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CULTIVATION SYSTEM AND FLORAL BIOLOGY OF OLIVE TREE (OLEA EUROPAEA L.) OF THE MOROCCAN PICHOLINE VARIETY CULTIVATED IN THE NORTHERN AND CENTRAL PART OF MOROCCO

Nabil Zaara [1]*, Miloud Chakit [2], Jamila Dahmani [3], Amina Ouazzani Touhami [4], Fatima Gaboun [5], Souad Skalli [6] and Allal Douira [7]

[1,3,4,7] Plant, Animal Production and AgroIndustry Laboratory, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco.
*Corresponding Author Email: nabil.zaara@uit.ac.ma
[2] Biology and Health Laboratory, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco.
[5] Biotechnology Unit, Regional Center of Agricultural Research of Rabat, National Institute of Agricultural Research (INRA), Rabat, Morocco.
[6] Plant and Microbial Biotechnologies, Biodiversity, and Environment Center, Faculty of Sciences, Mohammed V University, Rabat, Morocco.

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Abstract

The diversity of the Moroccan olive varieties is particularly marked by the predominance of the Moroccan Picholine variety, and the optimization of the production that's requires a better knowledge of this variety, especially with regard to its development. To this end, a phenological study of the Moroccan Picholine variety grown in two regions of Morocco was carried out in the present study. In each of these six stations, five trees were sampled, with 40 inflorescences (clusters) taken from each tree. Eight quantitative characteristics relating to the average length of clusters (ACL), total number of flowers per cluster (TNF/C), flower abortion rate (AR/C), number of perfect flowers (PF), flowering rate (FR), fruit set rate (FSR/B), fruit set rate (FrR) and flowering period were taken into consideration. The results show that Moroccan picholine does not behave in the same way at the different sites studied. Trees grown in an irrigated system showed higher values than trees grown in a rainfed system for the parameters ACL, TNF/C, FR, FrR and flowering period. For the rest of the parameters, there is a certain similarity between all the stations studied. This can be explained, on the one hand, by the effect of the genotype and, on the other hand, by the environmental conditions, especially those related to climate, but also by the nature of the olive-growing system.

Keywords: Olive Tree, Moroccan Picholine, Regions, Diversity, Cropping System, Floral Phenology.

1. INTRODUCTION

The olive tree (Olea europapaea L) is a woody species belonging to the Oleaceae family. It is considered to be one of the most characteristic plant species of the Moroccan agricultural system. Its cultivation has influenced the history of our country and has left its mark on the Mediterranean civilizations that have succeeded one another over the centuries [1]. Human migrations and trade between the East, Africa and Europe led to the introduction of the olive tree into the Mediterranean basin, where it has formed a very important and diverse olive-growing genetic heritage. The olive tree (cultivated and wild) is the only species capable of developing marginal land while satisfying the vital needs of rural populations [2, 3].

Olive growing is one of the oldest and most widespread activities in the arid and semi-arid areas of the Mediterranean basin, mainly because of its great capacity to adapt to water-deficit conditions and its nutritional value. That said, olive productivity can be limited by both the availability of water and nutrients; yields vary according to the soil and fluctuating rainfall over the season and the year. The global market for virgin olive oil has been growing in recent decades, encouraging the cultivation of olive trees, which are often planted under intensive farming conditions [4].

In Morocco, the olive tree is of vital socio-economic importance, both in terms of the area it occupies and the number of trees planted (100,000 ha, 100 million trees, 65% of the national tree-growing area). The oil obtained by cold-pressing the fruit has excellent nutritional and dietary properties and has proven medicinal potential in the Mediterranean diet [5].

The Mediterranean countries are home to a diversity of varieties that constitute a much sought-after source of new characteristics for exploiting the genetic diversity that can be used to improve and enhance the production of cultivated plants such as olives. Morocco's olive-growing heritage also contains a rich, diverse and little-studied genetic resource [6].

Morocco has a wide variety of olive trees, including Zeitoun, Bouchouk, Hamrani, Meslal, Semlal, Kortbi, Menara and Haouzia [7]. However, the main variety grown in Morocco is the Moroccan Picholine, which accounts for around 96% of orchards. It is used to extract olive oil and to prepare table olives. The oil extracted is of good quality and keeps well thanks to the natural antioxidants it contains. The oleic yield is average compared with other varieties, at 18%. Plantation density varies, depending on the age of the orchard and its geographical location, from 80 to 400 plants per hectare, rarely more. The average fruit yield (olives) is around 50 kg/tree. Two Moroccan Picholine clones have been developed by INRA in Morocco: Haouzia and Menara, with yields of up to 60 kg/tree, reduced alternation and high oil content (up to 24%) [8, 9].

In order to gain a better understanding of the plant's needs and optimize olive tree production, it is necessary to study the flowering phenomenon in both cultivated trees and olive trees. The 'perfect' olive tree flower is hermaphroditic. Self-pollination can occur, but olive cultivars are mainly self- incompatible. Three modes of abortion have been identified in cultivated olive trees: male sterility (absence of stamens or no functional stamens), abortion of the female reproductive system (absence of pistil) and self-incompatibility. Male and female abortions are due to the interruption of microsporogenesis, which no longer produces pollen grains, and megasporogenesis, and are under genetic control. However, little is known about flowering and fertilisation in oleaster plants [10].

Flowering is one of the critical phases in the chronological development of the annual biological cycle that determines tree production. For a variety, the number of flowers per inflorescence, their fertility and the ability to bear fruit by dominant or non-dominant self-pollination are characteristics that affect the fruiting rate [5].

2. MATERIALS AND METHODS

2.1 Study Stations

We chose six study sites, three in the northern region (Tetouan, Chefchaouan and Ouazzane) and three in the center of the country (Settat, Kelaa des Sraghna and Marrakech) during the 2022/2023 agricultural season.

The first zone covers most of the Western Rif Mountain range. It has a rugged topography with steep slopes, with the exception of the outlying areas facing inland.

Ecologically, the area is favorable for olive growing, with rainfall in excess of 450 mm [11]. The agro-ecosystems in this area are predominantly agroforestry with subsistence farming activities; they form specific landscape units where small areas (< 0.5 ha) predominate and mixed farming is practiced [12].

The town of Settat is located on the edge of the Chaouia plateau and plain. It is characterised by rainfall of around 372 mm/year and an average annual temperature of 18°C [13]. In this zone, calcimagnesic soils predominate (31%), followed by slightly evolved soils (23.4%), with iron oxide soils (7%) and vertisols (7%) occupying the smallest areas. Cultivation in this region is dominated by cereals (wheat, barley), legumes (lentils), fodder crops (oat vetch, white lupin) and arboriculture (pomegranate, fig, vine) [13].

The Marrakech Safi region, located in central western Morocco, is characterized by an arid to semi-arid climate, which is subject to a combination of climate change and environmental variations. The climate of this area is influenced by three fundamental factors: the pre-Saharan latitudes, the high altitudes in the mountains and the influence of the Atlantic Ocean. This climate is characterized by significant rainfall-temperature variability, with maximum temperatures of around 38°C and minimum temperatures of around 4.9°C; 80% of the region has an average temperature of around 18°C [14]. Rainfall in this region is fairly irregular in space and time. It varies from one year to the next, from 190 mm on the plains to 650 mm in mountainous areas [15]. Agriculture is the main economic activity in this area, which accounts for 22% of the country's utilized agricultural area, putting it in first place in terms of the size of this area. The region's UAA accounts for 48.6% of the total regional surface area (1,904,363 hectares). By province, El Kelâa des Sraghna accounts for 31%, followed by Safi 30% and Chichaoua 15%. The irrigated surface area of this zone is of the order of 301 277 ha, i.e. almost 16% of the regional UAA and 24% of the irrigated UAA at national level. The agricultural vocation of the region is predominantly agro-sylvo-pastoral. Cereal crops predominate, accounting for almost 78%, followed by fruit plantations (9.5%), fodder crops (1.8%) and market gardening (1.2%) (HCP 2015).

Climatic data from the stations studied (Table 1) were compiled (Mokhtari et al., 2013; website 1) to highlight their variations along the North-South gradient. Similarly, the geographical data (Table 1, Figure 1) make it possible to locate the study areas. The map showing their location (Figure 1) was produced using ArcGIS software.

Table 1: Geographic Coordinates and Climatic Data of the Stations Studied

Stations	Bioclimatic stage	Altitude (m)	Geographical coordinates	Irrigation system	TM 2023/2024 ° C	PM 2023/2024 (mm)
Tétouan	Humid	107	35.49972 N-5.434661O	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
Settat	Semi-arid	250	33.05720 N-7.62687 O	Irrigated	22,18	12,54
Kelaa of the Sraghna	Aride	430	32.17732 N-7.65792 O	Irrigated	23,54	17,50
Marrakech	Aride	466	31.62942 N-8.06191 O	irrigated	24,36	17,72

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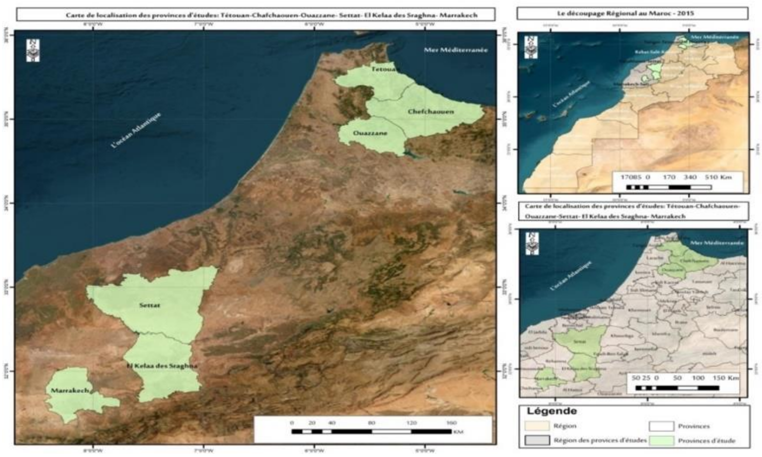

Figure 1: Location of Study Stations (Ourselves, 2023)

2.2 Sampling

Two regions of Morocco known for olive growing are considered in the present study with 3 sites each. The first region in the north is represented by Tetouan, Chaouen and Ouazzane and the second in the center of the country by Marrakech, Kelaa des Sraghna and Settat. We sampled 5 flowering trees per station. For each tree, at the average height on the south side, we took 40 inflorescences which will be the subject of the phenological characterization. The identification of the phenological phases F, F1 and G was checked each week from the opening of the first flowers to the fall of the petals and made it possible to note the duration of each phenological phase: F: 10% of the flowers open (start of flowering), F1: 50% of the flowers open (full flowering), G: 50% of the flowers have lost their petals (end of flowering). After taking samples from each station, using forceps and a graduated ruler (Figure 2), we proceeded to take measurements and determine the various parameters of the study: length of clusters, total number of flowers per cluster, number of perfect flowers, number of imperfect flowers, etc. The characteristics were studied during the period of full flowering and open pollination (Table 2).

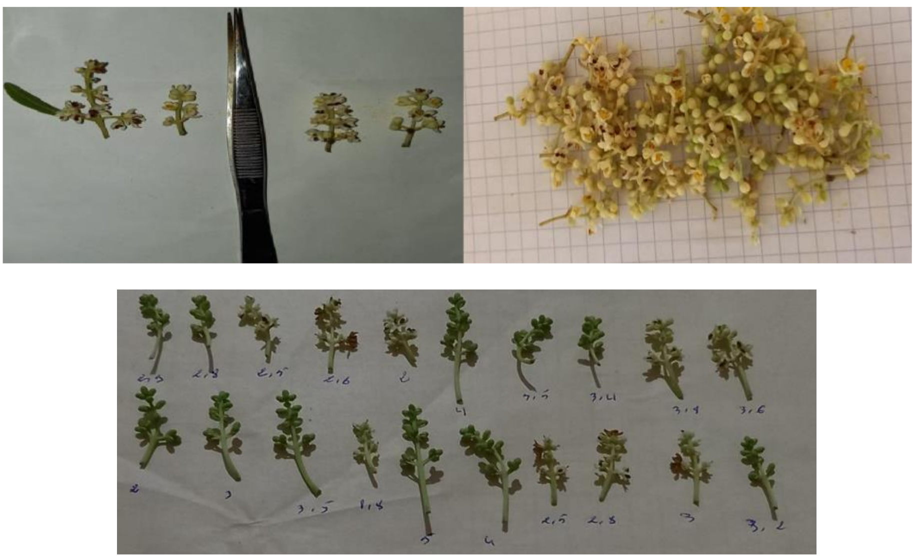

Figure 2: Plant Material (Inflorescences) used to Study Flowering

Table 2: Studied Characteristics

Characteristics studied	abbreviations
Average length of clusters	ACL
Total number of flowers per cluster	TFN/C
Rate of flower abortion per bunch	FAR/C
Perfect flowers	PF
Flowering rate	FR
Fruit set rate	FSR/C
Fruiting rate	FrR
Flowering periods	FP

2.3 Statistical Analysis

The data obtained were subjected to an analysis of variance in order to distinguish between trees at the same station and between stations, and a comparison of means (New Man and Keuls test at 5%) was applied in cases where a significant differences.

The quantitative variables were subjected to principal component analysis and the hierarchical clustering method, in order to demonstrate the degree of similarity between the possible groupings of the studied stations; this similarity is measured by the Euclidean distance, which also makes it possible to visualise the relationships between the stations.

The software used were: GenStat (18th Edition SNI Product) for the PCA, hierarchical clustering (CAH) and SAS (SAS® OnDemand for Academics) for the analysis of variance.

3. RESULTS

3.1 Characteristic Linked to the Average Length of Clusters

In terms of the average cluster length (ACL), the findings did not indicate a notable disparity among trees within the same station, implying the absence of a discernible genotype effect.

Across all stations, the coefficient of variation exhibited a range typically spanning from 2 to 8.5%. Moreover, the coefficient calculated between stations remained relatively low, with a maximum value of 12.24%. Notably, Settat and Marrakech showcased the lengthiest bunches, measuring 3.21 and 2.99 cm, respectively, while the remaining stations (Tetouan, Chaouan, Ouazzane, and Kelaa des Sraghna) presented lengths ranging between 2.24 and 2.86 cm.

Subsequently, the observed results facilitated the categorization of the stations into five distinct groups based on their ACL values: Group 1 comprised Settat, exhibiting a cluster length of 3.21 cm, followed by Group 2 represented by Marrakech with a length of 2.99 cm.

Group 3 included Tetouan, displaying an ACL of 2.86 cm, while Group 4 encompassed Kelaa and Ouazzane, characterized by cluster lengths ranging between 2.69 and 2.7 cm. Lastly, Group 5 comprised Chaouan, with a cluster length of 2.24 cm.

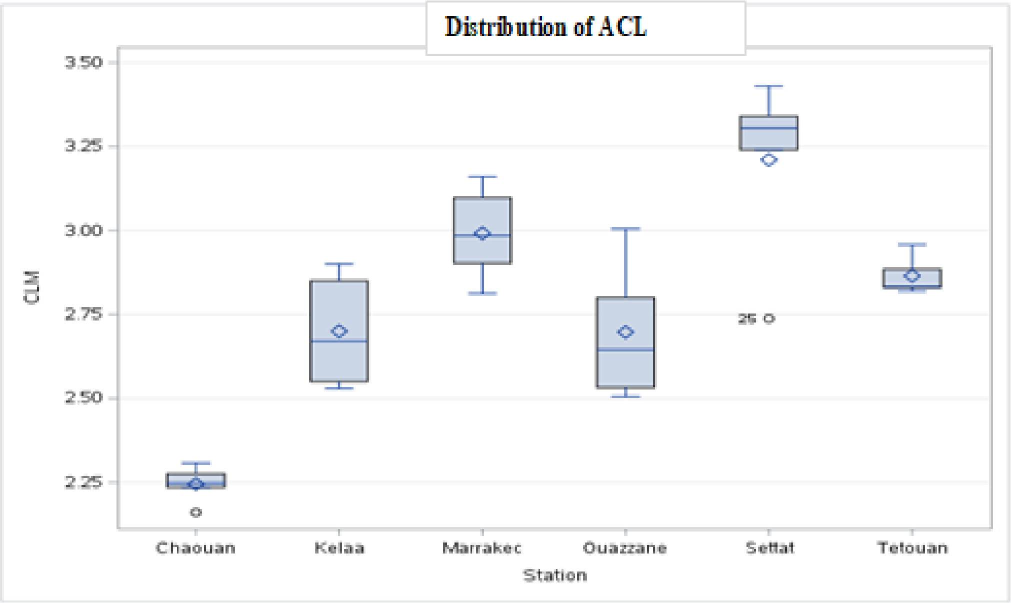

Figure 3: Distribution of Stations According to Average Cluster Length

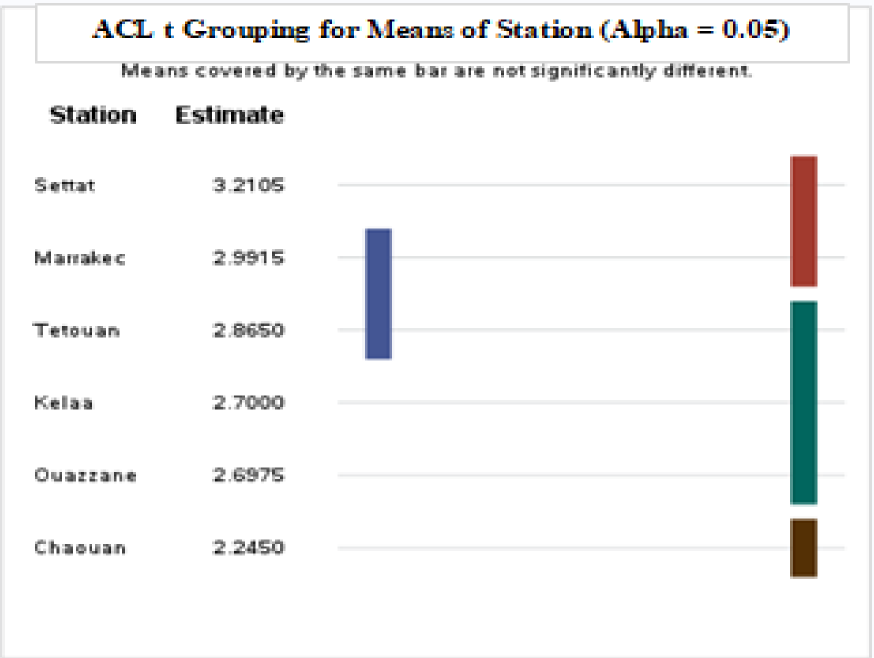

Figure 4: Groups of Different Stations (ACL)

3.2 Characteristic Linked to the Total Number of Flowers per Cluster

The examination of the total number of flowers per cluster indicated a lack of significant variance among trees within the same station, suggesting the absence of a discernible genotype effect. Moreover, the coefficient of variation observed between trees within the same station remained notably low, with a maximum value of 5.51%. Similarly, the comparison between stations revealed minimal discrepancy, with the coefficient of variation reaching only 6.87%. Notably, irrigated stations such as Marrakech, Kelaa, and Settat exhibited a total number of flowers per cluster exceeding 15, contrasting with the Bour stations (Tetouan, Chaouan, and Ouazzane) where the total number of flowers per cluster surpassed 14 for the same attribute (refer to Figure 5). Statistical analysis delineated two primary groups based on this parameter: Group 1 comprised Settat, Kelaa des Sraghna, and Marrakech, showcasing a total number of flowers per cluster ranging from 15.07 to 15.60. In contrast, Group 2 encompassed Chaouan, Ouazzane, and Tétouan, displaying a total number of flowers per cluster varying between 13.45 and 13.75 (refer to Figure 6).

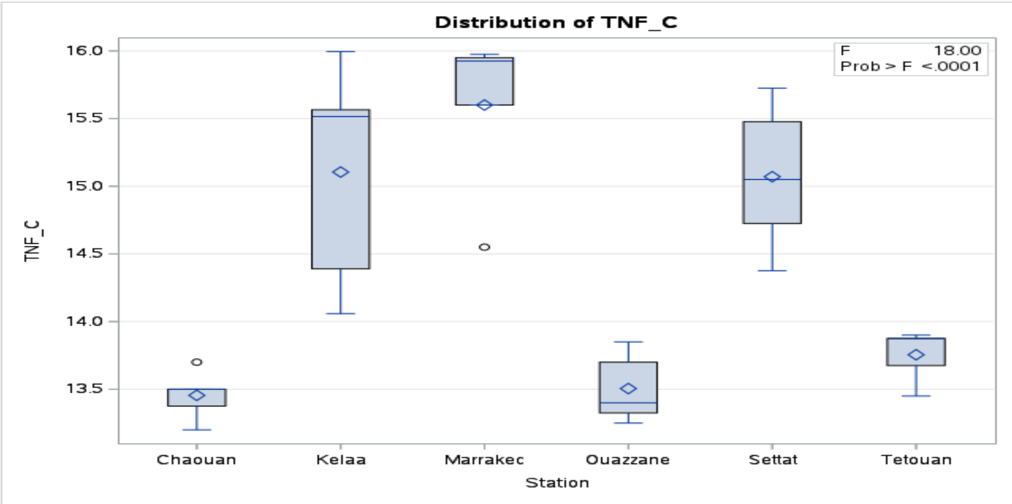

Figure 5: Distribution of Stations by Total Number of Flowers per Cluster

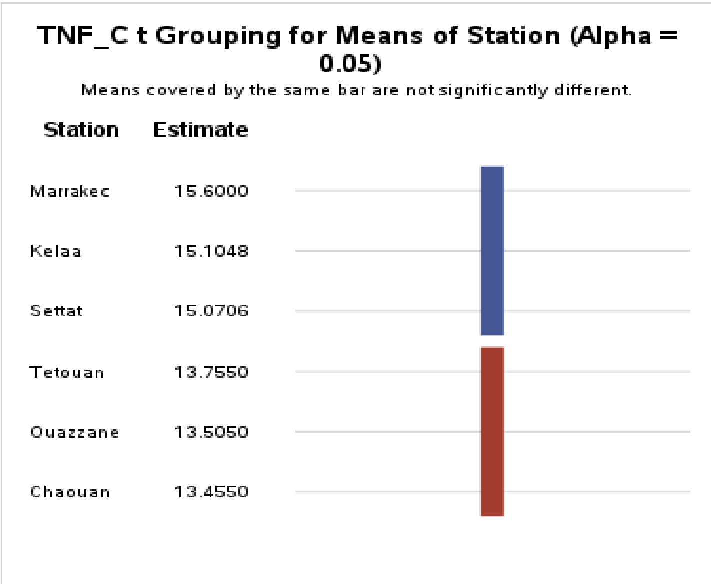

Figure 6: Groups of Stations Studied for the TNF/C Trait

3.3 Flower Abortion Rate per Bunch

The analysis of the flower abortion rate per cluster (AR/C) revealed substantial variations across stations, with a coefficient of variation reaching up to 35%. Additionally, notable distinctions were observed among trees within the same station, particularly evident at Kelaa des Sraghna, Ouazzane, Settat, and Tetouan, where coefficients of variation amounted to 25%, 16.15%, 23%, and 14.52% respectively, indicating a potential genotype effect at these specific locations. Conversely, for the remaining stations, the coefficient of variation remained below 11%. Notably, Marrakech exhibited the highest abortion rate at 22.03%, trailed by Chaouan at

19.83%, Tetouan at 14.94%, Settat at 13.95%, Ouazzane at 12.21%, with Kelaa des Sraghna demonstrating the lowest abortion rate at 7.19%. This metric was determined through the enumeration of abnormal or imperfect flowers, facilitating the categorization of stations into three distinct groups (refer to Figures 7 and 8): Group 1 encompassed Marrakech and Chaouan, exhibiting abortion rates of 22.03% and 19.83% respectively; Group 2 comprised Tétouan, Settat, and Ouazzane, showcasing abortion rates of 14.94%, 13.95%, and 12.21% respectively; and Group 3 represented Kelaa des Sraghna, characterized by a notably lower abortion rate of 7.19%.

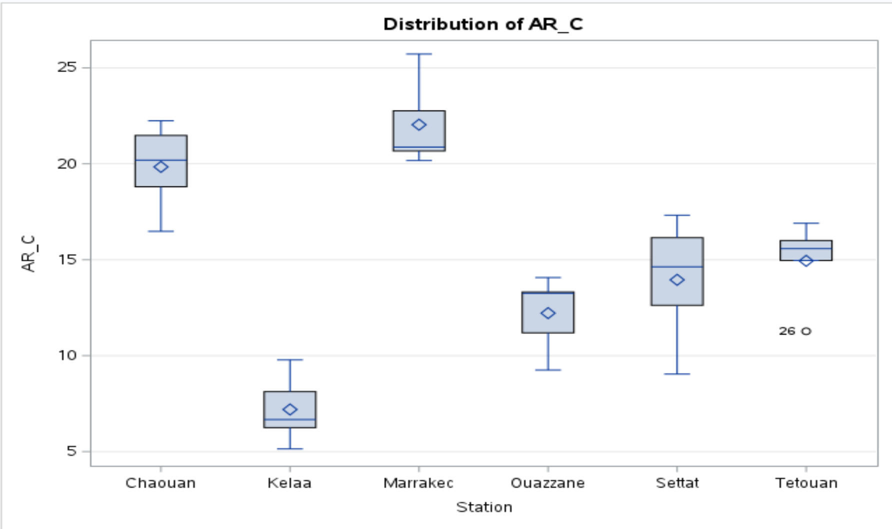

Figure 7: Distribution of Stations According to AR/C Character

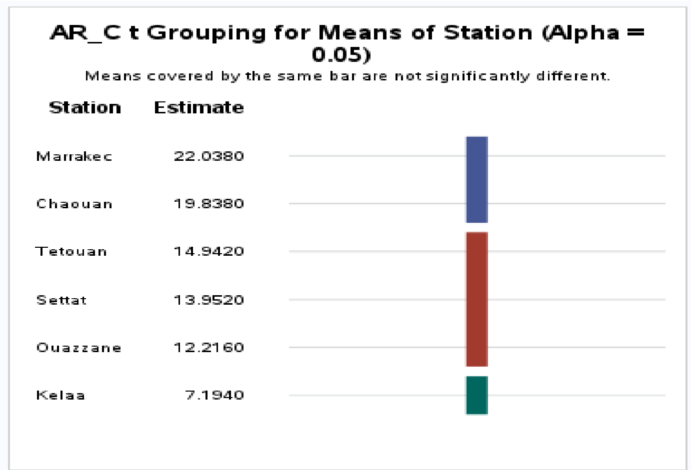

Figure 8: Groups of Different Stations for the AR/C Characteristic

3.4 Characteristic Linked to the Number of Perfect Flowers per Cluster

The examination of the parameter concerning the number of perfect flowers per cluster revealed no significant disparities among trees within the same station, with the coefficient of variation (CV) generally ranging between 1.72% and 7.68%. Consequently, no discernible genotype effect was observed among trees within the same station. Moreover, the inter-station variability remained relatively modest, as the CV did not surpass 14.86% across stations (Figure 9). This analysis facilitated the categorization of stations into four distinct groups: Group 1 comprised Settat, exhibiting 12.95 perfect flowers per cluster; Group 2 included Marrakech, Ouazzane,

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and Tetouan, showcasing a range of perfect flowers percentage between 11.68 and 12.07; Group 3 represented Chaouan, with a recorded value of 10.76; and Group 4 consisted of Kelaa des Sraghna, characterized by the lowest percentage of perfect flowers at 7.94 (Figure 10).

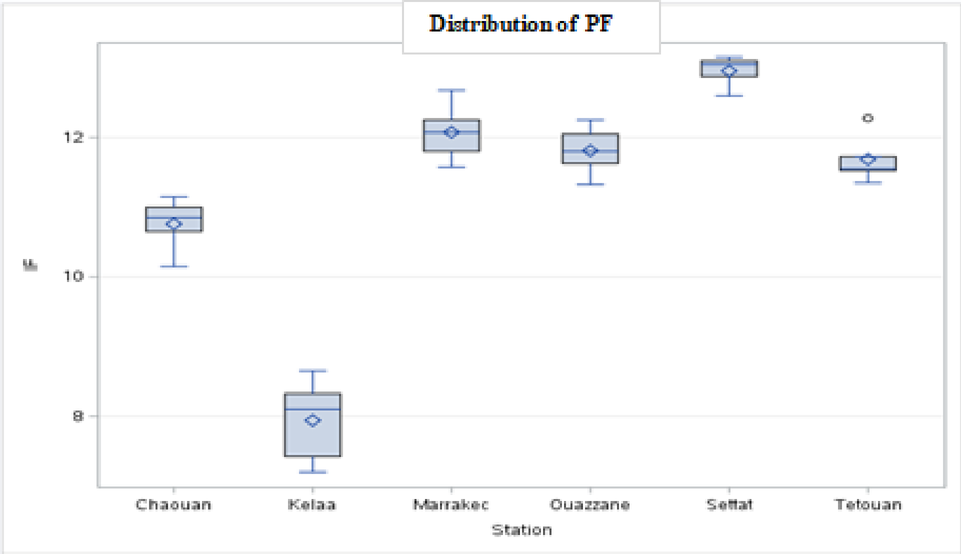

Figure 9: Distribution of the Different Stations According to PF Characteristics

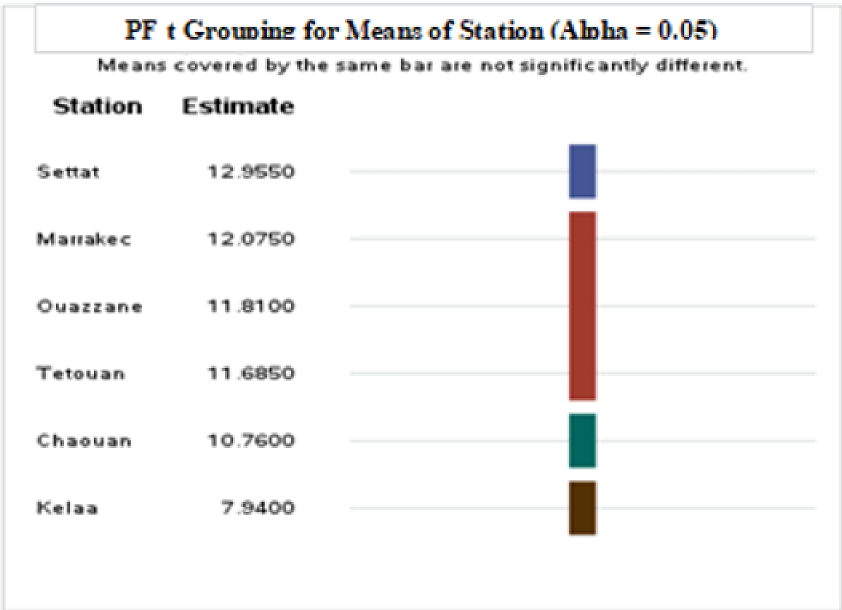

Figure 10: Groups of Different Stations According to FP Character

3.5 Flowering Rate Trait

The analysis of the flowering rate parameter revealed a significant discrepancy among the studied stations, with a coefficient of variation (CV) of 23.40%. Conversely, minimal variation was observed among trees within the same station, with a CV not exceeding 12.90%. The highest flowering rates were documented at the irrigated stations of Kelaa des Sraghna, Marrakech, and Settat, boasting rates of 90.25%, 86.19%, and 77.88% respectively, followed by the rain-fed stations of Tetouan (64.03%) and Chaouan (58.32%). In contrast, the Bour station in Ouazzane exhibited the lowest flowering rate, registering not more than 45.98%. This analysis facilitated the classification of stations into four distinct groups based on their flowering rates (Figures 11 and 12): Group 1 encompassed Marrakech and Kelaa des Sraghna, showcasing flowering rates ranging between 90.25% and 86.19%; Group 2 comprised Settat, characterized by a flowering rate of 77.88%; Group 3 included Tetouan and Chaouan, exhibiting flowering rates between 64.03% and 58.32%; and Group 4 represented Ouazzane, with a flowering rate of 45.98%.

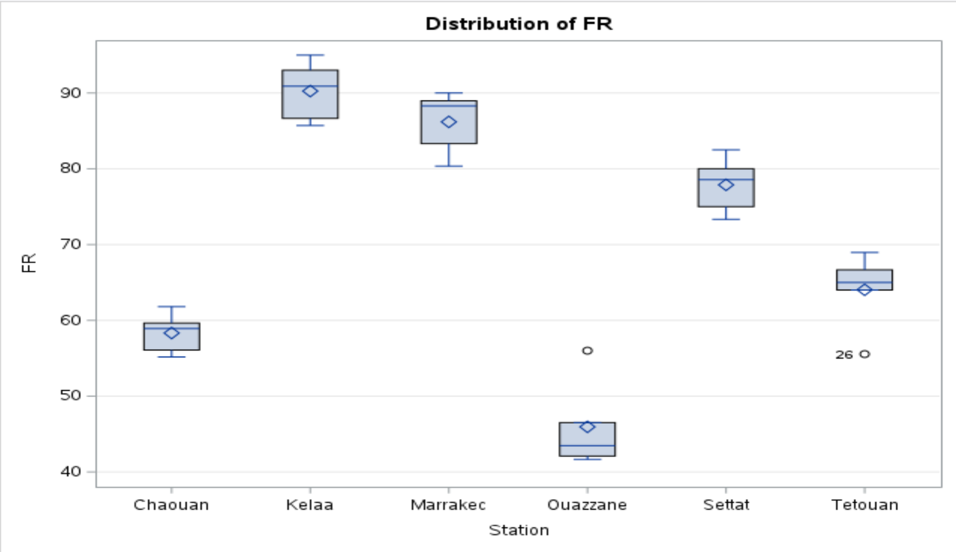

Figure 11: Distribution of Stations for the FR Characteristic

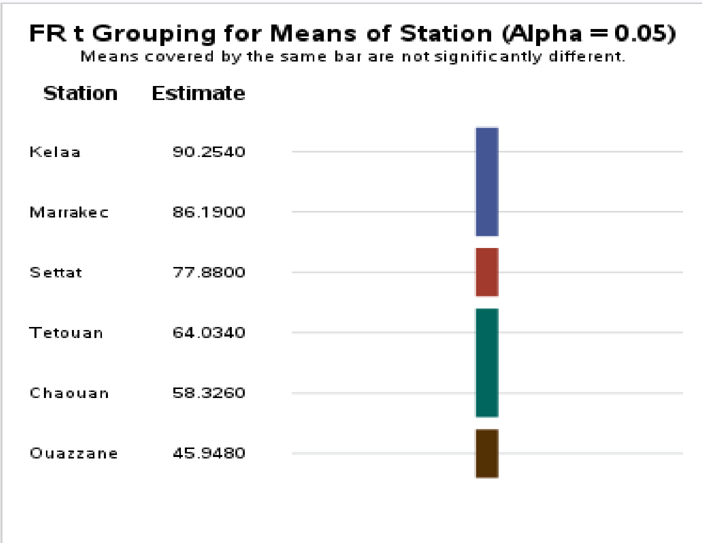

Figure 12: Groups of Different Stations for Flowering Rate (FR)

3.6 Characteristic Linked to Fruit Set Rate per Bunch

The analysis revealed a substantial variation between stations, indicating a coefficient of variation exceeding 51%. Moreover, considerable divergence was observed among trees within the same station, particularly notable in Ouazzane, followed by Marrakech, Chaouan, and Settat, where the coefficient of variation ranged from 80.99% to 42.75%. Notably, a significant difference was discerned at the Tétouan station (31.34%), hinting at a potential genotype effect at these specific stations. Conversely,

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Kelaa des Sraghna exhibited the lowest coefficient of variation, standing at 14.79% (Figure 13). Examining the fruit set rates, Tétouan and Kelaa des Sraghna emerged with the highest rates at 4.16% and 3.99% respectively, trailed by Marrakech, Ouazzane, and Settat, showcasing average fruit set rates ranging between 3.10% and 2.36%. In contrast, Chaouan exhibited the lowest fruit set rate, not surpassing 1.86%. These findings facilitated the categorization of stations into three primary groups based on their fruit set rates (Figure 14): Group 1 comprised Tétouan (4.16%) and Kelaa des Sraghna (3.99%); Group 2 included Marrakech (3.10%), Ouazzane (3.02%), and Settat (2.36%); and Group 3 represented Chaouan (1.86%).

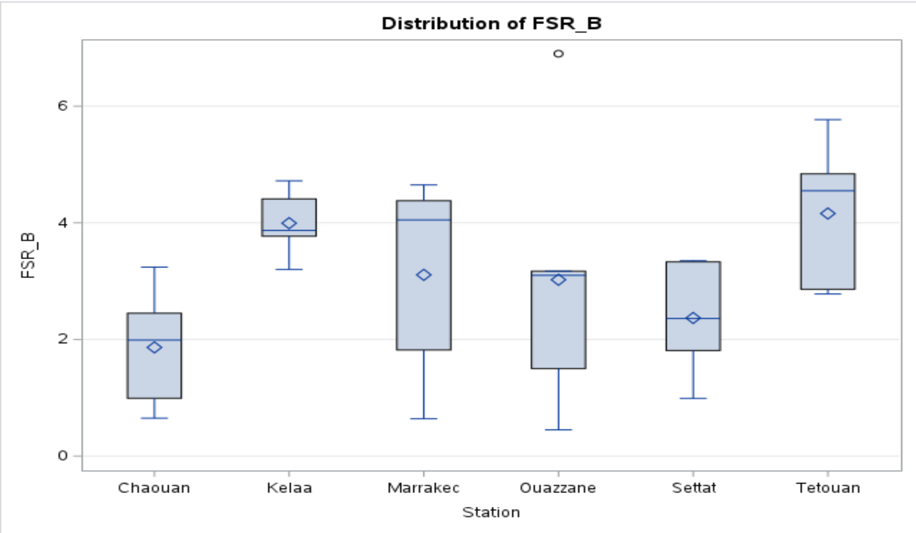

Figure 13: Distribution of Stations for the Fruit Set Rate Characteristic

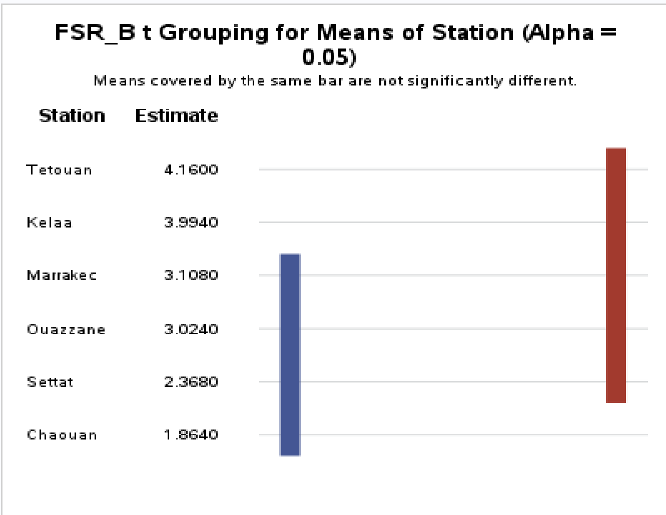

Figure 14: Different Groups of Stations for the Fruit Set Rate Characteristic

3.7 Characteristic Linked to Fruiting Rate

The analysis of fruiting rates exhibited substantial variability among the studied stations, with a coefficient of variation (CV) reaching as high as 82.82%. Similarly, significant divergence was observed among trees within the same station, with cv ranging from 82.66% to 59.29%, except for Kelaa des Sraghna, where the cv remained below 21.81%. Nevertheless, even at Kelaa des Sraghna, there was a noteworthy disparity, suggesting the potential influence of genotype across all stations concerning fruiting rates. Kelaa des Sraghna demonstrated the highest fruiting rate at 3.21%, followed by Marrakech at 1.45% and Settat at 0.96%. In contrast, the other rain-fed stations (Tétouan, Ouazzane, and Chaouan) exhibited comparatively lower fruiting rates in comparison to the irrigated stations (Kelaa des Sraghna, Marrakech, and Settat), with rates ranging between 0.7% and 0.84%. These results facilitated the identification of two primary groups (refer to Figures 15 and 16): Group 1 comprised Kelaa des Sraghna with a fruiting rate of 3.21%, while Group 2 included Marrakech (1.45%), Settat (0.96%), Tétouan (0.84%), Ouazzane (0.75%), and Chaouan (0.7%).

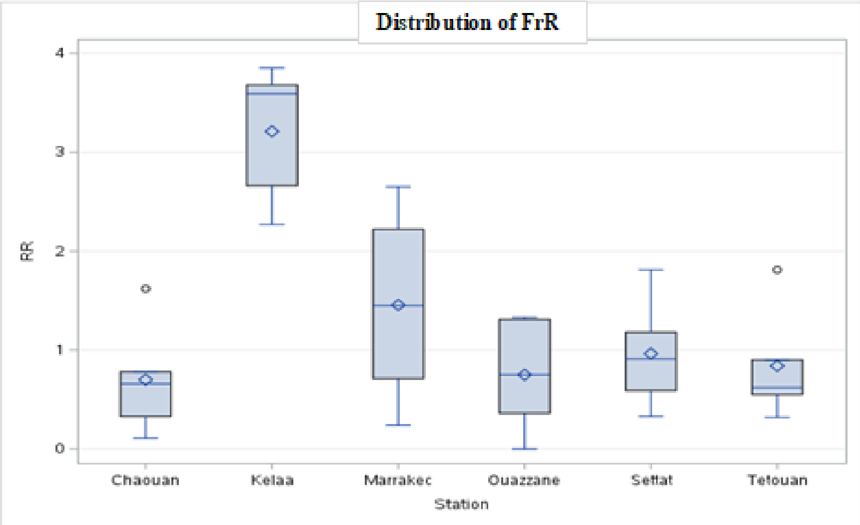

Figure 15: Distribution of Stations According to Fruiting Rate

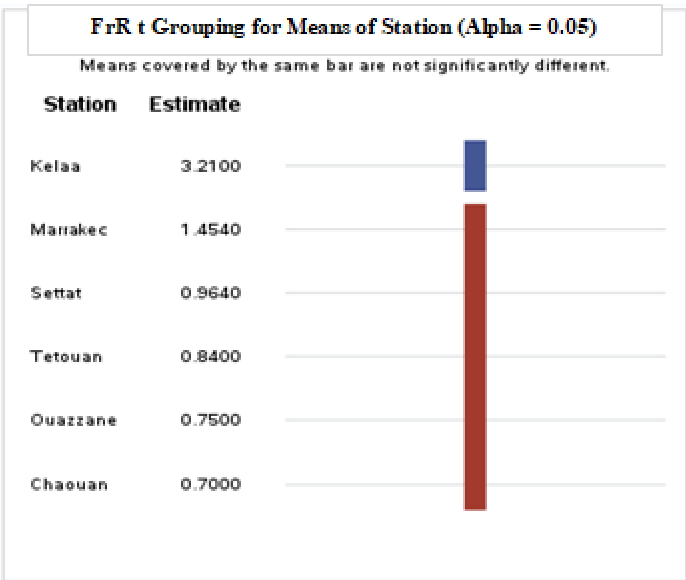

Figure 16: Different Groups of Stations for the Fruiting Rate Parameter

3.8 Characteristic Linked to the Flowering Period (FP) in the Stations Studied

The flowering phase exhibits variations across the different stations under investigation. Specifically, the divergence in the onset, peak, and conclusion of flowering is estimated at 35, 37, and 39 days, respectively. Kelaa des Sraghna, characterized by an arid climate and an irrigated cultivation system, initiates flowering

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earliest, followed by Marrakech, also featuring an arid climate and irrigated cultivation. Subsequently, Tétouan, with a humid climate and rain-fed cultivation, commences flowering, trailed by Ouazzane, characterized by a sub-humid climate and rain-fed cultivation, Chouan with a humid climate and rain-fed cultivation, and lastly, Settat, characterized by a semi-arid climate and irrigated cultivation. Regarding the duration of the flowering period, Tétouan and Settat exhibit the longest spans, lasting 20 days, followed by Marrakech with 19 days, Chaouan with 18 days, Ouazzane with 17 days, and Kelaa des Sraghna with 16 days. Consequently, the stations can be categorized based on their phenological stages as follows: Kelaa des Sraghna and Marrakech are classified as early flowering stations, Tétouan, Chaouan, and Ouazzane as seasonal flowering stations, while Settat is categorized as a late flowering station.

Table 3: Flowering Periods at the Various Stations

	Tetouan	Chaouan	Ouazzane	Kelaa	Marrakech	Settat
Beginning of flowering	08. April.2022	20. April.2022	15. April.2022	18. March.2022	06. April.2022	22. Apri.2022
Full flowering	15. April.2022	28. April.2022	22. April.2022	24. March.2022	13. April.2022	30. Apri.2022
End of flowering	28. April.2022	08. May.2022	02. May.2022	03. April.2022	25. April.2022	12. May.2022

Table 4: Variation in Parameters Studied by Station

Stations	ACL	TNF/C	AR/C	PF	FR	FSR/B	FrR
Kelaa des Sraghna	2,70 c	15,10 a	7,19 C	7,94 d	90,25 a	3,99 a	3,21 a
Marrakech	2.99 ab	15,60 a	22,03 a	12,07 b	86,19 a	3.10 ab	1,45 b
Settat	3,21 a	15,07 a	13,95 b	12,95 a	77,88 b	2.36 ab	0,96 b
Tetouan	2.86 bc	13,75 b	14,92 b	11,68 b	64,03 c	4,16 a	0,84 b
Chaouan	2,24 d	13,45 b	19,83 a	10,76 c	58,32 c	1,86 b	0,70 b
Ouazzane	2,69 c	13,50 b	12,21 b	11,81 b	45,94 d	3.02 ab	0,75 b

Means in the same column with the same letter do not differ significantly from each other at =5%.

3.9 Structuring Polymorphism and Station Differentiation

The dendrogram shows four clearly distinct groups that oppose the stations with good flowering parameters to the other stations. It is important to point out that the first group, with low flowering parameters, includes the stations located in a traditional rain-fed agrosystem: Tétouan, Chaouan and Ouazzane. On the other hand, the groups with good flowering parameters include stations in a regularly irrigated cropping system: group 2 (Kelaa des Sraghna), group 3 (Settat) and group 4 (Marrakech) (Figure 17).

Discriminant factor analysis was used to verify the structuring revealed by the hierarchical analysis. The factorial design (1, 2) shows good structuring of the variability, accounting for almost 70% of the variance. The discriminant factorial axis 1 covers 38.71% of the variance, corresponding to stations with low flowering parameters. This axis is defined by the variables of average cluster length, total number of flowers per cluster and flowering rate. Discriminant factorial axis 2 accounts for 30.38% of the variance and is explained by the ripening rate, the number of imperfect flowers, the rate of flower abortion per cluster, the number of perfect flowers and the fruit set rate (Figure 18).

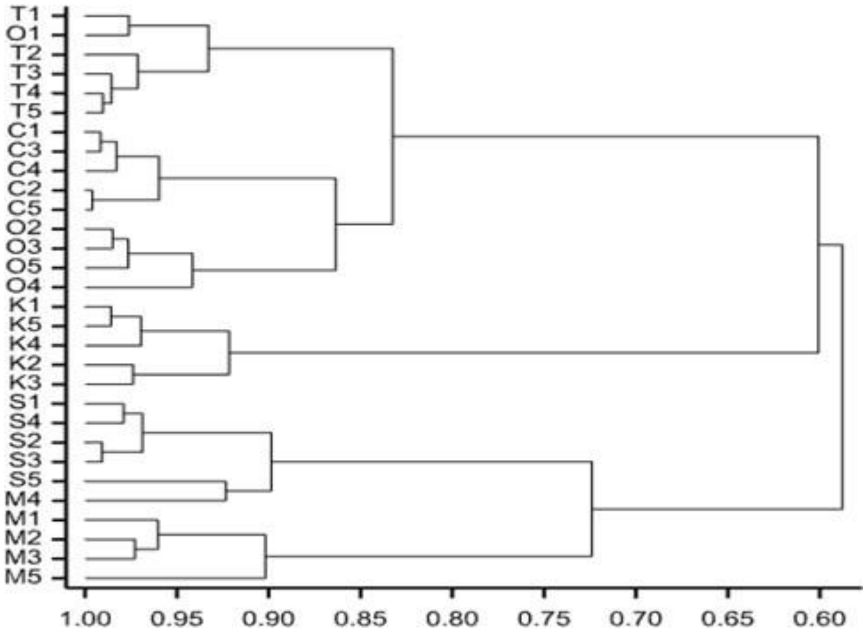

Figure 17: Hierarchical Classification Dendrogram

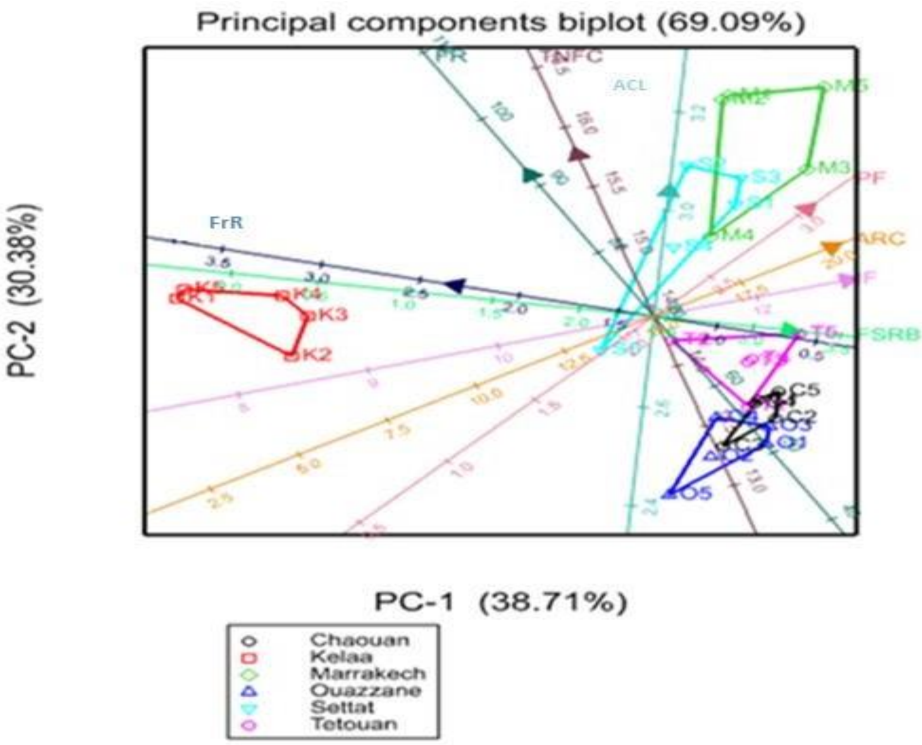

Figure 18: Discriminant Factor Analysis of the Different Stations

4. DISCUSSION

For average cluster length (ACL), we have results consistent with [16] who found that Moroccan Picholine, grown under irrigated conditions in a geographically marginal site (Beni Tajjit) located in the south-western part of the eastern region of Morocco, is characterised by an average length of 2 cm.

These results are close to those found by us at the Ouezzane, Chaouan and Kelaa des Sraghna station, where the length of the bunches does not exceed 2.7 cm.

Mekkaoui, [17] found that Moroccan Picholine in the Meknès region under irrigated cultivation had an average bunch length of up to 2.98 cm. This is similar to the results from our stations, notably Tetouan, Marrakech and Settat. According to Breton [10], a long inflorescence is apparently better for fruit production, but we shall see that this is not so obvious. The shape of the inflorescence depends on the genotype [18].

The total number of flowers per cluster (TNF/C) varies considerably from one region to another. Boulouha found that out of a total of 2413 inflorescences examined, the average number of flowers per cluster was 11. Mekkaoui [19], found that in an irrigated cultivation system this number exceeded 19 flowers per cluster. Kartas et al [20] found that the number of flowers per inflorescence, recorded over several consecutive years of experimentation varied for the local varieties and types considered generally between 11.34% and 24.69%. Moroccan Picholine and Dahbia grown in the Ouazzane region under a rainfed cultivation system showed the lowest values for this parameter (13.87 and 11.034 flowers per inflorescence respectively). Hannachi [21] found that the average number of flowers per cluster varied between 16.73 and 26.37 for all the oleaster varieties studied. Our results show an average number of flowers per cluster that varies between 13.45 and 15.60 in all the stations studied, which is in line with the results of previous studies. The variation observed in the number of flowers per inflorescence for the Moroccan Picholine variety could be explained by the genotype, the variety, the physiological state of the tree or the climatic conditions. In fact, the number of flowers per inflorescence obtained from trees that had been subjected to temporary water stress at the beginning of March was lower than that of control trees (which had not been subjected to any water deficit) [4,22]. This shows that this parameter is more influenced by the cropping system, confirming our results showing a higher number of flowers per cluster in irrigated stations compared with rain-fed stations.

In addition, the rate of flower abortion per cluster (AR/C) can determine olive tree production. It is therefore an important parameter that can be considered as an indicator. Kartaset al [20] found that the average pistil abortion rates obtained for local varieties and types (BouchoukLaghlid, BouchoukRkik, Bouchouika, BakhboukhBeldi, Picholine marocaine, Dahbia...)in the Ouazzane region vary between 9.90 and 81.53%.Hannachi [21] found that the percentage of pollen abortion varied between 5.66 Oleaster 4 (OI4) and 35.90% Oleaster 1 (OI1) with an average of 22.13% for oleasters in the Ichkeul park in Tunisia, and from 10.22 (OB3) to 38.83% (OB2) with an average of 21.99% for oleasters in the Belvedere park . Female abortion ranged from 1.49 (OI4) to 30.75% (OI3) and from 12.56 to 88.12% (OB2) for trees in the Ichkeul and Belvedere Parks respectively [19] indicates that flower abortion was low in the Dahbia variety and high in the Moroccan Picholine in an irrigated cultivation system in the Meknès region of Morocco. Boulouha found that the rate of flower abortion varied between 43.48 and 45.4% in the Menara variety in Marrakech. Our results are in line with those obtained by Kartass et al [20]; we found that the rate of flower abortion per bunch ranged from 7.19% to 22.03% at all our stations. The abortion rate can be affected by several factors: genotypic (variety), environmental (insufficient light, winter cold), and exogenous (soil nutrients, water stress, nitrogen deficiency, leaf diseases...) [20, 23, 24]. Temperatures above 30°C inhibit pollen growth and encourage ovarian abortion [25].

The perfect olive flower is hermaphroditic. Self-pollination can occur, but olive cultivars are mainly self-incompatible. Three modes of abortion have been identified in cultivated olive trees: i) male sterility (absence of stamens or no functional stamens), ii) female abortion (absence of pistil) and iii) self-incompatibility. Plants can show both male and female abortion as well as many other processes that have failed during microsporogenesis such as pollen abortion [10].

Perfect flowers (pistillate and fertile) are those whose floral parts are normally developed, i.e. without malformations and therefore capable of receiving viable, compatible and fertilising pollen in their receptive stigmas. In floral clusters, the high number of perfect flowers is linked to abundant ontogeny of the inflorescence [26]. According to Kartas et al [20], the number of perfect flowers per cluster varies between 4.85 and 12.99. Boulouha found that this number for the Moroccan Picholine variety varies between 5.6% and 41% [27] for the Moroccan Picholine and the Languedoca Picholine respectively gave a number of perfect flowers per bunch of 15.5 and 20. This parameter is influenced by several factors such as the physiological and nutritional state of the tree, climatic conditions (soil humidity, temperature, rainfall) and exposure. The northern exposure of the forest canopy generally produces a large number of flowers per cluster [28]. The low yields observed on certain varieties such as Frantoio, Hojiblanca and Sigoise are linked to the lack of water and therefore to hydric stress, which can influence flower formation through pistillary abortion [23]. These results are consistent with our own; the number of perfect flowers per cluster that we found varied between 7.94 and 12.95 in all the trees and stations studied.

The rate of flowering per shoot assesses the ability of the buds of cultivars and local types to undergo induction, floral initiation, flower differentiation and the fruiting potential of the inflorescence. This quantitative characteristic makes it possible to determine olive productivity. The flowering rate varies between 50% and 71% [20]. For Moroccan Picholine, in an irrigated cultivation system, this rate varies between 51% and 56%. Other studies have found that Moroccan Picholine has a flowering rate of between 52% and 83.4% [29, 30]. Our results show values ranging from 77.88% to 90.25% in the irrigated stations (Settat, Marrakech and Kelaa des Sraghna) and from 45.94% to 64.03% in the rain-fed stations (Ouazzane, Chaouan and Tétouan), confirming the positive effect of irrigation on the olive tree. According to several studies, the flowering behaviour of each cultivar depends on the genetic stock and sudden variations in temperature on the vegetative growth and fruiting activity of the tree and on the olive tree cycle; not forgetting the impact of intrinsic factors (physiological state of the tree, alternate bearing) and extrinsic factors (temperature, rainfall, humidity), and other endogenous trophic and complex hormonal factors that considerably influence floral initiation, floral differentiation and the development of inflorescences leading to flower production [4,8,31-34].

Fruit set is the initial phase of fruit formation, when the ovary of the flower is transformed into fruit after fertilisation. It begins in June. Many authors have shown that, generally after a productive year, fruit set is low, even when there are a large number of flowers on the tree. The rate of fruit set is a parameter that can be considered as an indicator of the olive tree's productivity. This rate is 71% for the Chemlali variety in Tunisia [35]. In Morocco, according to Mekkaoui [11] for Moroccan Picholine, the fruit set rate for cross-pollination is 13.61%, for self-pollination 6.66% and for open pollination 7.17%. On the other hand, the Dahbia variety had a fruit set rate of 25.87% for cross- pollination, 42.88% for self-pollination and 39.48% for open pollination, indicating that Dhabia has a higher fruit set rate than Moroccan Picholine. The results we have obtained show very low fruit set rates compared with the values quoted above; they vary between 1.86% and 4.16% in all the stations studied, which is due to the low rainfall and periods of drought in recent years. Hydric stress can seriously affect fruit set by increasing the proportion of staminate flowers; receptivity to the stigma is probably a difficult stage to determine because fruit set in olive trees is very specific. In controlled crosses, fruit set results from both self-pollination and cross-pollination [18]. It is also the result of the interaction between the physiology of the olive tree and the environment. The main factor reducing fruit set is not only due to pistil abortion, but also to flower abscission, which results in a low percentage of fruit. It has been reported that in a normal flowering year, 1 to 2% of the final fruit set will result in a high olive yield [36]. It has been shown that cross-pollination determined the optimal pollen-pistil interaction and considerably increased the percentage of fruit set. When pistil abortion increases, fruit set decreases; this is also linked to agricultural techniques such as irrigation [20].

The rate of fruit set (FrR) is closely linked to environmental conditions (temperature, humidity, rainfall, etc.), and fruit set in olive trees is relatively low, at between 1 and 3%. In years of good flowering, fruiting of 1 to 2% of the flowers is enough to ensure a good harvest. Kartas et al [20] found that the Moroccan Picholine variety has a fruiting rate which varies between 0.56 and 2.85% in the case of self-pollination and from 0.9 to 2.94% in the case of open pollination. Unlike the Dahbia variety which is characterized by a fruiting rate of 1.372% in self-pollination and 1.73% in open pollination in a rainfed cultivation system. The fruiting rate obtained by self-pollination is in most cases different from that obtained by open pollination, and this parameter also varies according to environmental conditions [37]. This parameter also varies according to environmental conditions, Boulouha found that the fruiting rate in Moroccan Picholine varies according to the type of shoot; fruiting is 3.2% in the case of main shoots, 2.3% in lateral shoots and 4.4% in the case of vertical shoots for the Menara Marrakech variety. Mekkaoui [11] found that the Moroccan Picholine from the Meknes region in the irrigated cultivation system had a fruiting rate of 8.31% compared with the Dahbia variety, which did not exceed 2.97%. Our open pollination results are in line with these results, which show high fruiting rates at irrigated stations; this is the case at the Settat, Kelaa des Sraghna and Marrakech stations, where the fruiting rate varies between 0.96 and 3.21%, whereas at the rain-fed stations (Tetouan, Chaouan and Ouazzane), this parameter varies only between 0.7 and 0.84%.

The varieties Moroccan Picholine, Bouchouk Rkike and Beldi are characterised by the longest flowering periods compared to other autochthonous varieties and local types; these periods are 19, 18 to 20 and 20 days respectively [20]. The full flowering dates of these varieties coincide with most of the other varieties studied and the most widely observed local types. Dahbia flowers fairly early compared with Moroccan Picholine [11]. The first flowers opened at the end of March for Dahbia and by the first week of April this variety was already in full flower, whereas Moroccan Picholine was in the early stages of flowering. The end of flowering for Dahbia was observed during the last decade of April, when Moroccan Picholine is in full flower. [25] Found that flowering took place at all stations at the same time, generally between 2 May and 8 June in southern Italy. The delay in flowering was 23 days (flowering in Palermo on 25 April and on 18 May in Avellino). These results reflect differences in latitude and therefore differences in the environment that influence the start date of flowering. The olive tree generally starts to flower when the average temperature reaches values close to 16°C. This confirms that the phenological phases of the olive tree are mainly affected by temperature and not by photoperiodic phenomena [38] Consistent with all this, the results we obtained show a flowering period ranging from 16 to 20 days; it generally begins at irrigated stations before rain-fed stations for all the stations studied. Flowering periods are influenced by several endogenous factors (genotype, variety, nutrition, etc.) and exogenous factors (temperature, rainfall, altitude, etc.). [4, 20, 39,40].

5. CONCLUSION

The present study is an important contribution to the characterisation of the floral biology of the Moroccan Picholine variety grown in different regions of Morocco: the northern region (Tétouan, Chaouan and Ouazzane), which is characterised by a rain-fed cultivation system, and the central region of Morocco (Settat, Kelaa des Sraghna and Marrakech), which is characterised by an irrigated cultivation system. The results obtained show that the trees from the irrigated stations have higher values than those from the rain-fed stations in terms of average cluster length, which varies between 2.7 and 3.21 cm for the irrigated stations and between 2.24 and 2.86 cm for the rain-fed stations, the total number of flowers per cluster, which ranges from 15,07 to 15.60 for irrigated stations and from 13.45 to 13.75 for rainfed stations, the flowering rate from 77.88 to 90.25% for irrigated stations and from 45.94 to 64.03% for rainfed stations, the fruiting rate which varies between 0.96 and 3.21% for irrigated stations and between 0.7 and 0.84% for rainfed stations.

Flowering generally begins at the irrigated stations, followed by the other stations. For the other parameters (flower abortion rate, number of perfect flowers and fruit set rate), there is a certain similarity between all the stations studied. The northern part of Morocco has higher rainfall than the south, but rainfall is irregular and the dry season is longer. The fact that the rainfall system is dependent on rainfall rates and their distribution throughout the year could explain the poor results obtained in the northern stations compared with those in the centre, which are irrigated. In the latter, low rainfall is compensated for by irrigation, which justifies the high percentages of most parameters in these stations. It would therefore be interesting to think about an irrigation system that is suited to the mountainous terrain in the north of the country and that can use water without wasting it to improve yield rates. This is because olive growing is currently a means of subsistence for the local population, which could be developed to improve their standard of living.

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