EGYPTIAN JOURNAL OF BOTANY (EJBO)

Print ISSN: 0375-9237
Online ISSN: 2357-0350

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PUBLISHED BY
THE EGYPTIAN
BOTANICAL SOCIETY

Study of the floral biology of olive tree (Olea Europaea L.) of the *Moroccan Picholine* variety grown in the northern and central regions of Morocco

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Moroccan Picholine, a dominant variety in Morocco's olive sector, requires a detailed understanding of its growth patterns for optimal production. To this end, a phenological study was conducted at six stations during the 2023/2024 agricultural campaign: Tetouan, Chaouen, Ouazzane, Settat, Kelaa of Sraghna, and Marrakech. At each station, five trees were sampled, and 40 inflorescences (clusters) were collected per tree. Eight quantitative traits were analyzed: average cluster length (ACL), total number of flowers per cluster (TNF/C), flower abortion rate (AR), number of perfect flowers (PF), flowering rate (FR), fruit set rate (FSR), fructification rate (Fr), and flowering period (FP). The results revealed significant variability in the growth behavior of *Moroccan Picholine* across the different stations. Trees cultivated under irrigated conditions exhibited higher values for AR, PF, FSR, Fr, and flowering period compared to those grown under rain-fed conditions. For ACL, TNF/C, and FR, however, the stations displayed more similarity, likely influenced by genetic factors and environmental conditions, particularly climate. The olive-growing system also plays a crucial role in shaping the phenological behavior of this variety.

Keywords: Olive tree, *Moroccan Picholine*, regions, diversity, culture system, climate, Floral phenology

ARTICLE HISTORY
Submitted: October 16, 2024
Accepted: January 31, 2025

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DOI: 10.21608/ejbo.2025.328727.3037

EDITED BY: M. Abd El-Ghani

INTRODUCTION

The olive tree (*Olea europaea* L.) is a characteristic tree of the Mediterranean basin. It has long played a very important social and economic role in the lives of Mediterranean people. Olive oil is a major component of the Mediterranean food system, given its nutritional importance. Currently more than 750 million hectares are cultivated in olive trees, 95% of which are in the Mediterranean basin (Trabelsi, 2013). *Olea europaea* L. is a woody perennial species belonging to the family Oleaceae. It is one of the main plant species of the Moroccan agricultural system. Its cultivation has influenced the history and culture of our country and marked the Mediterranean civilizations that have succeeded throughout the centuries (Kartas *et al*., 2014).

Olive trees dominate the Moroccan landscape, covering a vast area of approximately 1 million hectares with an estimated 100 million trees. This constitutes a significant 65% of the nation's total tree area, highlighting the socio-economic importance of olive cultivation across various regions of Morocco. Cold-pressed olive oil, derived from these trees, is renowned for its exceptional nutritional, dietary, and medicinal properties, making it an asset to human health (Kartas *et al*., 2015). The Moroccan olive-growing heritage is characterized by very rich and diversified genetic resources, with many cultivars widespread for their economic values, but they haven't been exploited yet because their productivity and quality potential are still unknown, not to mention the threats that affect this heritage and its diversity because modernization and rural migration (Boulouha, 2006; 2010).

The study and identification of olive genetic resources play a key role in the improvement of national olive cultivation to meet the new economic requirements of a free and competitive market and a deep cultural significance as a symbol of traditional society and links with the land. The identification and selection of a rich array of olive cultivars with a higher oil yield is the first step in studying the behavior of these varieties in a given region. They are generally based on agronomic performance descriptors (Ouazzani & Adil, 2013) (Ouazzani, 2014).

The Moroccan olive sector consists of 96% of the *Moroccan Picholine* variety, a double-purpose variety (oil and table olive). The rest of the olive heritage consists of *Meslala*, *Dahbia*, *Picholine de longuedoc*, concentrated mainly in irrigated areas (Haouz, Tadla, Kelaa), *Ascolana dura*, *Manzanille*, *Frantoio*, *Picual*, *Gordale* (Walali *et al*., 2003). *Moroccan Picholine* is a renowned olive variety prized for its high-quality, long-lasting oil, rich in natural antioxidants. While its oleic acid yield is moderate at 18%, its overall quality compensates. Plantation densities vary widely, ranging from 80 to 400 trees per hectare, influenced by orchard age and geographic location. The average olive yield per tree is approximately 50 kg. To enhance yield and quality, INRA Morocco has developed two clones of *Moroccan Picholine*: *Haouzia* and *Menara*. These clones offer superior performance, with yields exceeding 60 kg/tree, reduced biennial bearing, and a higher oil content of up to 24% (Mouhtadi *et al*., 2014; Khaloui *et al*., 2007; Khadari & Mukhli, 2016). Environmental factors significantly impact the physiology of olive trees, thereby influencing fruit and oil quality. Geographical location, altitude, soil properties, climatic conditions, genetic variation, and agronomic practices such as fertilization and irrigation play crucial roles in shaping olive oil quality and composition (Sakar *et al*., 2022). Neglecting cultivation practices can lead to substantial losses, including increased sorting rates due to small size, damaged fruit, or insect infestation. These losses can reach up to 30% of the total harvest, significantly exceeding the 10% rate observed in other olive-growing countries (Khaloui & Nour, 2007).

Flowering is a first step in the study. To improve the olive trees, it is necessary to understand the process of flowering both for the cultivated olive trees and for the oleaster. The "perfect" flower of the olive tree is hermaphrodite. Self-pollination may occur, but olive cultivars are mainly self-incompatible. Three methods of abortion were identified in cultivated olive trees: male sterility (absence of stamens or no functional stamens), female abortion (absence of pistil) and self-incompatibility. Plants may have both male and female abortions, as well as other processes that failed during microsporogenesis in the form of pollen. Both abortion and megasporogenesis are subject to genetic control. However, flowering and fertilization are largely unknown in oleaster trees (Hannachi & Marzouk, 2012). The characteristics of floral biology, tolerance and/or sensitivity to various biotic (diseases, pests) and abiotic (climatic hazards) stresses also depend on genetic makeup. Flowering is one of the critical phases in the chronological course of the annual life cycle that determines production. For a cultivar, the number of flowers per inflorescence, their fertility, and the ability to grow by dominant or non-dominant self-pollination are varietal traits that affect the rate of fruiting (Kartas *et al*., 2015; Bradley & Griggs, 1963; COI, 1997).

The northern region occupies most of the West Rif Range. It is an area consisting of rugged terrain with steep slopes apart from peripheral areas oriented towards the interior of the country. This territory is in an area favorable to olive growing with a rainfall greater than 450 mm (Balaghi *et al*. 2013). The agro-ecosystems of this region are characterized by the presence of sylvopastoral systems and subsistence-oriented agricultural activity, creating specific landscape units. These characteristics include traditional agriculture geared towards food crops, the adoption of polyculture, a predominance of small plots of less than 0.5 hectares and small-scale land ownership with less than 5 hectares (Barbara *et al*., 2020). The town of Settat, located on the edge of the plateau and plain of Chaouia, is characterized by a rainfall of the order of 372 mm/year and an average annual temperature of 18 ° C (Osrirhi *et al*., 2007). In this region, calcium-magnetic soils occupy the largest area (31%), followed by less developed soils (23.4%). Soils with iron sesquioxide (7%) and vertisols (7%) occupy the lowest areas. Cereal crops such as wheat and barley are dominant, followed by legumes and then forage crops such as oat vetch, white lupin, etc. Arboriculture is essentially based on pomegranate, fig trees and vine (Osrirhi *et al*., 2007).

For the Marrakech Safi region in western central Morocco, the arid to semi-arid climate is influenced by three fundamental factors: Presaharian latitudes, high mountain altitudes and the influence of the Atlantic Ocean. The climate is characterized by considerable rainfall, thermal variability, with maximum temperatures of about 38 °C and minimum temperatures of about 4.9 °C (Choukrani *et al*., 2018). Precipitation exhibits significant spatial and temporal variability, with annual fluctuations. Estimates indicate levels of 190 mm in the plains and 650 mm in mountainous areas (Saidi *et al*., 2012). The region in question is distinguished by its predominant commitment to agriculture, representing 22% of the nationally utilized agricultural area, placing it at the top of the ranking. The farmland in the region accounts for about 48.6% of its total area, or 1,904,363 hectares. In terms of provincial distribution, Kelaa of Sraghna ranks first with 31%, followed by Safi with 30% and Chichaoua with 15%. Irrigated land covers about 301,277 hectares, representing 16% of the regional utilized agricultural area and 24% of the national total. The agricultural nature of the region is dominated by the agro-silvo-pastoral system, where cereal crops dominate with almost 78%, followed by fruit plantations (9.5%), forage crops (1.8%) and vegetable crops (1.2%) (Ministry of the Interior, Kingdom of Morocco, 2015).

The objective of this study is to highlight the influence of the cultivation system (irrigated or rainfed) and climatic factors such as precipitation, temperature, humidity and altitude on the floral biology of the *Moroccan Picholine* variety cultivated in the northern and central regions of Morocco.

MATERIALS AND METHODS

Plant material

The plant material used in this study is the *Moroccan Picholine* variety (*Olea europaea* L.)

Study stations

We selected six study stations, three stations in the northern region (Tetouan, Chefchauan and Ouazzane) and three stations in the central part of the country (Settat, Kelaa of Sraghna and Marrakech) during the 2023/2024 agricultural campaign. Climatic data from different study stations (Table 1) were compiled (Mokhtari *et al.* 2013) (Website 1) to show their variations by North-South gradient. Thus, the geographical coordinates make it possible to locate the study areas. The map of their location (figure 1) was made using the Arcgis software.

Sampling

This study focuses on two key olive-growing regions in Morocco: the northern region encompassing Tetouan, Chaouen, and Ouazzane, and the central region including Marrakech, Kelaa of Sraghna, and Settat. Within each region, five heavily flowering trees were selected at each station. For each tree, forty inflorescences were sampled from a mean height on the south side of the tree. Phenological phases F, F1, and G (Kartas *et al*., 2015; COI, 1997) were monitored weekly, starting from the initial flower opening to petal fall. This allowed for the determination of the duration of each phase:

- F: 10% of flowers bloomed (beginning of flowering)
- F1: 50% of flowers bloomed (full bloom)
- G: 50% of flowers lost petals (end of flowering)

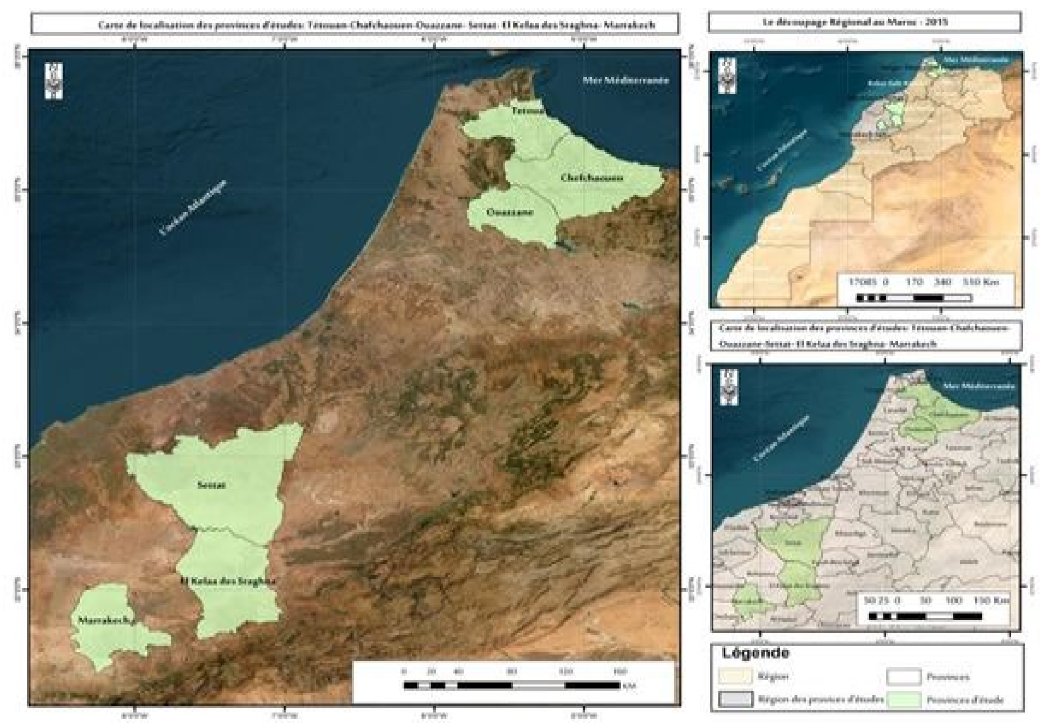

Figure 1. Location of studied stations green color (Ourselves, 2023)

Table 1. Geographical coordinates and climatic data of the stations studied (AT: average temperature, AP : average precipitation)

Study sites	Bioclimatic stage	Altitude (m)	Geographical coordinates	Irrigation system	AT 2023/2024 °C	AP 2023/2024 (mm)
Settat	Semi-arid	250	33.05720 N-7.62687 O	Irrigated	22,18	12,45
Kelaat Srghana	arid	430	32.17732 N-7.65792 O	Irrigated	23,54	17,50
Marrakech	Arid	466	31.62942 N-8.06191 O	Irrigated	24,36	17,72
Tetouan	Humid	107	35.49972 N-5.434661 O	Pluvial	19,72	14,27
Chefchaouan	Humid	283	35.23200 N-5.32437 O	Pluvial	19,81	22,54

Ouazzane	subhumide	300	34.82607 N-5.54991 O	Pluvial	23,18	23,45

After taking samples from each station, using a clamp and a graduated ruler, we took the measurements and determine the different parameters of the study: the average length of the clusters (ALC), total number of flowers per cluster (TNF/C), number of perfect flowers (PF), the flower abortion rate per cluster (AR), Flowering rate (FR), Fruit setting rate (FSR), Fruiting rate (Fr) and Flowering Period (FP). The parameters were studied during the full flowering period and in free pollination (Table 2).

Table 2. The parameters studied and their abbreviations

Parameters studied	Abbreviations
Average cluster length	ACL
Total number of flowers per cluster	TNF/C
Abortion rate of flowers per cluster	AR
Perfect flowers	PF
Flowering rate	FR
Fruit set rate	FSR
fructification rate	Fr
Flowering Period	FP

Statistical analysis

The obtained data underwent analysis of variance aimed at distinguishing between trees within the same station and between stations. The comparison of the means (Newman-Keuls test at 5%) was applied in cases where there is a significant difference. The quantitative variables were subjected to the principal component analysis and to the hierarchical grouping method, to demonstrate, according to the degree of similarity, the possible groupings of the stations studied. This similarity is measured by the Euclidean distance which also makes it possible to visualize the relations between the stations. The software used is GenStat (18th Edition SNI Product) for ACP, hierarchical grouping (CAH) and SAS (SAS® On Demand for Academics) for variance analysis.

RESULTS

Average cluster length (ACL)

For the average cluster length, results show that there is a small significant difference between trees at the same station. The coefficient of variation (cv) generally varied between 4.98% and 15.13%, suggesting a genotype effect at some stations such as Chaouan (cv=12.37%), Tetouan (cv=12.53%), and Ouazzane (cv=15.13%). However, in the other stations (Settat, Kelaa of Sraghna and Marrakech) the cv does not exceed 10.03%. This coefficient calculated between the stations remains low and does not exceed 11.75%. Tetouan and Chaouan have the highest cluster lengths of 3.26 cm and 2.91 cm, respectively. For the other stations (Settat, Ouazzane, Marrakech, Kelaa) the length is between 2.79 and 1.99 cm (Figure 2). From these results, four groups were distinguished (Figure 3):

- Group 1: Tetouan 3.26 cm
- Group 2: Chaouan 2.91 cm
- Group 3: Settat and Ouazzane (2.79 and 2.72 cm)
- Group 4: Marrakech and Kelaa (2.23 and 1.99 cm)

Total number of flowers per cluster (TNF/C)

The total number of flowers per cluster showed a significant difference at the Kelaa of Sraghna station (cv = 19.62%) and a small significant difference at the Chaouan station with a cv of 16.01%, indicating a genotype effect at both stations. For the rest of the stations (Marrakech, Ouazzane, Settat, and Tetouan), the cv of the trees at these stations varies between 1.92% and 9.80%, suggesting that there is no genotype effect. The coefficient calculated between the stations remains low and does not exceed 11%. Chaouan has the highest number of flowers per cluster, 15.70, followed by the rest of the stations whose number of flowers per cluster generally varies between 14.20 and 11.25 (Figure 4). Four groups were distinguished from the statistical analyses (Figure 5):

- Group 1: Chaouan 15.70
- Group 2: Settat 14.20
- Group 3: Tetouan (13.60), Marrakech (13.60) and Ouazzane (13.30)
- Group 4: Kelaa of sraghna 11.25

Abortion rate of flowers per cluster (AR)

The abortion rate of flowers per cluster varies significantly between stations and the coefficient of variation can be as high as 106.88%. Thus, a significant significant difference is noted between the trees of the same station. Chaouan, Kelaa, Marrakech, Ouazzane, Settat and Tetouan show coefficients of variation of 111.94%, 99.43%, 102.57%, 82.81%, 62.43%, 141.44% respectively. This presupposes the presence of the genotype effect in these stations. The highest abortion rate was observed at Chaouan station (11.07%), followed by Settat (8.47%), Kelaa (6.88%), Ouazzane (5.13%), Marrakech (4.80%) and Tetouan with the lowest abortion rate (1.78%). This was determined by counting imperfect or abnormal flowers. This results in the identification of three groups (Figures 6 and 7):

- Group 1: Chaouan 11.07%
- Group 2: Settat, Kelaa, Ouazzane and Marrakech (8.47%; 6,88% ; 5,13% ; 4,80%)
- Group 3: Tetouan 1.78%

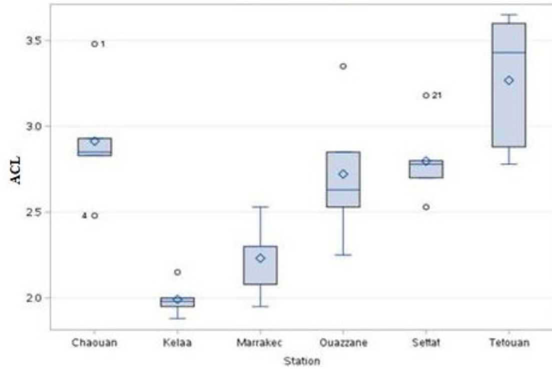

Figure 2. Difference between stations according to average cluster length (ACL)

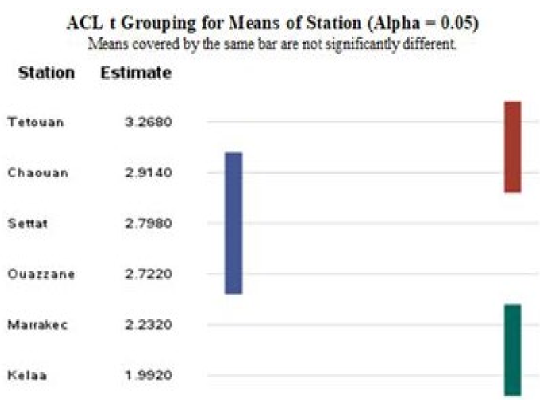

Figure 3. Groups of different stations by average cluster length (ACL)

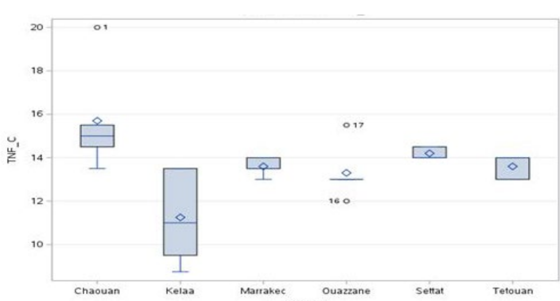

Figure 4. Distribution of stations by number of flowers per cluster (TNF/C)

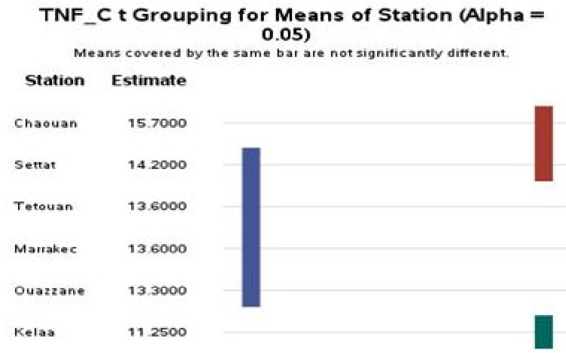

Figure 5. Station groups according to total number of flowers per cluster (TNF/C)

Number of perfect flowers per cluster (PF)

Analysis of perfect flower count revealed significant variability among trees within the same station, particularly at Chaouen, Kelaa, Ouazzane, and Tetouan, where coefficients of variation (cv) were 13.16%, 14.93%, 15.35%, and 16.55%, respectively. This suggests a potential genotypic influence at these locations. In contrast, Marrakech (cv = 9.45%) and Settat (cv = 6.66%) exhibited less variability, indicating a minimal genotypic effect. Overall, the coefficient of variation remained low, not exceeding 12.46% across all stations. Settat station recorded the highest number of perfect flowers per cluster (13), followed by Marrakech (12.35), Chaouen (11.60), Kelaa (10.25), Ouazzane (9.45), and Tetouan (9.25). Statistical analysis further delineated four distinct groups (Figures 8 and 9).

- Group 1: Settat and Marrakech (13; 12,35)
- Group 2: Chaouan 11.60
- Group 3: Kelaa 10.25
- Group 4: Ouazzane and Tétouan (9.45; 9,25)

Flowering rate (FR)

Based on the results obtained, we have a significant difference between the stations studied; the cv of the flowering rate is 29,87%. Thus, the trees of the same station are characterized by a very significant difference at Ouazzane level with a cv of 46.98% and a significant difference at Chaouan, Kelaa of Sraghna and Settat stations with a cv of 30.08%, 31.23% and 31.24% respectively. This presupposes the presence of the genotype effect in these stations. For the rest of the stations (Marrakech and Tetouan), they are characterized by a small significant difference with a cv that is not exceeding 15.47%. The highest flowering rate was generally observed at the rain stations of Tetouan (78.04%) and Ouazzane (54.89%), followed by Settat (47.66%), Marrakech (44.12%) and Kelaa of Sraghna (38.96%), which are irrigated stations and finally Chaouan (rain) with 38.19%. According to the statistical analyses, two major groups were distinguished (Figures 10 and 11):

- Group 1: Tetouan (78.04%)
- Group 2: Ouazzane (54.89%), Settat (47.66%), Marrakech (44.12%), Kelaa of Sraghna (38.96%) and Chaouan (38.19%)

Fruit set rate (FSR)

The fruit set rate varies significantly between the stations studied and the cv can range up to 46.66%. The same is true for the trees of the same station in which we observe a very significant difference; the cv varies between 28.44% and 108.64% apart from Tetouan and Ouazzane whose cv does not exceed 10.98% but which remains a small significant difference. This assumes the genotype effect in all stations regarding the fruit set rate. The highest setting rate was observed at the Kelaa of Sraghna station 13.45%, followed by Marrakech 8.32%, then by Chaouan, Ouazzane, Tetouan and Settat with a setting rate of 6.66%, 6.64%, 6.35% and 3.40%, respectively. Four groups were distinguished (Figures 12 and 13):

- Group 1: Kelaa of Sraghna 13.45%
- Group 2: Marrakech 8.32%
- Group 3: Chaouan (6.66%), Ouazzane (6.64%) and Tetouan (6.35%)
- Group 4: Settat 3.40%

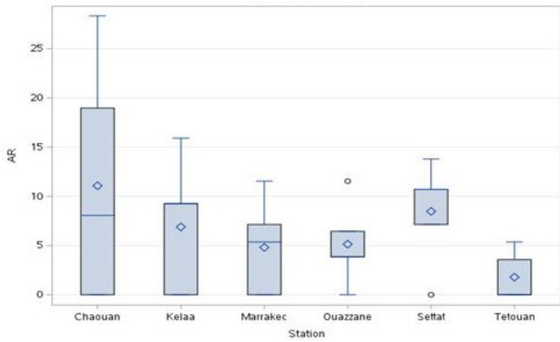

Figure 6. Distribution of different stations by abortion rate of flowers per cluster

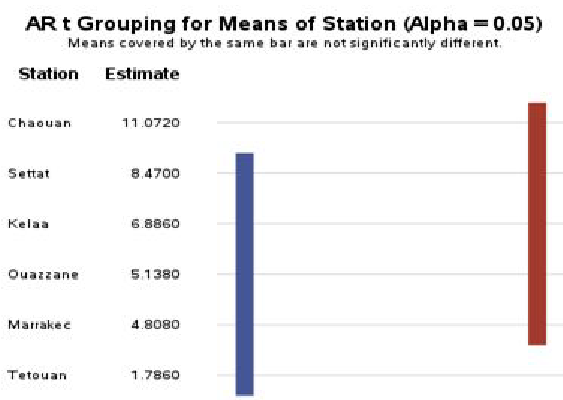

Figure 7. Groups of different stations for the abortion rate of flowers per cluster (AR)

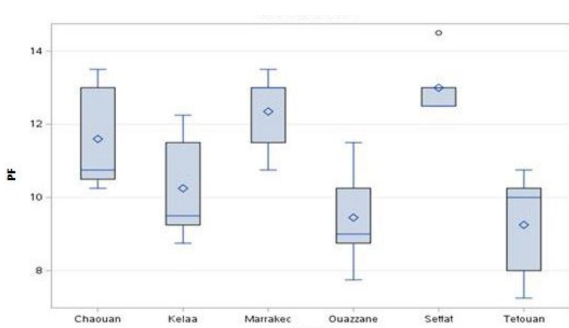

Figure 8. Distribution of different stations by number of perfect flowers per cluster (PF)

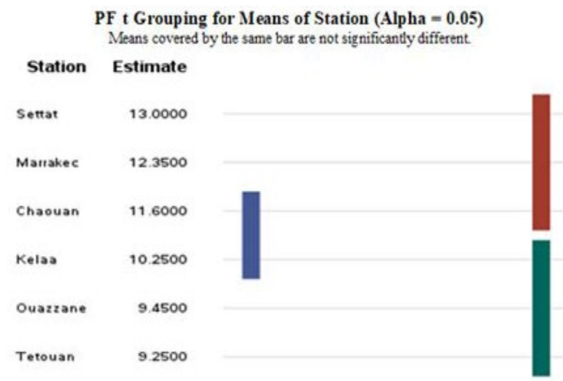

Figure 9. Station groups by perfect flowers (PF)

Fructification rate (Fr)

Because of the results obtained, it has been found that there is a very high significant difference between the stations with a coefficient of variation which exceeds 111%. Trees at the same station showed a very significant difference among all trees at the stations studied, with a typical cv ranging from 35.49% to 149.64%. This could indicate the genotype effect in these stations. The highest rate of fructification was recorded at the Kelaa of Sraghna station 2.18%, followed by Settat 1.82%, which are irrigated and then Tetouan rain stations (1.17%), Chaouan (1.02%) and Marrakech (irrigated) with a fructification rate of 0.43% and finally Ouazzane (rainy) with a fructification rate not exceeding 0.36%. According to the statistical analyses, three main groups were distinguished (Figures 14 and 15):

- Group 1: Kelaa of sraghna 2.18%
- Group 2: Settat (1.82%), Tetouan (1.17%), Chaouan (1.02%), Marrakech (0.43%)
- Group 3: Ouazzane 0.36%

Flowering period of different stations (FP)

The flowering period differs from one station to another. Indeed, the results show that this difference is estimated at 18 days concerning the beginning of flowering, 15 days for full flowering and 20 days for the end of flowering. Flowering begins first at the Kelaa level of the Sraghna (arid climate, irrigated growing system) followed by Marrakech (arid climate, irrigated growing system) then by Tetouan (wet climate, rainy growing system), Ouazzane (sub-humid climate, rainy growing system) and finally Chaouan (wet climate, rainy growing system) and Settat (semi-arid climate, irrigated growing system).

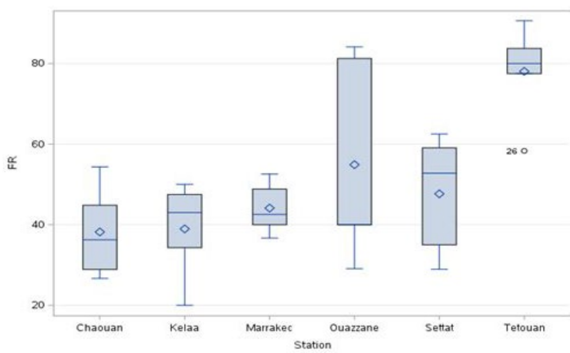

Figure 10. Distribution of different stations by flowering rate (FR)

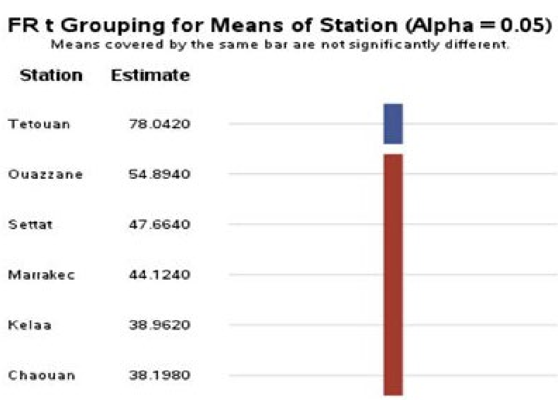

Figure 11. Flowering rate of each station (FR)

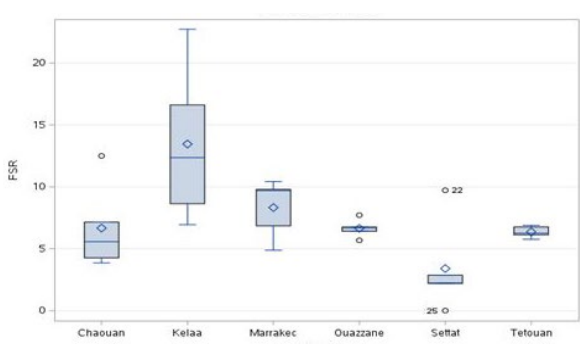

Figure 12. Distribution of different stations by fruit setting rat (FSR)

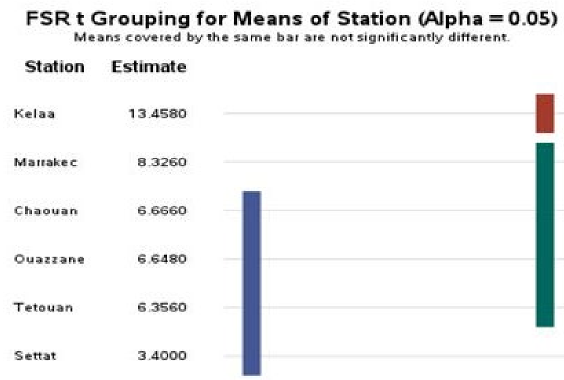

Figure 13. Station groups by fruit setting rat (FSR)

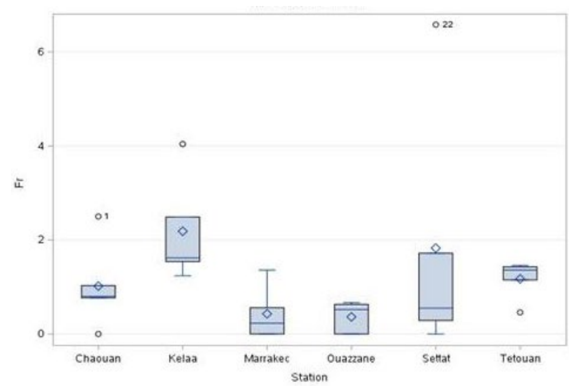

Figure 14. Distribution of stations for fructification rate (Fr)

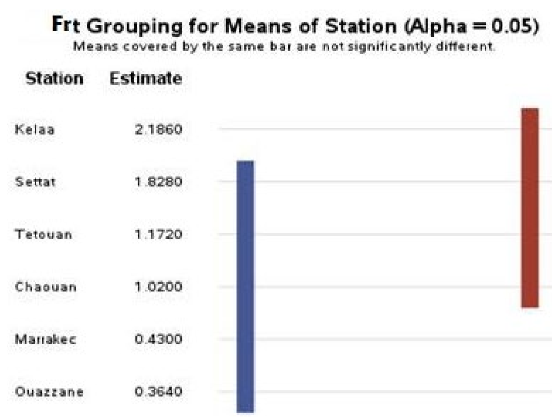

Figure 15. Different groups of stations for fructification rate (Fr)

The longest flowering period (beginning to end of flowering) was recorded at Settat station (19 days) followed by Kelaa of sraghna (17 days) followed by Chaouan (15 days) followed by Marrakech (14 days) and Ouazzane (14 days) followed by Tetouan (13 days). From these results it is possible to classify the stations according to the following phenological stages:

- Early flowering stations: Marrakech and Kelaa of Sraghna
- Seasonal flowering stations: Ouazzane and Tetouan
- Late flowering stations: Chaouan and Settat (Table 3).

The results obtained reveal significant differences in the floral biology parameters of the *Moroccan Picholine* variety across all the studied stations (Table 4). The letters “a”, “ab”, “b” and “c” represent different groups in our statistical analysis. Each group comprises one or more stations. Groups sharing the same letters do not show significant differences, whereas those with different letters demonstrate significant variations between them.

Structuring of the polymorphism and differentiation of stations

The discriminant factor analysis made it possible to verify the structuring highlighted by the hierarchical analysis. The factorial design (1.2) presents a good structuring of the variability up to nearly 55.07% of the variance. The discriminant factorial axis 1 encompasses 31.07% of the variance. This axis is defined by the variables of abortion rate (AR) and the number of perfect flowers (PF), with Settat and Chaouan characterized by large values regarding these parameters (AR and PF), Tetouan and Ouazzane with low values and Kelaa of Sraghna and Marrakech with intermediate values. The discriminant factorial axis 2 represents 23.99%. This axis is defined by the average length of the clusters (ACL), the total number of flowers (TNF/C), flowering rate (FR), fruit setting rate (FSR) and the fruiting rate (Fr). The station of Chaouan, Tetouan, Ouazzane and Settat present values higher than those observed at Marrakech and Kelaa of Sraghna regarding ACL, TFN/C and FR. For the FSR and Fr parameters Kelaa of Sraghna and Marrakech have higher values compared to the other stations (figure 16).

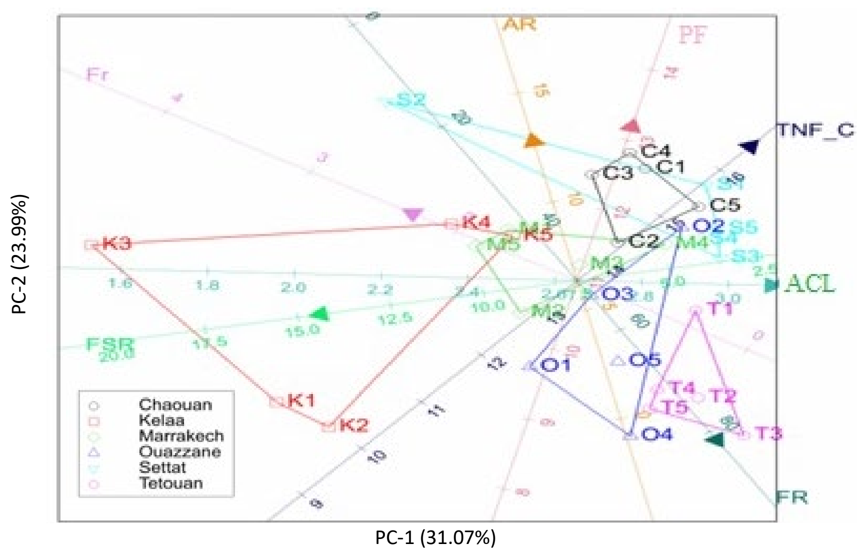

Figure 16. Discriminant factor analysis of different stations. T: Tetouan station, C: Chaouan station, O: Ouazzane station, S: Settat station, K: Kelaa of Sraghna station, M: Marrakech station.

Table 3. Flowering period of different stations (Stations : Tetouan, Chaouan, Ouazzane, Settat, Kelaa, Marrakech)

	Tetouan	Chaouan	Ouazzane	Settat	Kelaa	Marrakech
Start of flowering	09.april.2023	16.april.2023	09.april.2023	16.april.2023	29.march.2023	03.april.2023
Full flowering	16.april.2023	22.april.2023	16.april.2023	23.april.2023	08.april.2023	11.april.2023
End of flowering	22.april.2023	01.may.2023	23.april.2023	5.may.2023	15.april.2023	17.april.2023

Table 4. Variation of the studied parameters by station

	ACL	TNF/C	AR	PF	FR	FSR	Fr
Tetouan	3.26 a	13.60 b	1.78 b	9,25 c	78,04 a	6.35 ab	1.17 ab
Chaouan	2.91 ab	15,70 a	11.07 a	11,60 ab	38,19 b	6.66 ab	1.02 ab
Ouazzane	2.72 b	13.30 b	5,13 ab	9.45 c	54,89 b	6.64 ab	0.36 b
Settat	2.79 b	14,20 ab	8,47 ab	13 a	47,66 b	3.40 b	1.82 ab
Kelaa Sraghna	1.99 c	11,25 c	6,88 ab	10,25 bc	38,96 b	13.45 a	2.18 a
Marrakech	2.23 c	13.60 b	4.80 ab	13.35 a	44,12 b	8,32 b	0.43 b

DISCUSSION

The average cluster length (ACL) is a critical factor influencing olive tree productivity. In this study, ACL values ranged from 1.99 cm in Kelaa of Sraghna to 3.26 cm in Tetouan. These findings align with previous research. (Seifi *et al*.,2008) reported ACL values between 3 and 8 cm for *Manzanillo*, *Mission*, and *Frantoio* cultivars in southern Australia. Our results from Tetouan are particularly comparable, with a maximum ACL of 3.26 cm. (Iguer, 2016) investigated ACL in the Tizi-Ouzou region of Algeria, finding values between 3.116 and 0.373 cm for *Sevillan*, 3.862 and 0.441 cm for *Limli*, and 3.372 cm for Oleastre under rain-fed conditions. These results are consistent with our findings across both irrigated and rain-fed stations. (Mekkaoui, 1983) reported an ACL of 2.98 cm for *Moroccan Picholine* grown under irrigation in the Meknes region. This aligns with our results from Chaouan (2.91 cm), Ouazzane (2.72 cm), Settat (2.79 cm), and Marrakech (2.23 cm). (Khlil *et al*., 2016) found an ACL of 2 cm for *Moroccan Picholine* in irrigated areas of the Beni Tajjit region, like our results from Kelaa of Sraghna and Marrakech. The shape and number of flowers per inflorescence are influenced by genetic factors, tree physiological status, and environmental conditions (Trabelsi, 2013; Breton, 2013).

The total number of flowers per cluster (TNF/C) depends mainly on the environmental, climatic and genetic conditions of the tree. Our study showed that Chaouan has the highest number of flowers per cluster (15.70) followed by Settat (14.20), Tetouan and Marrakech (13.60), Ouazzane (13.30) and Kelaa of Sraghna (11.25). According to (Amar, 2017), in an irrigated growing system in the Sfax region of Tunisia, the *Picholine Languedoc* variety has a high number of flowers per cluster (21) compared to the *Meski* variety, which does not exceed 14 flowers per cluster. The results of the *Meski* variety are like those obtained at Settat, Marrakech, Ouazzane and Tetouan stations, where this number does not exceed 14.20. (Hannachi & Marzouk, 2012) found that in the *Oleaster* variety grown in rainfall conditions in two Tunisian parks Ichkeul and Belvedere, the number of flowers per inflorescence generally varies between 15 and 26. These are important results compared to the *Chemlali* variety. These results are close to our results found at the Chaouan station. In the Sfax region of Tunisia (Trabelsi, 2013) in a rainfall system, the average number of flowers per inflorescence does not exceed 10, while it may exceed 16 in the case of partial root drying (DPR) and complete irrigation (PE) treatments. (Kartas *et al*., 2015) found that the number of flowers per inflorescence recorded over several years of experimentation ranged from 11.34 to 24.69 for the local varieties and types considered.

Dahbia and *Moroccan Picholine* from the Ouazzane region of Morocco, grown under rainfall conditions, had the lowest values for this parameter, 11,034 and 13.87, respectively. The above-mentioned results are not entirely consistent with those found at all the stations we studied, which show several flowers per cluster between 11.25 and 15.70. Rather, our results fall within the lower limit of the mean range found in other studies (Hannachi & Marzouk, 2012) and can be considered consistent with the results of (Trabelsi, 2013). However, studies have linked the number of flowers per inflorescence to the genotype and position of the inflorescence. According to these same studies, this number varies between 10 and 30 (Breton, 2013). Moreover, environmental factors near flowering are important determinants in floral morphology, including the number of flowers per inflorescence and the rate of staminate flowers (Cruz *et al*., 2011). Variation in the number of flowers per cluster for the *Moroccan Picholine* variety could be explained by genotype, variety, tree physiological status, or climatic conditions (Kartas *et al*., 2015). This shows that this parameter (TNF/C) is influenced by the culture system (irrigated or rainy) and climatic conditions (precipitation) confirming our results which show a number of flowers per cluster close to each other in all irrigated stations studied (Marrakech, Settat and Kelaa of Sraghna) with flower numbers per cluster ranging from 11.25 to 14.20 and in all rain stations (Ouazzane, Chaouan and Tetouan) which experienced heavy rainfall during the flowering period and whose number of flowers per cluster varies between 13.30 and 15.70.

The flower abortion rate (AR) is a crucial factor influencing olive tree productivity. (Amar, 2017) reported (AR) values between 18.32% and 12.05% for *Meski* and *Picholine Languedoc* varieties in an irrigated plot in Sfax, Tunisia. (Hannachi & Marzouk, 2012) found pollen abortion rates ranging from 5.66% to 35.90% for Ichkeul Park Oleaster and 10.22% to 38.83% for Belvedere Oleaster in Tunisia. Female flower abortion rates varied between 1.49% and 30.75% at Ichkeul and 12.56% and 88.12% at Belvedere Park. (Trabelsi, 2013) observed a 10.56% (AR) in rain-fed plots in Sfax, Tunisia, and less than 2% in trees subjected to partial root drying and full irrigation in 2015. In 2017, the (AR) increased to 15.06% in unirrigated trees. These findings suggest that drought increases AR, while saltwater irrigation decreases it. (Kartas *et al*., 2015) reported (AR) values between 9.90% and 81.53% for various local varieties and types (*Moroccan Picholine, Manzanilla, Picholine Languedoc, Bouchouk Rkik, Bouchouika, Bakhboukh*) in a rain-fed system in the Ouazzane region of Morocco. These results are like our findings at Chaouan (11.07%) and Settat (8.47%). (Mekkaoui, 1983) noted a higher (AR) in *Moroccan Picholine* compared to *Dahbia*. Several factors influence (AR/C), including genetic factors (variety), environmental conditions (light, temperature, precipitation, soil nutrients), foliar diseases, water stress, and cultural practices (Riera, 1941; Kartas *et al*., 2015; Belguerri, 2016). High temperatures above 30°C can inhibit pollen tube growth and promote ovarian abortion (Romano *et al*., 2008).

It is hypothesized that nutritional resources may limit the development of all flowers, leading to the abortion of some pistils and the prioritization of pollen production to ensure sufficient hermaphrodite flowers for fruit set (Breton, 2013). Moreover, perfect flowers (PF) which are pistilled and fertile with normal development in their floral parts can receive in their stigmas a viable, compatible and fertilizing auto or allo pollen. (Ghrissi et al., 2001), found that the *Manzanille*, *Moroccan Picholine* and *Languedoc* varieties had a perfect number of flowers of 7.5, respectively 15.5 and 20. (Boulouha, 1984), found that the number of perfect flowers in *Moroccan Picholine* ranges from 5.6% to 41%. (Kartas *et al*., 2015) found that this number ranged from 4.85 to 12.99 for all the local varieties and types studied (*Moroccan Picholine, Manzanille, Picholine Languedoc, Bouchouk Rkik, Bouchouika, Bakhboukh beldi*) in rainfall conditions in the Ouazzane Morocco region. These results are consistent with our results across the stations studied, which show values between 9.25 and 13.35. It appears that this parameter is influenced by the physiological state, the nutritional state of the tree and the climatic conditions (rainfall, temperature, soil moisture) encountered during the flowering period during which the initiation, differentiation and complete development of the flowers occur during the year under consideration. According to (Hartmann & Panetsos, 1962), perfect flowers are most often located in the apical part of the tree. For (Shatat & Sawwan, 1986), the apical and mid-flower shoot panicles contain more perfect flowers than the basal shoot panicles. (Esna-ashari & Gholami, 1989) and (COI, 1997), found that the number of perfect flowers in the olive tree varies considerably not only according to variety and climatic conditions, but also in the same variety over the years according to the level of fruiting of the previous year.

Flowering in the olive tree represents a critical physiological phase in determining yield; abundance, fertility, pollen quality and fertilization can greatly influence the profitability of olive growing (Nait taheen *et al*., 1995). (Amar, 2017), found that the *Meski* variety showed higher flowering rate performance in 2010 and 2011 with values ranging from 40 to 50%. However, *Picholine Languedoc* showed a flowering rate of 43.32% in 2009. (Trabelsi, 2013), found that the flowering rate varies significantly with water treatments. The olive tree in irrigated cultivation has a high flowering rate compared to that in rainfed cultivation. Partial root drying treatment had the highest flowering rate (54.89%) and the rainfall had the lowest flowering rate (37.5%) for the *Chemlali* variety in Tunisia. (Kartas *et al*., 2015), found that the flowering rate varies between 50 and 71% in a rain-fed system in the Ouazzane, Morocco region. The *Moroccan Picholine*, *Dhabia* and *Picholine languedoc* varieties show flowering rates of 52 to 83.4% respectively; 56.45 to 84.9% and 54 to 81.7% (Filali, 1978) (Moundi, 1974). (Boulouha, 1984), found that the flowering rate in *Moroccan Picholine*, grown under irrigated conditions in the Meknes, Morocco region, varies between 51 and 56%. These results are consistent with our results, which show flowering rates ranging from 38.19% to 78.04% across the stations studied. Several studies show the influence of this parameter by a set of factors such as the genetic stock of the variety, sudden changes in temperature, not forgetting intrinsic factors such as the physiological state of the tree, alternating rolling and extrinsic such as precipitation, size, moisture, wind, and other endogenous trophic and hormonal factors that strongly influence initiation, floral differentiation, and the development of inflorescences leading to the production of flowers (Arfaoui *et al*., 2021; Abu-Saaid *et al*., 2022; Cruz *et al*., 2011; Romano, 2008; Belguerri, 2016).

Fruit set, the transformation of fertilized flowers into fruit, is a critical determinant of olive tree productivity. While abundant flowering, flower number, and inflorescence density are important, they do not guarantee high fruit set rates (Amar, 2017). In normal flowering years, a final fruit set of 1-2% can lead to significant commercial olive yields (Hannachi *et al*., 2012). (El Oualkadi *et al*., 2018) reported fruit set rates ranging from 1% to 99% for self-pollination and 42% to 100% for free pollination under irrigated conditions in Marrakech. (Mekkaoui, 1983) found fruit set rates of 6.66% for self-pollination, 7.17% for free pollination, and 13.61% for cross-pollination in Moroccan Picholine. (Kartas *et al*., 2015) reported fruit set rates ranging from 0.56% for *Moroccan Picholine* to 6.863% for oleaster in self-fertilization and free pollination, and from 0.9% for *Moroccan Picholine* to 4.49% for rain-fed oleaster in the Ouazzane region. (Trabelsi, 2013) found a fruit set rate of 7.54% for the *Chemlali* variety with partial root drying and no more than 2.8% under rain-fed conditions in Sfax, Tunisia. Our results align with these findings, with fruit set rates ranging from 3.40% to 13.45% in irrigated stations and no more than 6.66% in rain-fed stations. Adequate water and nitrogen supply during the spring growth period can enhance fruit set, final fruit load, olive tree productivity, and oil quality (Erel *et al*., 2008; Erel *et al*., 2013a). Conversely, water stress can negatively impact fruit set by increasing the proportion of staminate flowers. Stigma receptivity in olive trees is challenging to identify, and fruit set can result from both self-pollination and cross-pollination in controlled conditions (Breton, 2013).

For a given variety, (Bradley & Griggs, 1963), specify that the number of flowers per inflorescence, fertility, and ability to be pollinated by dominant or non-dominant self-pollination are varietal characteristics that may affect the rate of Fructification (Fr). (Kartas *et al*., 2015), found that the *Moroccan Picholine* variety has a fructification rate that ranges from 0.56 to 2.85% for self-pollination and from 0.9 to 2.94% for free pollination, unlike the *Dahbia* variety, which is characterized by a fruiting rate of 1.37% in self-pollination and 1.73% in free pollination in a rain-fed system. (Elouakadi *et al*., 2018), found that the fructification rate is between 0 and 92% in self-pollination and between 5 and 98% in free pollination. These results show an increase in the rate of fructification in mode of free pollination compared with self-pollination. In the case of self-pollination, the varieties *Koroneiki*, *Alameno* de Marchene and *Sevillano* de Jumilla have a high fructification rate of 92%, 44% and 40% respectively in irrigated Marrakech station in in Morocco. For (Boulouha, 1984), the rate of fructification varies according to the type of pollination, it may be up to 39% in free pollination and limited to 3.3% in self-pollination. It also varies according to the type of branches. The main branches have a fruiting rate of 3.2%, the lateral branches 2.3% and the vertical branches 4.4%. (Mekkaoui, 1983), found that the *Moroccan Picholine* in the Meknes region under irrigated conditions had a fruiting rate of 8.31% compared with the *Dahbia* variety, which did not exceed 2.97% under the same growing conditions. Our free pollination results are consistent with the above-mentioned results. The fructification rates are higher at the irrigated stations (Settat, Kelaa of Sraghna and Marrakech), where they vary between 0.43 and 2.18%; while at the rain stations (Ouazzane, Chaouan and Tetouan) these rates range between 0.36 and 1.17%. The rate of fruiting is a determining factor in the productivity of olives and is influenced by several factors such as the type of cultivar, temperature, precipitation, solar energy (El oualkadi *et al*., 2018; Trigui 1987; Baldy *et al*., 1981).

Flowering is the phenological stage which, after winter rests, announces the beginning of reproductive activity. The olive tree blooms between March and May; it covers thousands of small clusters of white-greenish flowers with a light fragrance and the flowering period is short. According to (Mekkaoui, 1983), the opening of the first flowers was observed at the end of March for the *Dahbia* variety and during the first week of April, this variety is already in full bloom, while *Moroccan Picholine* is not even at the beginning of flowering. The end of flowering for *Dahbia* was observed during the last decade of April, when *Moroccan Picholine* was in full bloom. So *Dahbia* has an early flowering compared to that of *Moroccan Picholine*. (Elloumi *et al*., 2022), suggest that the later flowering period is between the 5th to the 12th of May. It has been registered for the varieties *Chemlali* Sfax, *Koroneiki* and *Arbiquina* in the Sfax region of Tunisia. In this region the flowering was the shortest for all the varieties studied and lasted only 5 to 7 days compared to an average of 20 to 24 days recorded over a ten-year period in the same production area. (Kartas *et al*., 2015), found that the average flowering time is 14 days, with three types of varieties: early varieties (*Boucaik Rkik* and *Bakhboukh Beldi*), seasonal varieties (*Moroccan Picholine*, *Dahbia*) and late varieties (*Gordal*, *Ascolana*, *cucco*). The difference in the start of flowering between the three categories is estimated to be 7 days. *Moroccan Picholine* type flowers grown in the Mesmouda region, open one day before the *Moroccan Picholine* types of Mjaara. For the flowering of the varieties *Picual* in Mjaara and *Ascolana Terana* planted in Sidi Bousber, they started 2 to 3 days before the flowering of the same varieties grown in Ouazzane. This reflects the influence of soil climatic conditions associated with different local production areas. (Romano, 2014), found that flowering took place at all stations at the same time, usually between May 2nd and June 8th in southern Italy. The flowering delay was 23 days (flowering in Palermo on April 25th and May 18th in Avellino). (Bonofiglio *et al*., 2008), found that flowering was first observed in the Sicilian region of central Italy in late April, while Trapani olive trees began flowering in early May. These results are close to ours in all the stations studied; flowering begins in the irrigated stations (Kelaa and Marrakech) before the rain stations (Tetouan, Chaouan and Ouazzane), with a flowering period ranging from 13 days to 19 days for all the stations studied. Settat has a flowering star like the rain stations. This parameter is primarily dependent on environmental factors such as photoperiod, temperature, and water stress (Dahl *et al*., 2013). The olive tree is characterized by spring flowering and its reproductive cycle is regulated by bioclimatic requirements prevailing from the summer of the previous year until the appearance of flowering buds (Rojo & Perez-Badia, 2015). Indeed, the pollen production cycle of the olive tree alternates every two years and the interannual variation reflects this behavior (Ribeiro *et al*., 2005). The observed interannual variations are strongly influenced by climatic factors and more specifically by temperature (Orlandi *et al*., 2009).

CONCLUSIONS

This study aims to characterize the floral biology of the *Moroccan Picholine* variety across different regions of Morocco. We compared two distinct regions: the northern region (Ouazzane, Chaouen, and Tetouan), characterized by rain-fed cultivation, and the central region (Settat, Kelaa of Sraghna, and Marrakech), where irrigated cultivation is prevalent.

KEY FINDINGS

Irrigated vs. Rain-fed: Trees in irrigated stations exhibited higher values for perfect flower count, fruit set rate, fructification rate, and lower flower abortion rates compared to rain-fed stations.
Flowering Phenology: Flowering commenced earlier in irrigated stations.
Cluster Length, Flower Count, and Flowering Rate: No significant differences were observed among stations for these parameters.

IMPACT OF RAINFALL

The northern region experiences significant rainfall, but its irregularity and the prolonged dry season can negatively impact olive production. In contrast, the central region's irrigated system compensates for low rainfall, resulting in higher values for most studied parameters.

FUTURE CONSIDERATIONS

Enhance olive production and improve the livelihoods of the local population in the northern region, exploring suitable irrigation systems adapted to the mountainous terrain could be a promising strategy.

ACKNOWLEDGMENTS

I would like to thank everyone who contributed in one way or another to the success of this work, in particular Laboratory of Plant, Animal and Agro-industry Production, Faculty of Sciences, Ibn Tofail University, Kenitra, the National Institute of Agronomic Research RABAT (INRA) and Faculty of Sciences, Mohamed V University, Rabat, Morocco for allowing me to carry out the statistical analyzes of this work.

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