



The Phenology of Flowering and Ripening of Almond Cultivars Nonpareil, Texas, Ferraduel and Genco in Herzegovina

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Authors' contributions

This work was carried out in collaboration between all authors. Author JA designed the study, wrote the protocol, managed the analyses of the study and performed the statistical analysis. Author AO conducted the research in field, data collection and wrote the first draft of the manuscript and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The area of sub-Mediterranean Herzegovina, including the area of Mostar, is favourable for growing of almonds. However, this advantage has not been sufficiently exploited so far. A wide selection of almond varieties is available, so it is a challenge to select the best variety for successful cultivation in the agroecological conditions of Herzegovina, and to justify the economic investment. Therefore, it is necessary to evaluate their phenological characteristics in order to determine their adaptability to environmental conditions of Herzegovina. This paper describes the dynamics of flowering and fruit ripening of four varieties of almonds in climatic conditions of Herzegovina, in Mostar. The goal of this paper is to establish the dynamics of flowering in the Mostar area of these cultivar almond types: *Nonpareil*, *Texas*, *Ferraduel* and *Genco*.

Study Design: For the purposes of research work, there was an experiment set up by the *method of random pool arrangement*, with three trees of each cultivar.

Place and Duration of Study: The experimental part of this work was carried out in a part of private property located near the village of *Gnojnice*, Municipality of *Mostar*. The survey was

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conducted on two occasions, more precisely in two vegetations, during 2013 and 2014.

Methodology: The dynamics of flowering were recorded for each cultivar through three phenophases:

- Beginning of flowering - the date when 10% of tree flowers are opened;
- Full flowering - the date when 90% of tree flowers are opened;
- End of flowering - the date when more than 90% of leaf petal fell of the tree.

Results: The research results showed a big correlation between flowering phenophases flow and meteorological conditions in some research years. In 2014, the flowerings began 14 to 18 days earlier (depending on variety) in comparison to 2013. The earliest flowering was recorded for the variety "Texas", and the latest was recorded for varieties of Ferraduel and Genco.

Conclusion: Flowering duration was pretty equal for all the varieties (from 17 to 21,3 days), while the shortest duration was recorded for the varieties Genco (17) and Ferraduel (17,3) in 2013. All the varieties had earlier fruit ripening in 2014 in comparison to 2013. Fruits of Texas variety had the latest ripening, while the varieties Nonpareil, Ferraduel and Genco ripened at the same time. All the monitored varieties showed an extreme adaptability to agro-ecological conditions of Herzegovina and may be recommended for commercial cultivation.

Keywords: Almond; phenophase; flowering; ripening.

1. INTRODUCTION

The almond is a neglected fruit culture in Bosnia and Herzegovina, and its cultivation is mostly limited to the garden areas, while it is poorly represented in orchards or planting stocks. Current production of almonds in Bosnia and Herzegovina is not even close to meet market demands. The problem is more obvious, because the region of submediterranean Herzegovina has got special agroecological conditions and it is extremely favorable for the cultivation of this fruit culture.

The most important phenological traits of the almond are blooming time, duration of bloom and ripening season. One of the most important prerequisites for the improvement of almond production in Bosnia and Herzegovina is the selection of suitable cultivars, especially the choice of late-blossoming cultivars with good biological-productive characteristics.

The goal of this paper is to establish the dynamics of flowering in the Mostar area of cultivar almonds types: *Nonpareil*, *Texas*, *Ferraduel* and *Genco*. The successful realization of this goal will serve as a basis for comparing the already existing results of the researchers in some other areas, as in the territory of Bosnia and Herzegovina such data do not exist.

The almond blooms very early, during the period from the end of January to the end of March, which depends on cultivars, forms and weather, at first. This trait determines a flowering stage coinciding with late winter season, and consequently with low temperature and

precipitation that exert negative effects on pollination [1]. Flowering phenophases usually last from 5 to 25 days.

Considering the almond cultivars, there are early, medium, and late cultivars [2]. The flowering time and heat requirements before bloom are significantly different for some cultivars [3,4]. When cold season is long and followed by warm temperature, flowering is uniform, short, and of good quality [5].

The almond usually blossom at a temperature of 8°C to 10°C [6].

Almond flowering is mainly self-incompatible and, therefore requires cross-pollination [7], so it is important to take care of cultivars with pollinator when raising plants. The appearance of auto-sterile is caused by non-germination, pollen impurity, or incompatibility of diploid and triploid species.

The almond is a fruit species belonging to a group of non-pollinated (foreign fertile, cross-pollination) fruit species with self-fertilization that occurs sporadically [8].

Effective Pollination Period (EPP), receptivity to stigma for pollen with high temperatures during pollination may have an effect on fertility and set of fruits [9]. The results of their research suggest the importance of early pollination (pollination must be on time) to ensure an acceptable and good yield.

Genco cultivar had 30% of fetched fruits with their own pollen, as opposed to 35% of fetched

fruits that were fertilized with pollen-compatible cultivars [10].

In the first year of research, more than 50% of the flowers were damaged because of late spring frosts, and in the second year of research, the percentage of damage flowers was 100% [11]. The results of these studies show that almond is sensitive to late spring frosts.

2. MATERIALS AND METHODS

2.1 Experimental Location and Materials

The experimental part of this work was carried out in a part of private property located near Mostar, in the south of Bosnia and Herzegovina. Four cultivars, *Nonpareil*, *Texas*, *Ferraduel* and *Genco*, were included in this study. The bitter almond was used as a rootstock for all cultivars.

For the purposes of research work, there was an experiment set up by the *method of random pool arrangement*, with three trees of each cultivar. The survey was conducted on two occasions, more precisely in two vegetations, during 2013 and 2014.

The research plantation was planted in 2006 and 2007, with the planting area of 4.5 m x 3.5 m. The whole plantation occupied the area of 3000 m². The maintenance of the soil in the plantation was carried out by treating the area with inter row crop cultivator and the fertilization in the autumn, while the inter row area was maintained in condition of grassy surface, the only intervention was mowing of the grass. Also, all the other contemporary agrotechnical measures, such as plant protection, fertilization with mineral and organic fertilizers, irrigation, and pruning, were applied in the plantation.

2.2 Treatments and Methodology

There are several different measures that can be taken to record blooming time, estimating different percentages of open flowers and defining first, full, and final blooming times [12,13].

Blooming dates of the studied cultivars were determined according to IBPGR descriptors [14].

The dynamics of flowering were recorded for each cultivar through three phenophases:

- Beginning of flowering - the date when 10% of tree flowers are opened;

- Full flowering - the date when 90% of tree flowers are opened;
- End of flowering - the date when more than 90% of leaf petal fell of the tree.

It is necessary to record the period of botanical maturity to determine the maturation time of investigated cultivars for the two year period, it is the date when the green coat (pericarp) is cracked (or when 95% of mesocarp were opened).

The data measured was subjected to variance analysis variables and the averages were compared to the Tukey-Kramer test. Comparisons were made within the examined cultivars and years of research in the period 2013-2014 on the level of significance of 0.05.

3. RESULTS AND DISCUSSION

3.1 The Phenology of Flowering

The table presents the average dates of the flowering phenophase of the cultivars investigated during the research period and the duration of the flowering phenophase for the given average dates. Analysis of variance showed statistically significant differences between examined cultivars and between years at the beginning, at full, and at the end flowering.

It is evident that the beginning flowering phenophase (research form 2013), *Texas* cultivars started to bloom first, on March 10th, 2003, and the latest blooming cultivar was *Genco*, which started blooming on March 16th. During the exploration in 2013, the earliest occurred phenophase was in *Texas* cultivar, on March 16th, and the latest phenophase was recorded in *Genco* cultivar, on March 23rd. The end of flowering phenophase first occurred in *Texas* cultivar, on March 28th, and the latest phenophase occurred in *Ferraduel* and *Nonpareil* cultivars, on April 2nd (research form 2013).

Studies have shown that, in the course of 2014, the phenophase beginning of flowering first occurred in *Texas* cultivar on Feb 24th, and the latest phenophase beginning of flowering was recorded in *Nonpareil* cultivar on Feb 28th. Full flowering phenophase (during the 2014 research year), first occurred in *Texas* cultivar on Feb 28th, and the latest full flowering phenophase was recorded in *Nonpareil* cultivar on March 7th.

Table 1 shows the end of flowering phenophase during research in 2014. It first occurred in *Texas* cultivar, on March 16th. Also, it is evident that this phenophase was most recent in *Genco* cultivar on March 20th, from 2014.

Texas cultivar started to bloom 14 days earlier in 2014, compared to the beginning of bloom in 2013. Table 1: It is evident that *Ferraduel* cultivar started the phenophase beginning of flowering, even 18 days earlier in 2014, compared to 2013. *Nonpareil* started of flowering phenophase earlier in 2014, compared to the research form 2013, and the difference was 13 days

The same case is with *Genco* cultivar, form 2014, which started the phenophase beginning of flowering 18 days earlier, compared to the research from 2013.

Table 1 shows that *Genco* cultivar had the shortest flowering period (16 days) during the research in 2013, and the same cultivar had the longest flowering (22 days) in the course of the research from 2014.

Table 2 presents the average duration of flowering phenophase for all three representative samples of all tested cultivars. Table 2 also shows that the flowering phenophase was the shortest in *Genco* cultivar, during the research in 2013 (17 days), but it also was the longest one in the research from 2014 (21.3 days). If we consider the average for both research years, we can conclude that the flowering phenophase was longest for *Nonpareil* cultivar (19.6 days) and the shortest one was in *Ferraduel* cultivar (18.6

days). We can conclude that the duration of the flowering phenophase was fairly equal if we look at the average for both study years in all four studied cultivars, that period lasted from 18.6 to 19.6 days. The differences in the duration of flowering between cultivars were dependant on the temperature at the time of bloom [12,15].

Research has shown that from the point of view of the moving phenophase beginning of flowering, we have noted similar results as many other researchers. The beginning of flowering phenophase for *Ferraduel* cultivar was recorded on March 23rd [16], which is similar to our results.

The beginning of flowering phenophase for *Nonpareil* cultivar was recorded on March 19th in the ecological conditions of Skopje, [17], which is similar to the results of our research. The *Nonpareil* cultivar on the rootstock bitter almond started the phenophase flowering on March 16th [18], such as the full flowering started on March 21st which is similar to the results of our research.

According to the aspect of the full flowering date, we get similar results with other researchers.

The *Ferraduel* cultivar of the full flowering phenophase appeared on March 20th [19], which is different from the results of our research.

Beginning of flowering of cultivar *Ferraduel*, at Valu lui Traian, south-eastern Romania, was

Table 1. Avarage dates of the flowering phenophase

Cultivar	Texas		Nonpareil		Ferraduel		Genco	
	2013	2014	2013	2014	2013	2014	2013	2014
Beginning of flowering	10.03.d	24.02.a	13.03.e	28.02.c	16.03.f	26.02.b	16.03.f	26.02.b
Full flowering	16.03.e	28.02.a	20.03.f	07.03.d	20.03.f	04.03.b	23.03.g	06.03.c
End of flowering	28.03.d	16.03.a	02.04.e	19.03.b	02.04.e	19.03.b	01.04.f	20.03.c
Duration of flowering (days)	18b	20bc	20bc	19b	17a	21bcd	16a	22d

Means with the same letter are not significantly different from each other ($P>0.05$)

Table 2. Avarage duration of flowering phenophase

	Texas	Nonpareil	Ferraduel	Genco
2013	19b	20,7cd	17,3a	17a
2014	19b	18,6b	20c	21,3d
Avarage	19	19,6	18,6	19,1

April 16th [20]. Authors stated that the phenophases end of flowerings was at date April 28th, and the time of flowering was 12 days. In the same research, authors stated that the ripening date for cultivar Ferraduel was on Sep 28th.

The phenophases of flowering in Genco cultivar lasted for 9 days [21]. In this research, phenophases of flowering started on Feb 21st, and ended on March 1st.

From the aspect of the overall duration of flowering phenophase, in *Texas* cultivar we have noted similar results with other researchers. So, the flowering phenophase in *Texas* cultivar lasted for 19 days [16], which is very similar to the results of our research during the research from 2013, for *Texas* cultivar.

Our results are also similar to the results other researcher under the conditions of Herzegovina area (villages of *Buna* and *Hodbina*, near *Mostar*) from the aspect of the duration of the phenophase flowering of *Texas* cultivar. The researchers noted that the flowering phenophase lasted for 16 days in 1977 [22], which is similar to the results of our research. However, the same papers by these authors show that during the research in 1976, the flowering phenophase of *Texas* cultivar lasted for 34 days, which is different from the results of our research. In these studies, it is stated that the beginning of flowering phenophase of *Texas* cultivar in 1976 started on Feb 28th, the full flowering phenophase started on March 24th, and the end of flowering phenophase was on April 2nd. Also, the mentioned authors indicate that the beginning of flowering phenophase during the 1977 started on March 6th, the full bloom phenophase started on March 9th, and the

ending of the flowering phenophase was on March 22nd.

3.2. Fruit Ripening

The date of ripening is highly affected by the year, the ripening sequence of different cultivars is highly constant [23].

The Table 3 presents the harvest time, the ripening of the fruit of investigated almond cultivars during the research period. It is evident that the fruits ripened earlier in 2014 than in 2013. The fruits of *Texas* cultivar ripened later than other investigated cultivars whose fruits simultaneously ripened in both years of research. In the course of the research from 2013, *Texas* cultivar fruits ripened four days later compared to the 2014, while the fruits of remained three cultivars, in the research year 2013, ripened six days later than in 2014.

The harvest time of fruits for *Nonpareil* cultivar was done by Sept 6th in 1997 [16], is similar to the results of our research. Also, the same paper states that the fruits of *Texas* cultivars ripened on Sep, 6th, which does not match the results of our research. In the same research, in 1998, the authors state that the fruit ripening of *Nonpareil* cultivar was on Sept 4th, which is similar to the results of our research. However, on that date there was the ripening of *Texas* cultivar, which is different from the results of our research. Also, the same research shows that harvest of *Ferraduel* cultivar in 1998 was done on Sep 9th, which is different in relation to the results of our research.

The harvest of cultivars *Ferraduel* and *Genco* was done on Aug 29th [19], which is very similar to the results of our research.

Table 3. Harvest time investigated cultivars

	Texas	Nonpareil	Ferraduel	Genco
2013	20.09.bc	05.09.ab	05.09. ab	05.09.ab
2014	16.09.b	30.08.a	30.08. a	30.08. a

Table 4. Period required for the ripening fruits

	Texas	Nonpareil	Ferraduel	Genco
2013	175	160	161	161
2014	185	164	164	163
average	180	162	162,5	162

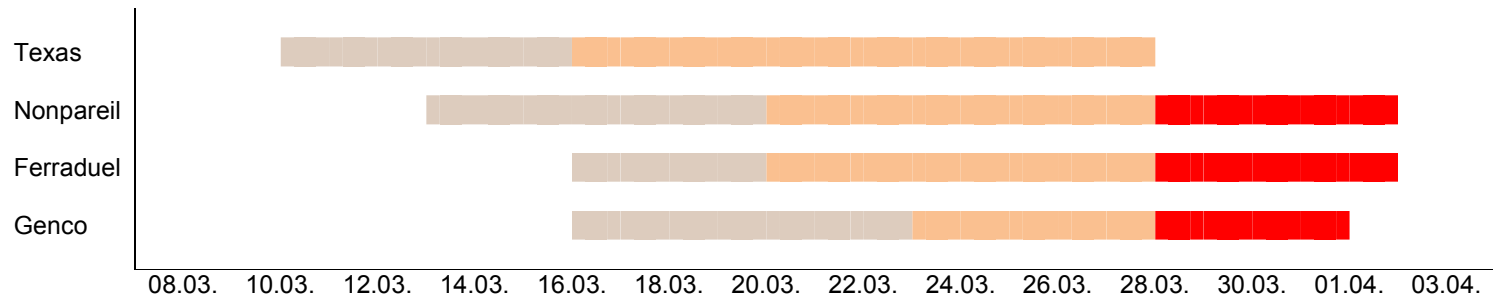


Fig. 1. Phenogram of flowering of almond in 2013

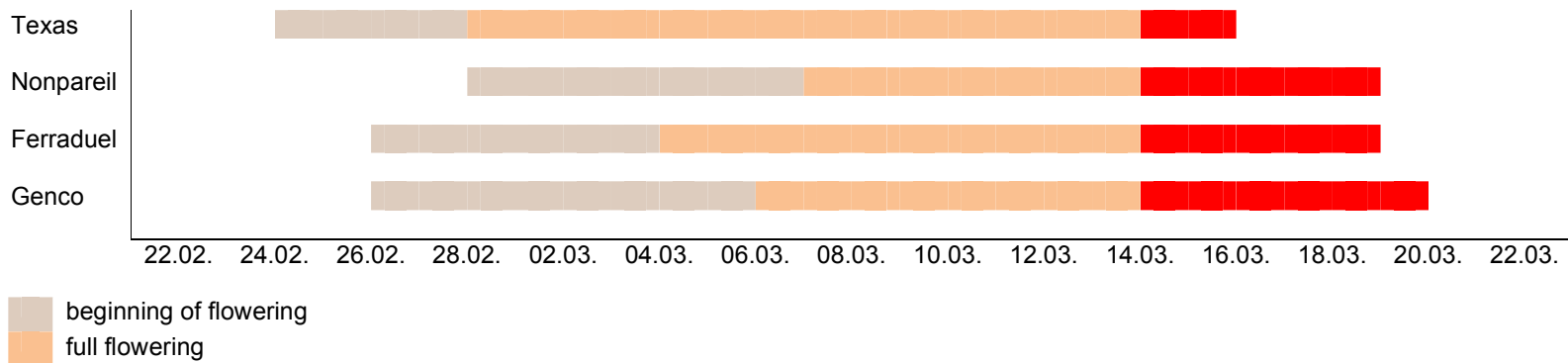


Fig. 2. Phenogram of flowering of almond in 2014

The Table 4 shows the period required for the ripening of the fruit, the average number of days for all three representative samples of the studied cultivars, the period from the end of the flowering to the harvest. It is evident that this period was a bit longer during the research in 2014. The *Texas* cultivar had the longest period needed for the ripening of the fruits in both years of research, compared to the other three studied cultivars, for which the period was fairly equal.

From the aspect of the time needed to ripening the fruits, the results of our research show that this period was longer for *Texas*, *Nonpareil* and *Ferraduel* cultivars than research results conducted by [16].

4. CONCLUSION

According to the research results of flowering dynamics, the following conclusions can be drawn:

- The earliest flowering in the examined period (2013-2014) was recorded in *Texas* cultivar on Feb 24th, and at the latest flowering was recorded for *Ferraduel* and *Genco* cultivars on March 16th. Studies have shown that, in the course of the research in 2013, beginning of flowering phenophase started with the difference of 1-6 days in all cultivars, the period of March 10th to March 16th, while in the course of 2014, the flowering phenophase started from Feb 24th to Feb 28th for all studied cultivars with the difference of 1-4 days. It was noticed that this phenophase was best overlapped among *Ferraduel* and *Genco* cultivars.
- Full flowering phenophase in the examined period (2013-2014) first occurred in *Texas* cultivar on Feb 28th, and at the latest was in *Genco* cultivar on March 23rd. The difference at the beginning of the full flowering phenophase, in 2013, was 1-7 days for all cultivars, and all cultivars started and ended the phenophase in the period from March 16th to March 23rd. Also, in the course from 2014, the difference in the beginning of full flowering phenophase was 1-7 days, and it lasted over a period from Feb 28th to March 7th. Full flowering phenophase in 2013 was best overlapped among *Ferraduel* and *Nonpareil* cultivars, and in the course from 2014, the best overlap was recorded among *Nonpareil* and *Genco* cultivars.
- During our research, the end of flowering first occurred in *Texas* cultivar on March 16th, and at latest was for *Nonpareil* and *Ferraduel* cultivars on April 2nd. Studies have shown that in the course of the research from 2013, the end of flowering phenophase occurred with a difference of 1-5 days (March 28th to April 2nd), in all studied cultivars, and in the course from 2014, there was the difference of 1-4 days (March 16th to March 20th). During these two years of research, phenophase had best overlapping results in *Ferraduel* and *Nonpareil* cultivars.
- From the aspect of the average duration of flowering phenophase, for all three representative samples of studied cultivars, we can conclude that the lowest duration occurred in *Genco* cultivar (16 days) during the research from 2013. Also, the flowering phenophase was the longest in *Genco* cultivar, but in the course from 2014 (22 days).
- If we consider the average duration of flowering phenophase for all representative samples of studied cultivars, and for both years of research, we can conclude that the flowering lasted from 18.6 to 19.6 days, which is fairly equal.
- The fruits of *Texas* cultivar, ripened later compared to the other three studied cultivars in the both years of research.
- The period required for the fruit ripening was the longest in *Texas* cultivar in both years of research, while this period was fairly equal for the other three studied cultivars in both years of research.

If we analyze the results of our research from the aspect of the flowering dynamics of the studied cultivars, we can conclude that most of flowering phenophases overlapped, which is very important for pollination, because almond is mostly a cross-pollinated fruit. Such overlapping of flowering phenophase gains significance because there are mutually good pollinators, combinations of *Texas-Nonpareil* and *Ferraduel-Texas* among the cultivars studied. According to the aspect of the beginning of the flowering phenophase the mild inferiority was demonstrated by the *Texas* cultivar, while for the three remaining studied cultivars the period of flowering phenophase started later, which is important when selecting cultivars to grow, because the cultivars that start the

flowering phenophase later are more preferred.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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