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Phenological and Biochemical Characteristics of Almond Cultivars in Arid Climate of Central Tunisia †

Samira Maatallah [1,2,*], Monia Guizani [1,2], Olfa Elloumi [3] and Mohamed Ghrab [3]

[1] Non-Conventional Water Valuation Research Laboratory (LR VENC), National Research Institute for Rural Engineering, Water, and Forestry (INRGREF), University of Carthage, Hedi EL Karray Street, El Menzah IV, Tunis 1004, Tunisia; guizanimonia2018@gmail.com

[2] Regional Center for Agricultural Research, Institution of Research and Higher Education Agriculture (IRESA), Sidi Bouzid 9100, Tunisia

[3] Olive Institute, University of Sfax, LR16IO01, LR16IO02, BP 1087, Sfax 3000, Tunisia; olfa.elloumi@io.usf.tn (O.E.); mghrab@gmail.com (M.G.)

* Correspondence: samiraham2003@yahoo.fr; Tel.: +216-97833374

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Abstract: Water scarcity is the main limiting factor for fruit trees in arid regions of Tunisia. In this area, almond is widespread, but severe conditions are a key issue for nuts production and kernel quality. In this study, phenological features and kernel quality of local and foreign almond cultivars irrigated with low water quality were investigated. Local cultivars presented an early flowering and seemed to be more appropriate to regional conditions and water salinity. All almond cultivars performed respectable kernel nutritional quality. In conclusion, local cultivars showed better adaptation with early bloom and higher fruit quality under warm conditions.

Keywords: *Prunus dulcis*; cultivar; water scarcity; salinity; bloom; phenol compounds; warm area

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1. Introduction

Almond (*Prunus dulcis* Mill) is well cultivated in arid and semi-arid regions of Tunisia. It occupies the second place after the olive tree with a cultivated area around 225,000 ha and providing 2.3% of the world production.

In warm area, almond production is highly linked to climatic conditions as precipitation and winter chill. Recent findings reported frequent warm winters with lack of winter chill [1]. These warm conditions caused yield losses and phenology disorders of nuts trees [2]. Moreover, low yield due to water scarcity has often been achieved.

New almond cultivars and rootstocks were planted [3] using various quality of irrigation water due to less water availability. Almonds are appreciated for their benefit to human health thanks to their antioxidant activity [4]. However, horticultural practices can have different effects on kernel quality. In this context, this work focuses on the phenological behavior and kernel quality of almond in Central Tunisia. Local and foreign cultivars irrigated with low water quality were investigated during a warmer year.

2. Materials and Methods

2.1. Experimental Site and Plant Materials

This study was carried out in an experimental almond orchard located 3 km south-west of Sidi Bouzid (central Tunisia) (35°01′21.9″ N, 9°26′31.3″ E; 160 m above sea level).This region is characterized by a typical Mediterranean climate.

Fourteen cultivars of mature almond trees including 8 local cultivars (Zahaf, Achak, Tlili2, Tlili6, Tlili9, Kf2, Bf1 and Am2) and 6 foreign cultivars (Mazzetto, Lauranne, Constanti, Tarraco, Marinada, Vairo) were selected. Trees were planted in 2012 at 5 m × 6 m spacing and drip-irrigated with low irrigation water quality (salinity: 2.7g L^{-1}; EC: 2.26 mS cm^{-1};

ion content: Na^+ 8.28 meq L^{-1}, K^+ 1.45 meq L^{-1}, Cl^- 15.33 meq L^{-1}) and trained according to standard horticultural management practices typical of the region.

2.2. Phenologivcal Surveys

The phenological stages of local and foreign almond cultivars were monitored based on the phenological growth stages defined by Baggiolini for stone fruits during 2021. The budburst, early and late flowering and the young fruit stages were recorded, and consequently the flowering period was determined.

2.3. Phenolic Compounds Determination

The total phenols and the *O*-diphenols contents were determined colorimetrically [5]. Total flavonoids were measured according to [6]. Flavonols were determined based on [7] using ethanol and HCl. Condensed tannins were evaluated according to [8]. The concentration of condensed tannins was expressed in mg catechin equivalent/100g of DW.

2.4. Statistical Analysis

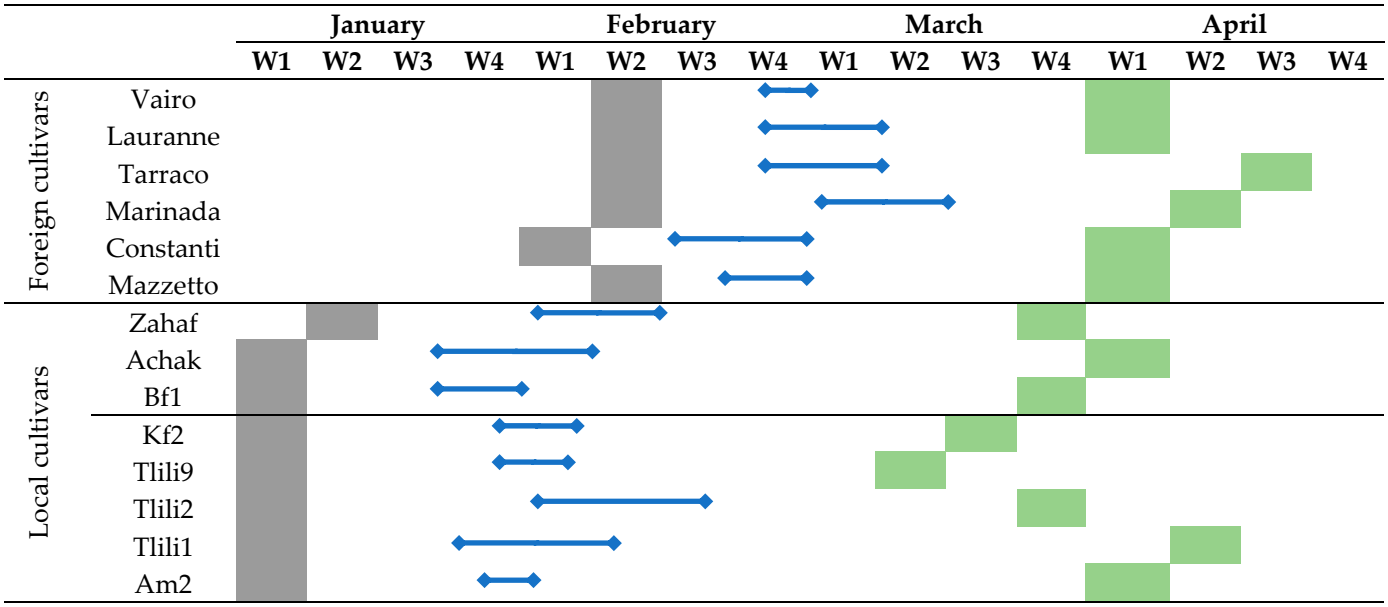
One-way ANOVA was applied on collected data using SPSS 17.0 for Windows (SPSS, Chicago, IL, USA). Means were compared using the Duncan test ($p < 0.05$).

3. Results

3.1. Phenological Features

Based on phenological observations, local cultivars are the earliest one (Table 1). Their bud-swelling stage occurred during the first two weeks of January against one month later for foreign cultivars (Table 1). The flowering period extended from the last week of January to the second week of February for local cultivars. Achak, Zahaf, Tlili1 and Tlili2 had an extended flowering period ranging between 14 and 20 days.

Table 1. Phenological stages of almond cultivars during 2021: Grey: bud swelling; Blue: flowering period; Green: Young fruit stage.



Considering the period in days between buds swelling and young fruit stages, results obtained showed that for local cultivars, this period was in the range of 64–91 days. Tlili9 and Tlili1 had the shortest and largest development cycle, respectively. For foreign cultivars, Terraco and Constanti had the largest development cycle of 70 days, while Vairo and Lauranne seemed to have the shortest one at about 51 days. Local cultivars are the

earliest and have the longest development cycle, whereas foreign cultivars presented late flowering and short development period.

3.2. Phenolic Compounds

The results showed that foreign cultivars had the richest kernels in phenols with total content varied from 1937 to 4281 mg/100 g DW for Tarraco and Constanti, respectively. For local cultivars, these contents were ranged between 316 and 4258 mg/100 g DW for Tlili1 and Bf1, respectively (Table 2). Concerning flavonoids, the local cultivars Achak and Zahaf showed the highest contents similarly to both foreign cultivars Mazzetto and Constanti (Table 2). The lowest flavonoids contents were obtained for Tlili2 and Tlili9. Flavonols concentrations varied between 37 and 860 mg/100 g DW in BF1 and Mazzetto, respectively. The highest content of *O*-diphenol was recorded in Mazzetto (1467 mg/100 g DW).The tannin contents varied significantly among cultivar and the highest values were recorded for Mazzetto and BF1cultivars.

Table 2. Variation of the phenolic compounds (mg/100g DW) among almond cultivars.

		Total Phenols	**Flavonoids**	**Flavonols**	***O*-Diphenols**	**Tannins**
Foreign cultivars	Vairo	1882.68 ± 60.62^{G}	125.28 ± 16.87^{FG}	647.16 ± 17.24^{C}	335.85 ± 19.61^{EF}	140 ± 0.01^{F}
	Lauranne	2048.65 ± 51.25^{E}	188.88 ± 13.07^{E}	652.61 ± 35.34^{C}	921.13 ± 10.93	310 ± 0.04^{DE}
	Tarraco	1937.39 ± 11.58	190.60 ± 11.52^{E}	375.24 ± 20.94^{D}	529.59 ± 34.42^{D}	290 ± 0.09^{DE}
	Marinada	1998.53 ± 72.40^{EF}	116.31 ± 26.82^{FG}	127.58 ± 40.29^{G}	471.94 ± 44.14^{D}	357 ± 0.02^{D}
	Constanti	4281.29 ± 71.26^{A}	473.86 ± 42.09^{C}	270.66 ± 7.39^{F}	1350.47 ± 39.58^{B}	270 ± 0.02^{E}
	Mazzetto	3411.45 ± 3.35^{B}	864.07 ± 84.29^{A}	860.87 ± 31.02^{A}	1467.97 ± 64.33^{A}	870 ± 0.04^{A}
Local cultivars	Zahaf	1700.85 ± 66.59^{H}	696.43 ± 7.47^{B}	722.55 ± 22.50^{B}	391.45 ± 47.31^{E}	320 ± 0.08^{DE}
	Achak	1992.27 ± 65.28^{EF}	517.28 ± 6.53^{C}	258.58 ± 39.38^{F}	490.92 ± 87.23^{D}	170 ± 0.08^{F}
	Bf1	4258.15 ± 92.61^{A}	205.43 ± 2.20^{E}	37.77 ± 1.46^{H}	155.07 ± 14.73^{G}	660 ± 0.02^{B}
	Kf2	2453.28 ± 35.79^{D}	292.28 ± 9.63^{D}	292.40 ± 0.69^{F}	274.22 ± 34.21^{F}	20 ± 0.01^{G}
	Tlili9	3309.19 ± 40.10^{C}	78.08 ± 1.41^{GH}	318.05 ± 31.30^{DE}	271.24 ± 20.04^{F}	470 ± 0.01^{C}
	Tlili2	365.51 ± 19.75^{IJ}	33.91 ± 1.41^{GH}	291.66 ± 15.02^{EF}	471.90 ± 21.62^{D}	80 ± 0.02^{FG}
	Tlili1	316.55 ± 18.34^{J}	162.52 ± 25.32^{EF}	100.92 ± 25.24^{F}	266.69 ± 4.65^{F}	110 ± 0.07^{F}
	Am2	416.07 ± 68.41^{I}	288.60 ± 6.77^{D}	335.63 ± 10.20^{CD}	133.08 ± 4.6^{G}	480 ± 0.02^{C}

Values are the means of three different almond samples (n = 3) ± standard deviation. The letters (A, B, C, D, E, F, G, H, I and J) indicate significant differences ($p < 0.05$) between the cultivars.

4. Discussion

Almond flowering and fruit set stages are a key process for yield as the occurrence of hazardous weather conditions during those critical stages has a major impact [9]. Flowering delay and extended duration occurred for both local and foreign cultivars as previously reported [10]. This could be a consequence of the exceptional warm winter with lack of chilling. A negative correlation was reported between flowering initiation and duration as well as winter chills [11]. Early flowering was considered as an interesting trait for almond growing in arid regions, where early blooming could also involve early ripening before the occurrence of extreme summer climatic conditions such as drought and higher temperatures. Local cultivars flowered earlier but had a delayed young fruit stage with the longest fruit development period. Late flowering seemed to be an inappropriate trait in warmer regions. Higher temperatures can affect stigma receptivity and reduce the effective pollination period [12].

Our results revealed rich almond kernels in total phenols content and confirm previous results showing total phenol content varied between 304 and 163715mg/100g [13]. Flavonoids contents recorded in local and foreign cultivars are comparable to previous findings [14]. The flavonoids contents varied with the geographical origin, the harvest period and cultivar [15]. As for results of flavonoids, local cultivars showed the highest values in flavonols with the foreign one Mazzetto, which revealed the highest content of

O-diphenol. These results integrated in part previous report [16]. The tannin contents varied significantly among cultivar and support results obtained by [17].

5. Conclusions

Almond cultivars irrigated with a low quality of water presented different phenological behavior and exhibited various kernel qualities. Local cultivars seemed to be well adapted to warm conditions and presented interesting fruit quality. Foreign cultivars had high kernel quality, while their phenological behavior could be affected by a lack of winter chill.

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