation was observed between the ripening period in 2017 and 2018 and the duration of flowering in 2017, and in this case the result is logical, since the periods required for ripening directly depend on the beginning of flowering and ripening phenophases, which is a characteristic of cultivars.

## CONCLUSIONS

According to the results of research on the phenology of flowering and ripening of introduced almond cultivars, it can be concluded that the earliest flowering in the examined period (2017-2018) was recorded in the Tuono cultivar on March 7, and the latest flowering was recorded for the Supernova cultivar on March 17. The research showed that the flowering phenophases in 2018 started much later with a difference of 1-6 days in all cultivars, in the period from March 10 to 16, while during 2017 the flowering phenophases ranged from February 28 until March 12 for all studied cultivars with a difference of 5-7 days. Full flowering in the study period (2017-2018) was recorded at the earliest at the Tuono cultivar on March 4, and at the latest at the Supernova cultivar on March 13. The full-flowering phenophase in 2017 overlapped best between Genco and Ferraduel cultivars, while in 2018, the best overlap was recorded between Nonpareil and Genco cultivars. The average duration of flowering phenophases for all examined almond cultivars ranged from 7-15 days during 2017 and 11-15 days during 2018. The earliest ripening was recorded in the cultivar Nonpareil on August 27, 2017, and the latest was recorded in the cultivars Ferragnes and Supernova on September 15, 2018, and it can be stated that these are cultivars of medium late to late ripening. The period required for ripening of the tested almond cultivars ranged from 176 days in Texas cultivars to 162 days in Ferraduel cultivars in 2018.

Based on phenological research with reference to the time of late flowering, the most promising cultivar for the area of Herzegovina is Supernova, and it can be recommended for wider production. In addition to the late phenophase of flowering, Supernova is classified as a self-fertilizing cultivar. In the future, it is necessary to continue and intensify the research of both introduced and autochthonous almond genotypes in Herzegovina for genetic characterization and breeding programs.

## REFERENCES

Aliman, J., Oručević, A. (2018): The Phenology of Flowering and Ripening of Almond Cultivars Nonpareil, Texas, Ferraduel and Genco in Herzegovina International Journal of Plant & Soil Science 21(3): Article no.IJPSS.39091 ISSN: 2320-7035.

Hadžiabulić, S., Aliman, J., Džubur, A., Skender, A., Šoše, I. (2011): Inventarizacija i morfološka karakterizacija genotipova badema *Prunus amygdalus* na području Hercegovine 46th Croatian and 6th International Symposium on Agriculture. Opatija. Croatia (1001-1005).

Kaska, N., Küden, A. (1998): Performances of some local and foreign almond cultivars in South East Anatolia, X GREMPA Seminar. Zaragoza pp. 181-183: CIHEAM, (Cahiers Options Méditerranéennes; n. 33)

Kester, DE., Gradiziel, TM., Janick, J., Moore, JN. (1996): Fruit Breeding. Vol. III. Nuts, John Wiley and Sons, New York. pp. 1-97.

Kodad, O., Socias, R. I Company, Morales, F. (2011): Evaluation of almond flower tolerance to frosts by chlorophyll fluorescence. Options Méditerr. 94:141–145.

Laghezali, M. (1985): L'amandier au Maroc. Options Méditerr. 85(I):91–96.

Manušev, B., Buljko, M., Efendić, K. (1978): Neke biološko – pomološke osobine sorti badema u Hercegovini, „Poljoprivreda i šumarstvo", Titograd. XXIV(3-4):305- 3141.

Miljković, I. (1991): Suvremeno voćarstvo. Znanje, Zagreb.

Polat, A. A., Durgaç, C., Kamiloglu, Ö. (2001): Determination of pomological characteristics of some local and foreign almond cultivars in Yayladagy (Hatay) ecological conditions. Options Méditerr. 56:381–384.

Vargas, FJ., Romero, MA., Rovira, M., Girona, J. (1984): Amélioration de l'amandier par croisement de variétés. Résultats préliminaires à Tarragone (Espagne). Options Méditerranéennes, Série Etudes 84-II: 111-122.

## FENOLOŠKE KARAKTERISTIKE INTRODUKOVANIH KULTIVARA BADEMA (*Prunus amygdalus*) NA PODRUČJU HERCEGOVINE

### Rezime

Istraživanje ima za cilj utvrditi fenološke karakteristike sedam introdukovanih kultivara badema (Ferragnes, Ferraduel, Tuono, Genco, Supernova, Texas, Nonpareil), na području Hercegovine, u privatnom nasadu koji se nalazi u blizini naselja Gnojnice, Općina Mostar. Područje Hercegovine - Mostar vrlo je povoljno za intenzivni uzgoj badema. Fenološka osmatranja obuhvatala su dvije vegetacijske godine (2017-2018). Fenološka zapažanja smatraju se osjetljivim metodama za prepoznavanje reakcija biljaka na klimatske promjene.

Period cvjetanja je važna karakteristika badema jer je važno izbjeći kasne mrazeve koji utječu na proizvodnju badema sa ranim cvjetanjem. Na temelju izučavanja fenoloških faza cvjetanja badema može se konstatovati da svi introdukovani kultivari badema pripadaju skupini srednje do kasnog cvjetanja, što pokazuje zadovoljavajuću prilagodbu ekološkim uvjetima Hercegovine. Postoje značajne razlike u vremenu početka zrenja kultivara badema u 2017. i 2018. godini, što je rezultat agroekoloških uslova. Najperspektivniji kultivar za područje Hercegovine je Supernova na osnovu fenoloških istraživanja sa osvrtom na vrijeme kasnog cvjetanja, može se preporučiti za širu proizvodnju. Pored kasne fenofaze cvjetanja Supernova se svrstava u samooplodne kultivare. U budućnosti je potrebno nastaviti i intenzivirati istraživanje kako introdukovanih, tako i autohtonih genotipova badema na području Hercegovine za genetičku karakterizaciju i oplemenjivačke programe.

Ključne riječi: *Prunus amygdalus, badem, fenofaze, cvjetanje, zrenje*