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Olive growing in arid area: further challenges from climate change

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Abstract

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In Tunisia, agriculture is vulnerable to climate change with harmful impacts subsequent warming and drying trends. In these regions, olive industry plays a key role at regional and national level. Therefore, the identification of adapted olive tree genotypes has become an urgent need to develop sustainable agriculture in arid lands. This study aimed to evaluate the impact of climatic variation on the olive growing systems in arid and sub-arid areas of Tunisia. The phenological behavior of Chemlali and Zalmati, main olive cultivars wide spreading in central and southern Tunisia, respectively, were considered to evaluate their capacity to adapt to contrasting climatic conditions. Over the 2005-2019 period, olive cultivars presented variable flowering dates related to local climatic conditions. Zalmati cultivar bloom in Zarzis seems to be earlier than Chemlali cultivar in Sfax region with average flowering dates of DOY-92 (April-3) and DOY-106 (April-17), respectively. A tendency for advancing the growing season was observed with warmer winters, which leads to disruption of pollination, high risk of insect attack, and consequently harmful effects on the production and product quality. This investigation serves as a basis for making recommendations taking into account the production areas as well as for addressing projected climate change.

1. INTRODUCTION

Olive tree (*Olea europaea* L.) is one of the oldest cultivated plants natives of the Mediterranean Basin. In Tunisia, olive growing covers 2 million hectares with 106 million trees performing the fourth largest olive oil production in the Mediterranean Basin (DGPA, 2022). Tunisian olive germplasm is characterized by a large genetic diversity with more than 200 cultivars (Trigui and Msallem, 2002). However, ninety percent of the national olive oil production derives from only two highly productive cultivars Chemlali in the central-southern region and Chetoui in the northern region (Taamalli et al., 2006).

Tunisia is considered to be one of countries most exposed to climate change, with more than two

thirds of its area under arid and semi-arid climates. These areas are characterized by severe summer conditions, including low rainfall, excessive heat and high daily irradiance. Olive culture is among the most important activities and in some cases the only crop able to grow in these local environmental conditions. Drought is assumed to be a natural and frequent hazard affecting agricultural production. During drought period, the decrease of olive production can reach 90%, as that observed during the drought episode of 1999–2002 (Gargouri et al., 2012) and which adversely affected farmer's income.

Climate affects all the physiological processes governing plant life. In fact, plant hormones react to variations in climate, leading to changes in both vegetative and reproductive phenological

phases, thus regulating the transition between the various developmental stages (Marletto et al., 1992). In recent years, important information regarding the reproductive development of the olive has come from analysis of phenological data that has allowed us to identify how plants adapt to their local climate and how they respond to climatic change (Orlandi et al., 2010). In Mediterranean region, the heat and chilling requirements of olive for flowering are still under debate. Few studies focused on the effect of climatic factors on flowering and fruiting of olive tree (Rallo and Martin, 1991; Galan et al., 2001; Bonofiglio et al., 2008). Recently, Elloumi et al. (2020) showed that winter temperatures appeared to be one of the principal factors in determining the olive cultivars' flowering time, mainly when quarterly and monthly mean temperatures were considered. In addition, a high yearly variation of chill accumulation (14-45 CP) was observed in central Tunisia, as a characteristic of a warm region, impacted significantly olive flowering. In this context, further studies are required to determine the plasticity of different olive cultivars to deal with environmental variability. The aim of this study was to determine the relationships between weather data (winter chill and rainfall) and the phenological behavior of two local olive cultivars 'Chemlali' and 'Zalmati' growing in central and southern Tunisia, respectively.

2. MATERIAL AND METHODS

2.1. Study area and plant material

This study focused on two main olive production areas Sfax and Zarzis of central and southern Tunisia, respectively. These production areas are characterized by a sub-arid and arid Mediterranean climate, respectively. The annual precipitation and reference evapotranspiration ETo were 200 and 1390 mm for Sfax and 180 mm and 1423 mm for Zarzis (Table 1). Precipitation is irregularly distributed over the growing season, and summer drought is associated with maximum air temperatures. An experimental olive orchard from each production region was surveyed from 2005 to 2019. Trees were planted at 17 m X 17 m apart. The soil in both orchards is characterized by loam-light-sandy texture. Two main local cultivars Chemlali and Zalmati, wide spreading in central and southern Tunisia, respectively were considered. Both orchards received all the usual horticultural practices for cultivation

under rain-fed conditions and without any fertilization.

Table1. Characteristics of production areas

	Sfax	Zarzis
Site	Central Tunisia	South Tunisia
Cultivar	Chemlali	Zalmati
Longitude	34° 56' N	33°36' N
Latitude	10°36' E	11°02' E
Altitude (m)	120	9
Precipitation	200 mm	180 mm

2.2. Phenological survey

During the experimental period, flowering dates, expressed in terms of Julian day (day of the year DOY), were determined. The beginning and the end of the flowering period were noted when 5% and 95% of inflorescences were opened, respectively.

2.3. Winter chill vs. flowering period

The relationship between flowering dates of olive cultivars and the chill accumulation were investigated. Winter chill was quantified, over the monitoring period (2005–2019), as Chill Portions (CP) using the Dynamic Model (Fishman et al., 1987a, 1987b). Temperature data were considered annually between October 1st and the date of budburst for each cultivar.

3. RESULTS AND DISCUSSION

3.1. Flowering trends of olive cultivars

Our long monitoring survey (2005-2019) highlighted that the phenological behavior of Chemlali and Zalmati olive cultivars, is closely related to cultivar and production area. In fact, important annual variations of flowering dates and duration were observed for both cultivars (Fig. 1).

Zalmati cultivar bloom in Zarzis seems to be earlier than Chemlali cultivar in Sfax region with average flowering dates of DOY-92 (April-3) and DOY-106 (April-17), respectively. The timing of flowering occurred when the heat needs were met, after a period of chill accumulation. The heat required for bloom depends on chill accumulation (Pope et al., 2014; Elloumi et al., 2020).

A tendency for advancing flowering period of these two olive cultivars was observed. This fact could be related to warm winter conditions that lead to lack of winter chill. In fact, frequent lack of winter chill occurred in both production areas over the monitoring period (Fig. 2). Exceptional warm winters were happened in 2007, 2016 and

2020. Benmoussa et al. (2020) identified Central and southern Tunisia regions as one of the most affected by future climate change.

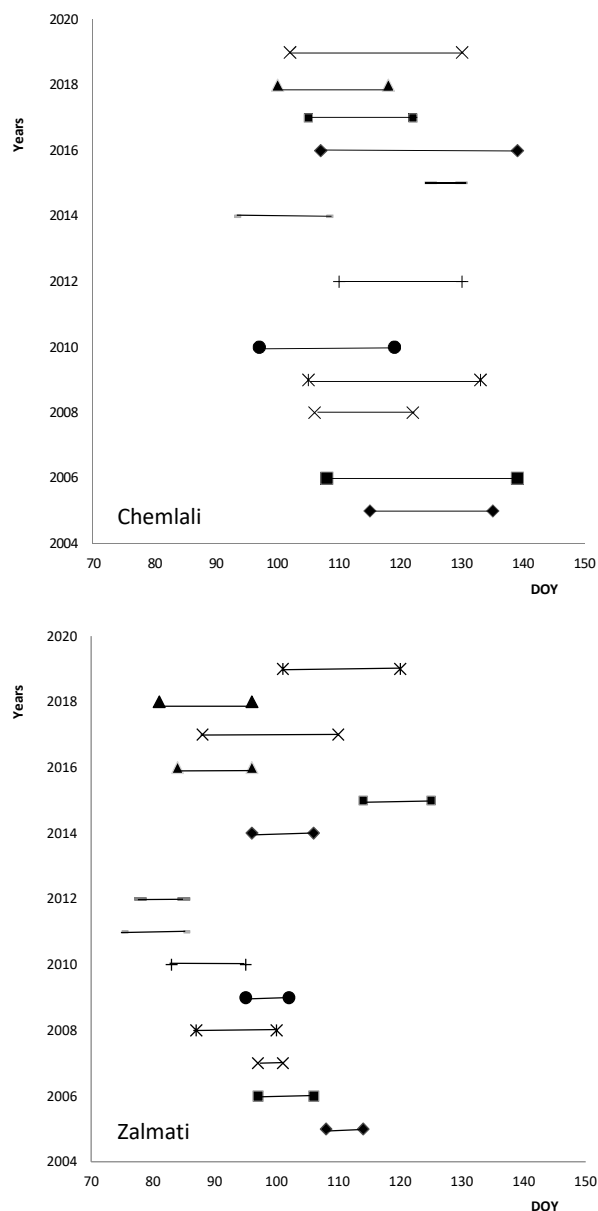


Fig. 1. Flowering diagram of Chemlali and Zalmati olive cultivars grown in Sfax and Zarzis regions respectively. Data non available for 2007, 2011 and 2013 in Sfax and for 2013 in Zarzis.

Olive flowering dates were significantly impacted by contrasting chill accumulation. Positive correlations between flowering dates and chill accumulation were observed in the two production areas (Fig. 3). Generally, an advancement of the flowering period was observed subsequent warm winter. Similarly, recent findings showed a tendency for earlier flowering of local and foreign olive cultivars, in central and southern Tunisia, that occurred as a

result of a lack of winter chill (Abichou and Msellem, 2015; Elloumi et al., 2020).

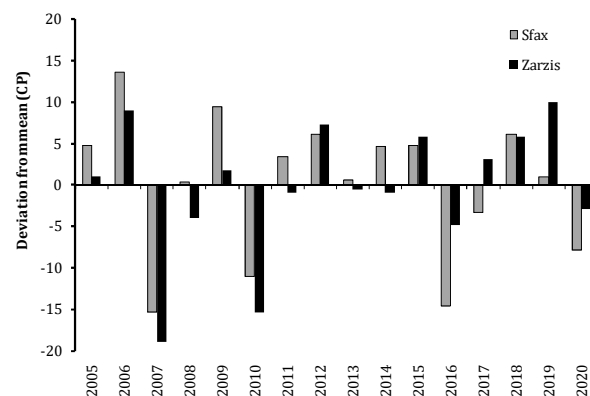


Fig 2. Chill portions (calculated using Dynamic model) deviation from mean calculated in the two main production areas for the experimental period.

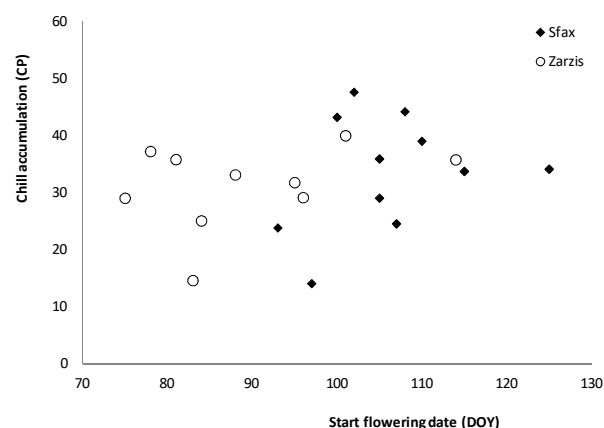


Fig. 3. Relationship between flowering date (day of the year, DOY) of Chemlali and Zalmati and chill accumulations (chill portions, CP).

For Chemlali cultivar in Sfax region, flowering dates were earlier by 4 to 13 days during low chill accumulation as observed in 2010 and 2014. The advancement of the flowering period was more marked for Zalmati cultivar in Zarzis region by 4 to 17 days (during 2008, 2010, 2011, 2012, 2016, 2017 and 2018). However, during the monitoring period a clear tendency for precocious flowering occurred during the first ten years (2005 -2014), and then high variability was observed in both productions' areas. Flowering advance leads to more advantageous exposition of the fruits to the attack of the olive-tree's fly (*Bactocera oleae*) (Abichou and Msellem, 2015) (Fig. 4). Consequently, increasing temperature in the near future in Mediterranean area as the main area of olive cultivation, may threaten olive production.

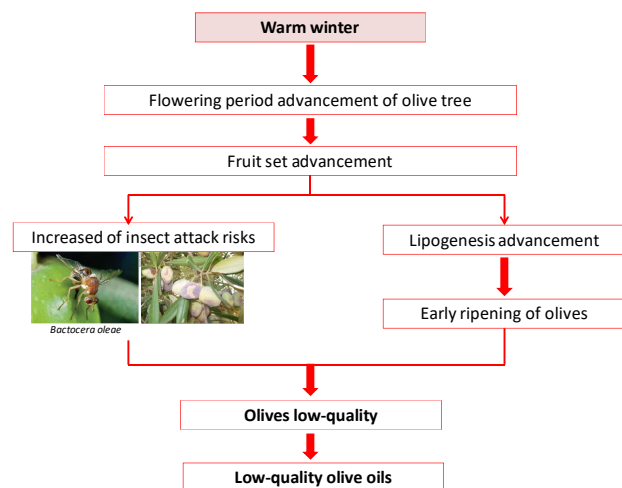


Fig. 4. Warm winter impacts on olive and olive oils productions.

3.2. Impacts of dry and warm winter

Sfax region was characterized by a long drought period between Octobre-2015 to August-2016. In fact, based on the Standardized Precipitation Index (SPI), the drought was more severe between December-2015 and March-2016 (Trabelsi et al., 2019). This period coincided with the dormant (from December to the beginning of February) and the budburst (February-March) stages of olive trees. In addition, in this year drought was joined by low chill accumulation (25 CP only). These harmful conditions impacted the phenological behavior of Chemlali olive cultivar. Our results showed that during 2016 the flowering period was the longest (33 days) compared to the other years and was characterized by two waves: from DOY-107 to DOY-132 and from DOY126 to DOY-139 (Table 2).

Table 2. Flowering periods (FP) of Chemlali and Zalmati in Sfax and Zarzis, respectively, during warm and dry year 2016

	Day of the year					
	84	96	107	126	132	139
Chemlali			First FP			
				Second FP		
Zalmati						

However, in Zarzis region and after the same winter chill accumulation (25 CP), the phenological behavior of Zalmati cultivar was different. Early (between DOY-84 and DOY-96)

and short flowering period (13 days) were observed (Table 2). The climatic conditions were quite different in Zarzis area with wet rainy season and warm winter (Fig. 5). These contrasting conditions seemed to affect differently the flowering behavior mainly by the combination of severe water stress and warm winter.

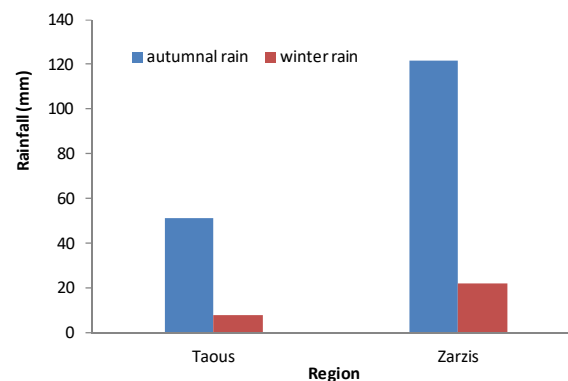


Fig. 5. Precipitation recorded during autumn and winter for Sfax and Zarzis regions.

4. CONCLUSION

Winter temperature and rainfall appeared to be the most important variables in determining phenological behavior of olive cultivars in arid and semi-arid region. Flowering advance subsequent warm winter can impact negatively the olive production of some cultivars. In addition, the combination of two (or more) climatic events can also jeopardize the production even with local cultivar. Selecting the most adaptative cultivar for these regions becomes more crucial.

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