RESEARCH
www.commprac.com
ISSN 1462 2815

OLIVE GROWING SYSTEM AND POMOLOGICAL CHARACTERISTICS OF THE PICHOLINE OLIVE (OLEA EUROPEAE L.) VARIETY GROWN IN NORTHERN AND CENTRAL MOROCCO

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

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

DOI: 10.5281/zenodo.12705084

Abstract

The Moroccan olive sector is characterized by a great variety of varieties, of which Moroccan Picholine is the dominant variety with nearly 96% of the crops. The objective of this work is the pomological characterization of olives and nuclei of the Moroccan Picholine variety grown in two major regions. The northern region represented by three stations (Tetouan, Chaouan and Ouazzane) and the central region represented by the stations of Settat, Kelaa of the Sraghna and Marrakech. At each site, five trees were sampled with 40 fruits collected per tree. Eleven quantitative characters related to the weight, size and shape of olives and stones are considered and then an indirect estimate of the oil content through the analysis of the pulp percentage (PP) is made. The results obtained have shown that Moroccan Picholine differentiates in the stations studied according to a gradual change in size and of productive potential, the characters related to the form play a secondary role in this differentiation. The olives are large in the Kelaa Sraghna and Marrakech stations, and small in the northern Moroccan stations (Ouazzane and Tétouan). At the other stations (Chaouan and Settat), olives are characterized by an intermediate size. This is explained by the environmental conditions, especially those related to the climate, but also by the nature of the cultivation system. The irrigated system shows larger olives and higher oil content compared to the rain system. These results are in line with the results found during the previous agricultural association (2022/2023) which confirms that the irrigated cultivation system gives good results as regards the weight, size and oil content of the olives compared to the rain-fed cultivation system.

Keywords: Olive Tree, Moroccan Picholine, Regions, Diversity, Climate, Culture System, Pomological Criteria, Oil Content.

1. INTRODUCTION

The olive tree is a plant species of the Mediterranean region par excellence [1]. It is characterized by a great variety in the different countries of the Mediterranean basin such as Spain, France, Italy, Portugal, etc. In contrast to this situation, Morocco has an exception in Mediterranean olive landscapes with a varietal profile dominated by a single Moroccan Picholine variety locally called Zeitoun or Zeitoun Beldi [2,3]. An analysis of the genetic diversity of the olive groves of the Menara Gardens considered as conservatory of Moroccan olive cultivation heritage confirms the age of this dominance [4, 5]. A large part of the international olive heritage is preserved in two collections, one in Marrakech (Morocco) and the other in Cordoba (Spain) [6,7].

Olive trees cover more than 11 million hectares in 47 countries on five continents. The first harvest takes place between October and April in the northern hemisphere, and the second harvest takes place between April and July in the southern hemisphere. In fact, 98% of world production is concentrated in the Mediterranean basin. Olive oil is currently consumed in more than 160 countries. In 2012, 3.1 million tonnes of olive oil were produced and consumed, or 1.7% of the 184 million tonnes of edible fat [6,8]. It is therefore a strategic sector because it plays a very important economic role internationally [7, 9]. Through successive civilizations in human history, olive oil has retained its important role in the diet of populations in Mediterranean countries [10].

In Morocco, the olive tree is the main fruit species because it occupies large areas. Olive cultivation is currently expanding considerably, with a continuous increase in olive cultivation areas from 350,000 ha in 1992 to 640,000 ha in 2005 and 930,000 ha in 2011 [11] to 1,220,000 ha in 2020 [12]. Olive trees in Morocco play a very important socio-economic role because their cultivation contributes greatly to the creation of agricultural incomes. The table olive industry is beginning to develop, with a total production of up to 2,500,000 tonnes per year, which makes Morocco the second largest exporter of table olives in the world after Spain. In addition, Morocco is the world's sixth largest producer of olive oil with a total olive oil production of 330,000 tones per year, of which approximately 33.33% is exported [13, 14].

In the olive tree a number of morphological, physiological and agronomic criteria show great variability between varieties. The main criteria studied include the shape, size of the fruit [6, 7] oil content, and relative levels of fatty acids [15, 16].

The study of pomological criteria forms the basis for the classification and identification of a large number of varieties. These criteria form the basis of a characterization methodology published by the International Olive Council (IOC). In order to improve the desired agronomic characteristics, it is necessary to reveal the production potential of cultivars in the face of rapidly growing domestic demand and an increasingly demanding international market. The cultivars that are requested are those characterized by a large fruit with a high proportion of pulp relative to the nucleus [17, 17, 16, 19].

2. MATERIALS AND METHODS

2.1 Study Stations

We selected six study stations, three in the northern region (Tetouan, Chefchauan and Ouazzane) and three in the central part of the country (Settat, Kelaa des Sraghna and Marrakech). This study was carried out during the agricultural association 2023/2024.

The northern region occupies most of the western and central Rif Range, from the Strait to Ouergha in the south, and does not include Atlantic plains and plateaus [40]. From the point of view of the environment, the region occupies a territory characterized by a physical environment with reliefs sufficiently accentuated and encased, to satisfy the criterion of partitioning which defines the mountain and isolates these populations. The climate is relatively favourable and characterized by humidity and relative warmth [20, 21] with rainfall greater than 450 mm [22]. From a biogeographical point of view, we find ourselves in an area of intersection of several bioclimatic influences and regions, hence its interest for biodiversity because it is recognized as a hot spot of Mediterranean biodiversity notably by the high rate of endemism of its flora [23,24]. The main features of traditional agro-ecosystems in this area are an agro-sylvo-postoral production system, with food-based agriculture, a wide diversity of low-yield hardy crops, and the predominance of micro-areas (< 0.5 ha) and small-scale property (< 5 ha) [25, 26].

For the Settat region, which belongs to the edge of the Chaouia plain plateau, it is characterized by a rainfall of the order of 372 mm/year and an average annual temperature of 18 ° C [27, 28]. The crop is dominated by cereals such as wheat and barley, legumes (lentils), forage crops (oats, white lupins) and arboriculture such as grenadier, fig and vines. The largest area of this region is occupied by calcium-magnetic soils (31%) followed by poorly developed soils (23.4%). Small areas are occupied by iron sesquioxide soils (7%) and vertisols (7%) [29, 30].

The region of Marrakech Safi, located in the western central part of the country with an arid to semi-arid climate, is undergoing a series of climate and environmental changes. The climate of this region is influenced by three fundamental factors: Presaharian latitudes, high mountain altitudes and the influence of the Atlantic Ocean. This climate is characterized by maximum temperatures around 38 ° C and minimum temperatures around 4.9 ° C and 80% of the region has an average temperature of about 18 ° C [31]. Rainfall varies from year to year; they range from 190 mm on the plains to 650 mm in mountainous areas [32]. In this region the main driver of economic activity is agriculture, which holds 22% of the country's useful agricultural area (SAU). Which classifies it in the first position seen the importance of this surface. The SAU of the region represents 48.6% of its total area estimated at1 904 363 hectares. By province, Kelaa of the Sraghna represents 31% followed by Safi 30% and finally Chichaoua 15%. Irrigated soils are of the order of301 277 haalmost 16% of the regional SAU and 24% of the SAU irrigated at national level. From an agricultural point of view, the region rather adopts an agro-sylvo-pastoral system where cereal crops dominate with almost 78% followed by fruit plantations 9.5% then forage crops 1.8% and vegetable crops 1.2% [33].

Climate data from the stations studied (Table 1) were compiled [34, 35] to highlight their variations according to the North-South gradient. Similarly, the geographical data (Table 1, Figure 1) make it possible to locate the various study stations. The map of their location (figure. 1) was made by using the 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

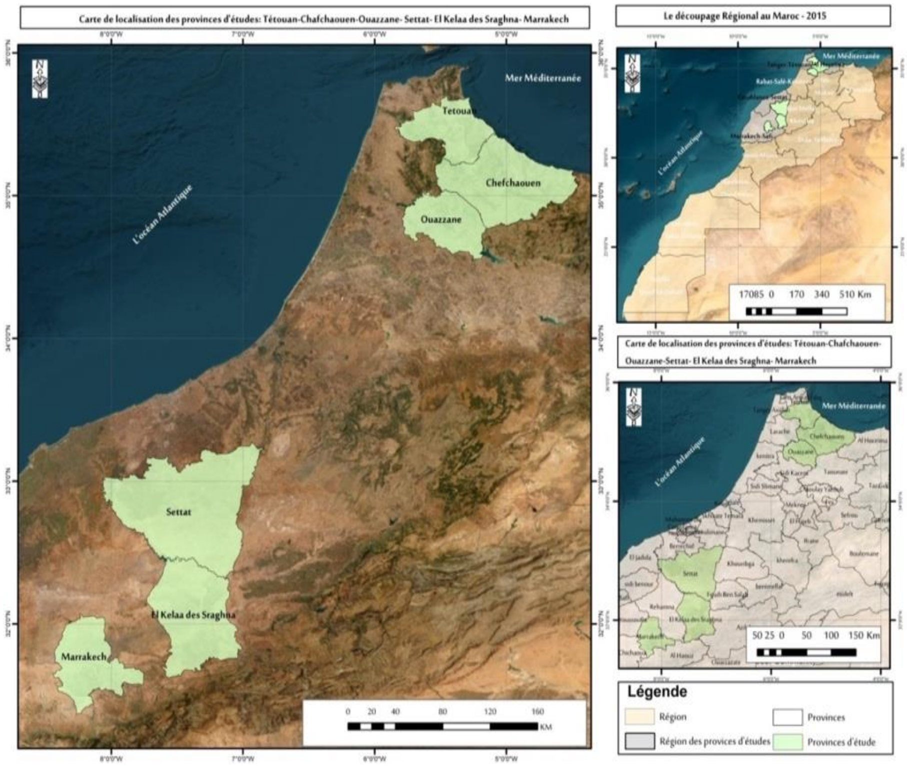

Figure 1: Location of Study Stations (Ourselves, 2023)

2.2 Sampling

The variety studied is Moroccan Picholine. Sampling was carried out at six stations, three at the northern level (Tetouan, Chefchauan and Ouazzane) and three at the central level (Settat, Kelaa of Sraghna and Marrakech) (table 1). For each station, 5 trees are considered, and for each tree, 40 fruits are taken for morphological and pomological characterization.

The measured parameters are the weight, length, and width of the fruit and pits. These allow for a quantitative evaluation of the fruit's and kernel's appearance, namely shape, size, and potentially indicating oil content. Other evaluations were conducted through the relationships among these measurements (Table 2). For this, the flesh was removed by hand using an iron sponge. The pits were then washed thoroughly and air-dried on paper overnight.

Table 2: Measured Characters and Their Codes

Organ	Character measured	Code	Unit
Fruit	Mass	FM	g
	Length	FL	mm
	Breadth	FW	mm
	Length/width	FL/FW	…
	Percentage of flesh	PP	%
Core	Mass		g
	Length		mm
	Width	CW	mm
	Length/width	CL/CW	...
Report	Length of fruit over length of kernel	FL/CL	…
	Mass of the fruit on mass of the kernel	FM/CM	…

2.3 Statistical Analysis

The data obtained were subjected to a variance analysis in order to distinguish the trees within and between stations, and a comparison of the means (New Man and Keuls test at 5%) was applied in cases where there were significant differences. The quantitative variables were subjected to the principal component analysis and the hierarchical clustering method, in order to demonstrate the degree of similarity between 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 was: GenStat (18th edition of the product SNI) for ACP, hierarchical clustering (CAH) and SAS (SAS ® OnDemand for Academics) for variance analysis.

3. RESULTS

3.1 Fruit Mass Character (MF)

Results show that there is no significant difference in fruit mass between trees at the same site except at the Ouazzane site with a coefficient of variation (cv) of 41.30% and the Tetouan site with a cv of 16.32%; which would indicate the effect of the genotype at these stations. The rest of the stations show a CV between 2.85 and 9.92%. Between the stations, a small significant variation is noted with a cv which does not exceed 14.46% (FIG. 2). On the basis of these results, it is possible to classify the various stations according to the weight of their fruits. For this, the [18] scale (1997) is used: If the weight of the fruit is less than 2 g, the fruit is said to be reduced, if the weight is between 2 and 4 g the fruit is medium, between 4 and 6 g the fruits are large and if the weight is greater than 6 g it is said that the fruits are very large.

The stations at Marrakech (4.76 g) and Kelaa of the Sraghna (4.52 g) have high weight fruits. Unlike Chaouan (3.81 g), Settat (3.70 g), Ouazzane (2.53 g) and Tetouan (2.48 g) stations with medium weight fruit. However, the statistical study allowed us to distinguish three groups by fruit weight (Figure 3):

- Group 1: Marrakech (4.76 g) and Sraghna Kelaa (4.52 g).
- Group 2: Chaouan (3.81 g) and Settat (3.70 g).
- Group 3: Ouazzane (2.53 g) and Tetouan (2.48 g).

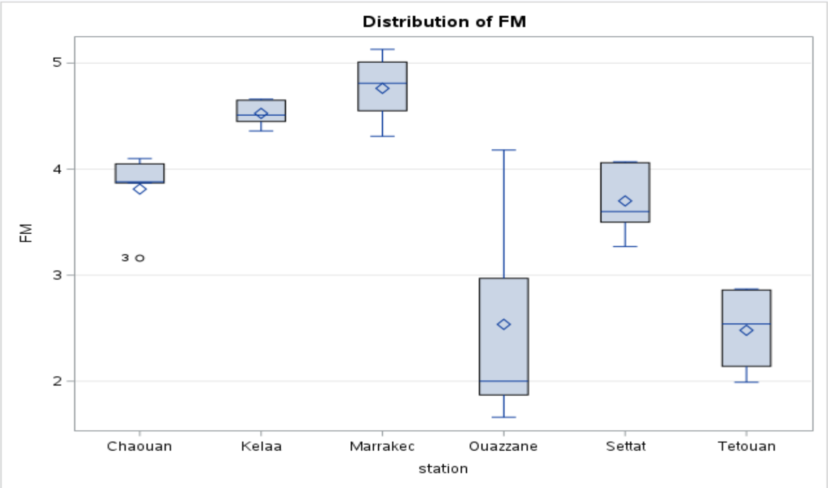

Figure 2: Distribution of Fruit Masses in Each Station

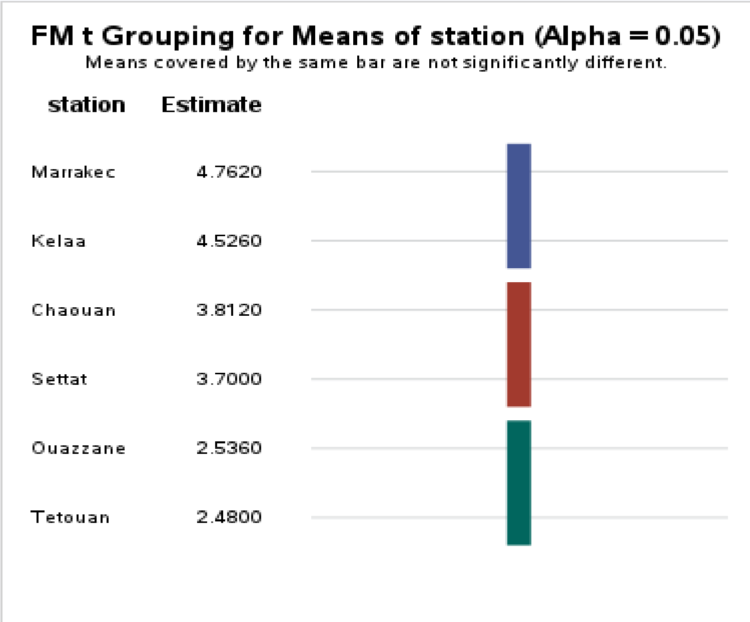

Figure 3: Station Groups by Fruit Weight

3.2 Core Weight Character (CM)

The results obtained show that there is no significant difference in the mass of the nucleus between the trees of the same station (no effect of the genotype), as well as for the stations with a cv not exceeding 5.47% (FIG. 4). On the basis of these results, it is possible to classify the various stations according to the weight of their cores. For this, the [18] scale (1997) is used: If the weight of the fruits is less than 0.3 g, the nuclei are said to be reduced, if the weight is between 0.3 and 0.45 g, the nuclei are average and if the weight is greater than 0.45 g, it is said that the nuclei are very high.

All sites studied had large nuclei ranging in weight from 0.63 to 0.79 g. Statistical analysis allowed us to distinguish two major groups according to the weight of the nuclei (Figure 5):

- Group 1: Marrakech (0.79 g), Sraghna Kelaa (0.78 g) and Settat (0.74 g).
- Group 2: Tetouan (0.68 g), Ouazzane (0.67 g) and Chaouan (0.63 g).

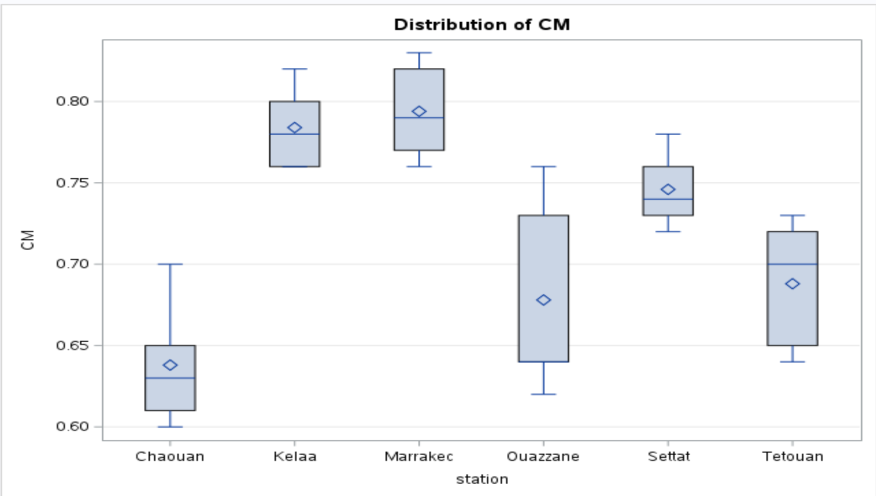

Figure 4: Kernel Mass Distribution in Each Station

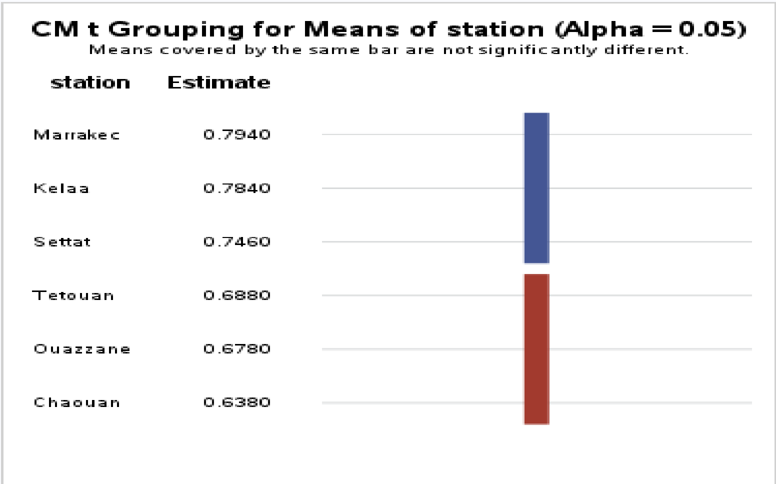

Figure 5: Station Groups by Kernel Weight

3.3 Character related to Mass of Fruit to Mass of Nucleus (FM/CM)

The coefficient of variation (CV) for the FM/CM ratio revealed minimal significant differences between trees within each station, with CVs generally ranging from 1.55% to 10.95% across all stations, except for Ouazzane (CV exceeding 31%). This suggests a stronger influence of genotype on the FM/CM ratio at the Ouazzane station. Similarly, a small, but significant, difference was observed between stations (CV of 12.35%), indicating some variation across the studied regions (Figure 6). The FM/CM ratio itself displayed limited variation between stations. Irrigated stations (Settat, Kelaa des Sraghna, and Marrakech) exhibited ratios between 5.01 and 6.08, while rain-fed stations in the north ranged from 3.58 to 5.97. Statistical analyses further identified four distinct groups based on the FM/CM ratio (Figure 7):

- Group 1: Marrakech (6.08) and Chaouan (5.97)
- Group 2: Kelaa of the Sraghna (5.81)
- Group 3: Settat (5.01)
- Group 4: Ouazzane (3.66) and Tetouan (3.58).

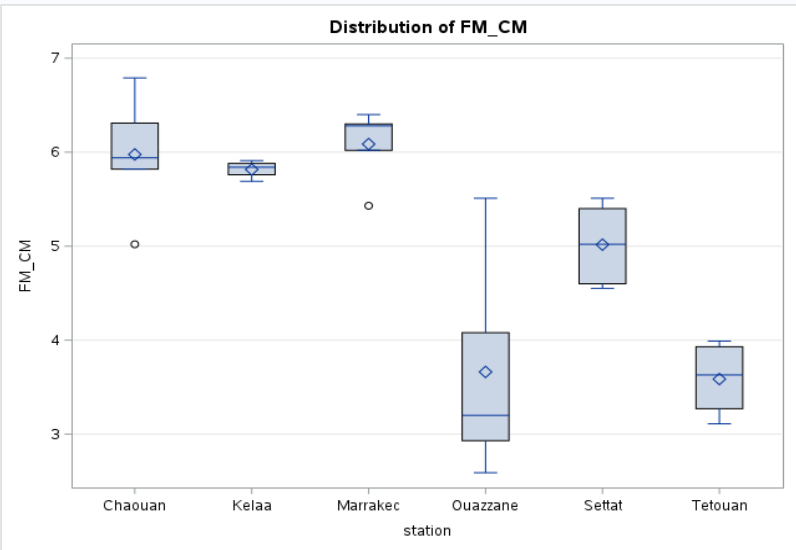

Figure 6: Distribution of FM/CM Ratio by Station

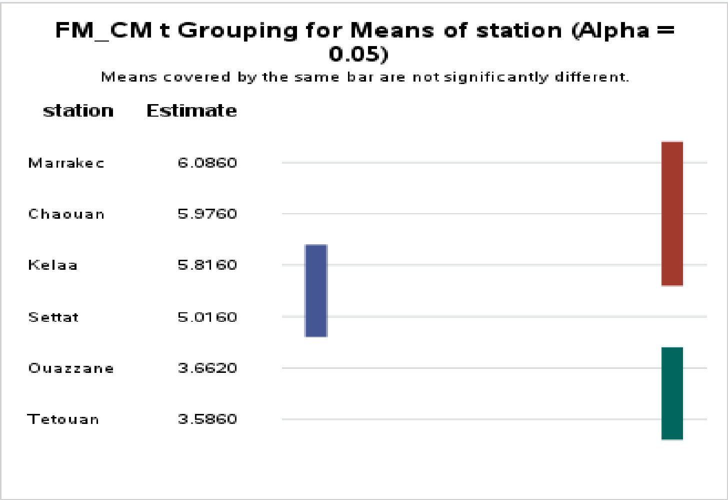

Figure 7: Groups of different Stations by FM/CM Ratio

3.4 Character Related to the Length to Width Ratio of the Fruit (FL/FW)

Concerning this character, the results obtained show that there is no significant difference between the trees of the same station. The stations studied are characterized by a very low coefficient of variation which does not exceed 4.05% (Figure 8).

The calculation of the length-to-width ratio of the fruits (FL/FW) gives an idea of the shape of the fruits of the different stations studied. The more this ratio is less than 1.25, the more spherical the shape, if this ratio is between 1.25 and 1.45 the shape is ovoid, and if this ratio is greater than 1.45 the shape is elongated.

Settat, Marrakech, Kelaa of the Sraghna and Chaouan have ovoid fruit with an FL/FW ratio of 1.34 to 1.40; for the rest of the stations, Ouazzane and Tétouan have slightly elongated fruit with a ratio of 1.47 to 1.48. Two major groups were identified (Figure 9):

- Group 1: Tetouan (1.48) and Ouazzane (1.47).
- Group 2: Chaouan (1.40), Kelaa of Sraghna (1.38), Marrakech (1.34) and Settat (1.34).

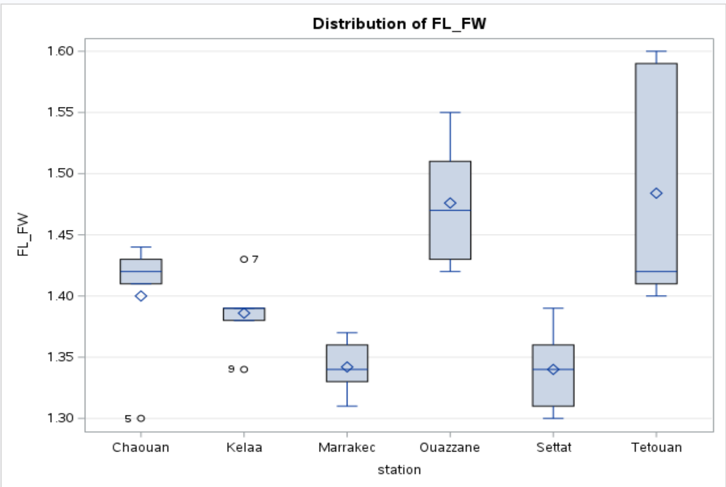

Figure 8: Distribution of the FL/FW Ratio in Each Station

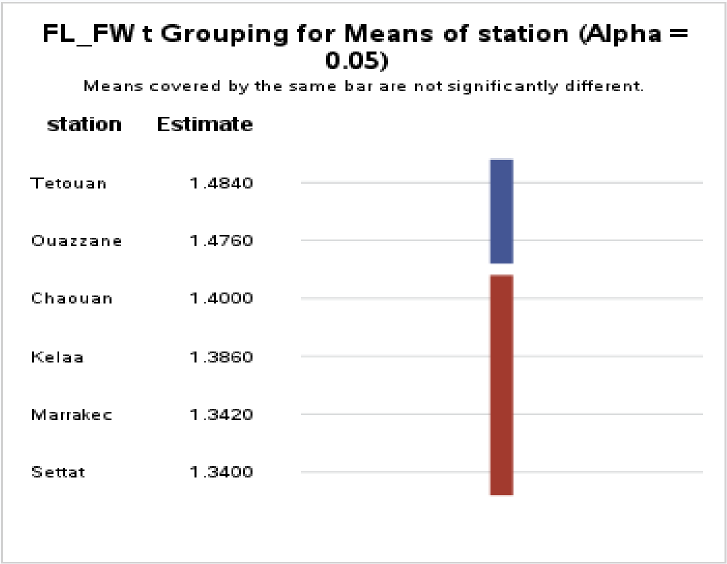

Figure 9: Groups of Different Stations According to the FL/FW Ratio

3.5 Character Related to Kernel Length to Width Ratio (CL/CW)

For this character, the results obtained show that there is no significant difference between the trees of the same station. However, the various stations studied have a very small significant difference whose coefficient of variation does not exceed 4.74% (FIG. 10).

With regard to the shape of the nuclei, if the CL/CW ratio is less than 1,4 the shape is called spherical, if CL/CW varies between 1,4 and 1,8 the form is ovoid, if this ratio is between 1.8 and 2.2 the shape is elliptical and if this ratio is greater than 2.2 the shape is said to be elongated. Based on these standards [18], all the stations have elliptical cores because this ratio varies between 1.8 and 2.2 for all the stations studied. Based on statistical analyses, three groups were identified (Figure 11).

- Group 1: Chaouan (2, 13)
- Group 2: Marrakech (2.11), Ouazzane (2.05), Kelaa of Sraghna (2.03) and Tetouan (2.02)
- Group 3: Settat (2.01).

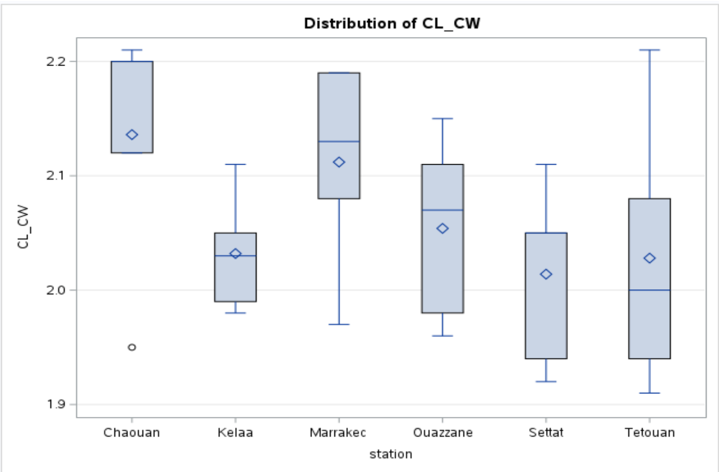

Figure 10: Distribution of the LC/WC Ratio in the Various Stations Studied

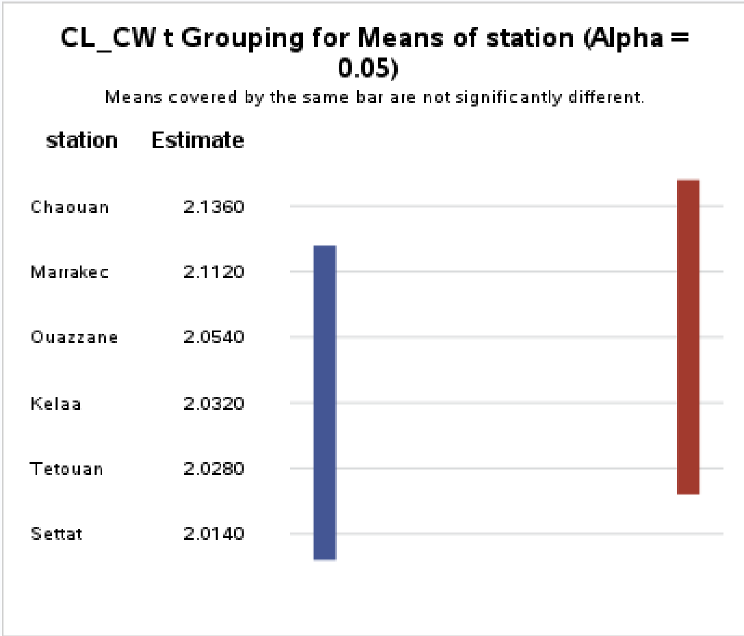

Figure 11: Groups of Different Stations According to the LC/WC Ratio

3.6 Character Related to Length of Fruit to Length of FL/CL Kernel

The results obtained show that there is no significant difference between the trees of the same station and the stations between them (low coefficient of variation 3.65%) (FIG. 12). According to statistical analyses, four groups were distinguished for this character (Figure 13):

- Group 1: Marrakech (1.42) and Sraghna Kelaa (1.40)
- Group 2: Chaouan (1.37)
- Group 3: Settat (1.34)
- Group 4: Tetouan (1.22) and Ouazzane (1.21).

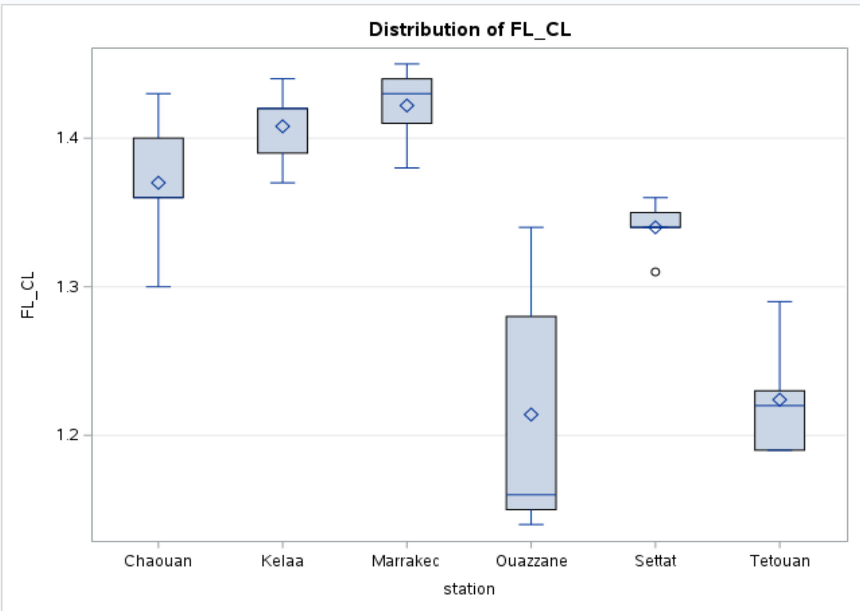

Figure 12: Distribution of the FL/CL Ratio in the Various Stations Studied

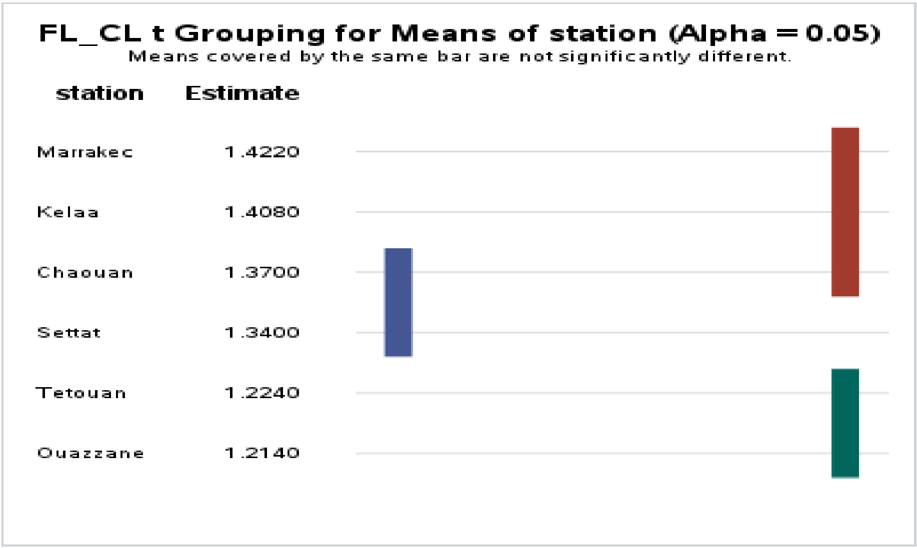

Figure 13: Groups of Different Stations According to the FL/CL Ratio

3.7 Percentage of Flesh (PP)

There was no significant difference between the trees at the same station except at the Ouazzane station, which had a low coefficient of variation not exceeding 11.45%. Similarly, the stations show no significant difference between them (figure 14).

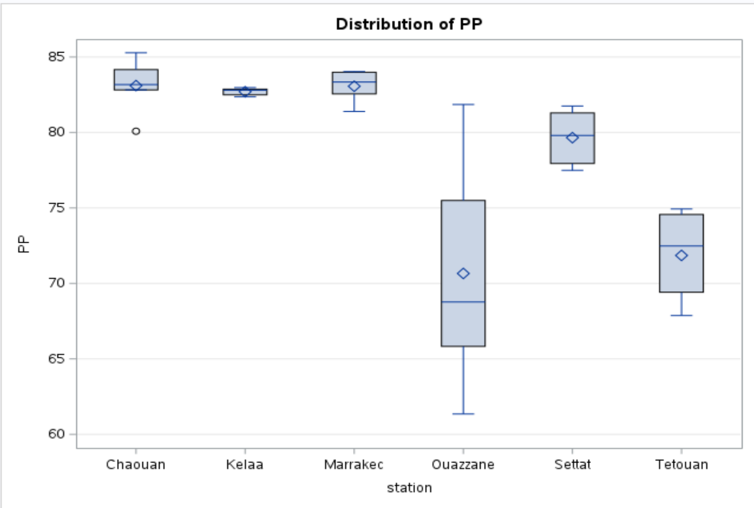

Figure 14: Percentage Distribution of Flesh (PP) by Tree at Each Station

The most common indirect method for assessing olive oil content relies on the percentage of flesh (PP), considered the most reliable indicator. Other parameters, such as flesh-to-pit mass ratio (MF/MN) and flesh-to-pit length ratio (LF/LN), also indirectly estimate oil content by reflecting the relative amount of flesh in the olive. While these methods don't directly measure oil content, they are valuable for comparing the oil production potential across different stations in this study. Based on the flesh percentage (PP) results, the stations can be classified into two main groups (Figure 15).

- Group 1: Chaouan (83.10%), Marrakech (83.06 %), Kelaa of Sraghna (82.69 %) and Settat (79.65 %)
- Group 2: Tetouan (71.85 %) and Ouazzane (70.65 %)

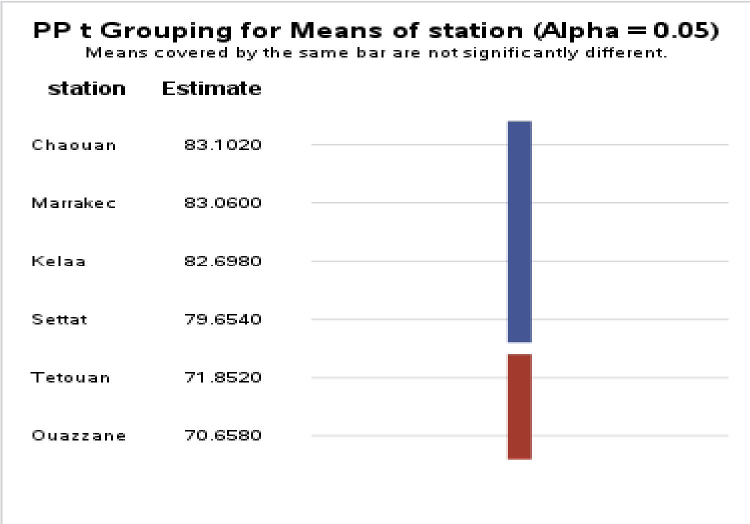

Figure 15: Percentage of Flesh (PP) at Stations

3.8 Characters Related to the Size of Fruit and Stones:

The mean values of several parameters – fruit weight (FM), length (FL), and width (FW), and pit weight (CM), length (CL), and width (CW) – allow us to identify size differences between stations (Figures 16 and 17). Marrakech and Kelaa des Sraghna take the lead with the largest fruits, averaging up to 4.76 g in weight and 23.74 mm in length. Settat and Chaouan follow with medium-sized fruits ranging from 3.70 to 3.81 g and 21.16 to 21.42 mm, respectively. Finally, Tetouan and Ouazzane have the smallest fruits, averaging between 2.48 and 2.53 g and 19.04 to 19.16 mm in length. A similar trend is observed for pit size. Marrakech, Kelaa des Sraghna, and Settat have the largest pits, generally weighing between 0.74 and 0.79 g and measuring 15.82 to 16.82 mm in length. The remaining stations (Tetouan, Chaouan, and Ouazzane) have medium-sized pits ranging from 0.63 to 0.68 g and 15.62 to 15.66 mm in length. (Table 3).

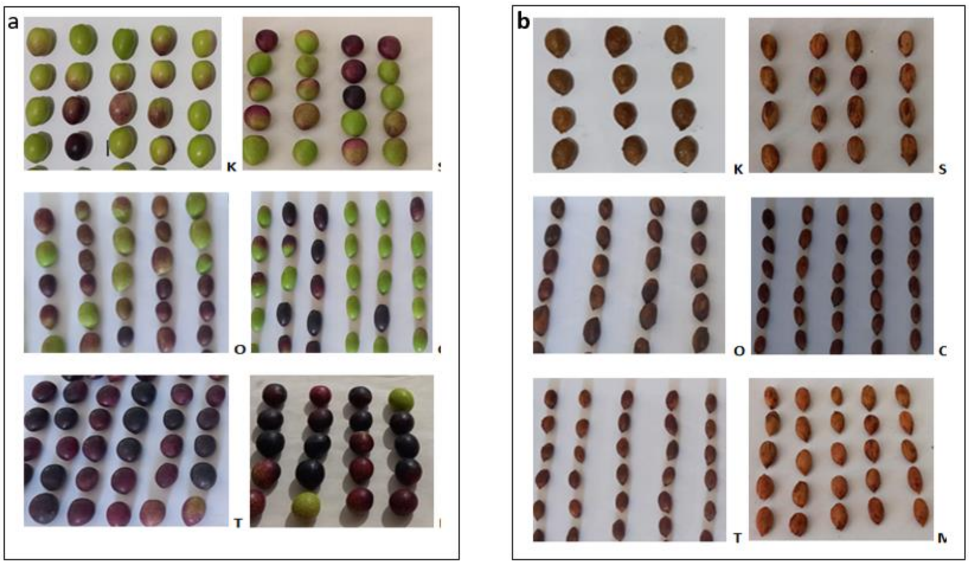

Figure 16: Different Forms of the Fruits (a) and Nuclei (b) of the Stations Studied; K: Kelaa, S: Settat, O: Ouazzane, C: Chaouan, T: Tetouan, M: Marrakech

ISSN 1462 2815

Table 3: Different Parameters Studied in Each Station

	FM	CM	FL	CL	FW	CW	FM/CM	PP
Tétouan	2.48 c	0.68 b	19.16 c	15,66 c	12,96 d	7,74 bc	3.58 c	71.85 b
Chaouan	3.81 b	0.63 b	21,42 b	15,62 c	15.30 c	7,32 d	5,97 a	83,10 a
Ouazzane	2.53 c	0.67 b	19.04 c	15.64 c	12,96 d	7,62 cd	3.66 c	70.65 b
Settat	3.70 b	0.74 a	21,16 b	15,82 bc	15,80 bc	7,88 ab	5,01 b	79.65 a
Kelaa	4.52 a	0.78 a	23,32 a	16,60 ab	16,90 ab	8,18 a	5,81 ab	82,69 a
Marrakech	4.76 a	0.79 a	23,74 a	16,82 a	17,72 a	8 ab	6.08 a	83.06 a

3.9 Structuring of Polymorphism and Differentiation of Stations

The dendrogram shows four clearly distinct groups that contrast stations with good pomology parameters to other stations. It is important to note that the first group and the second group which combine the Kelaa stations of the Sraghna and Marrakech (irrigated growing system) and some trees of Chaouan have the right pomology parameters. While the third group, which includes two Settat trees, three Tetouan trees and one Ouazzane tree (rain-growing system), has medium pomology parameters, and the fourth group, which includes three Ouazzane trees and two Tetouan trees, has low pomology parameters (Figure 17).

The discriminating factor analysis made it possible to verify the structuring demonstrated by the hierarchical analysis. The factorial plane (1,2) exhibits good structuring of the variability up to almost 94% of the variance. The discriminating factor axis 1 encompasses 70.61% of the variance, which corresponds to stations with low pomology parameters. This axis is defined by the variables of the length-to-width ratio of the fruit and the length-to-width ratio of the core. While the discriminating factorial axis 2 represents 23.85% of the variance and is explained by the percentage of flesh, the ratio of fruit length to nucleus length and the ratio of fruit mass to nucleus mass (Figure 18).

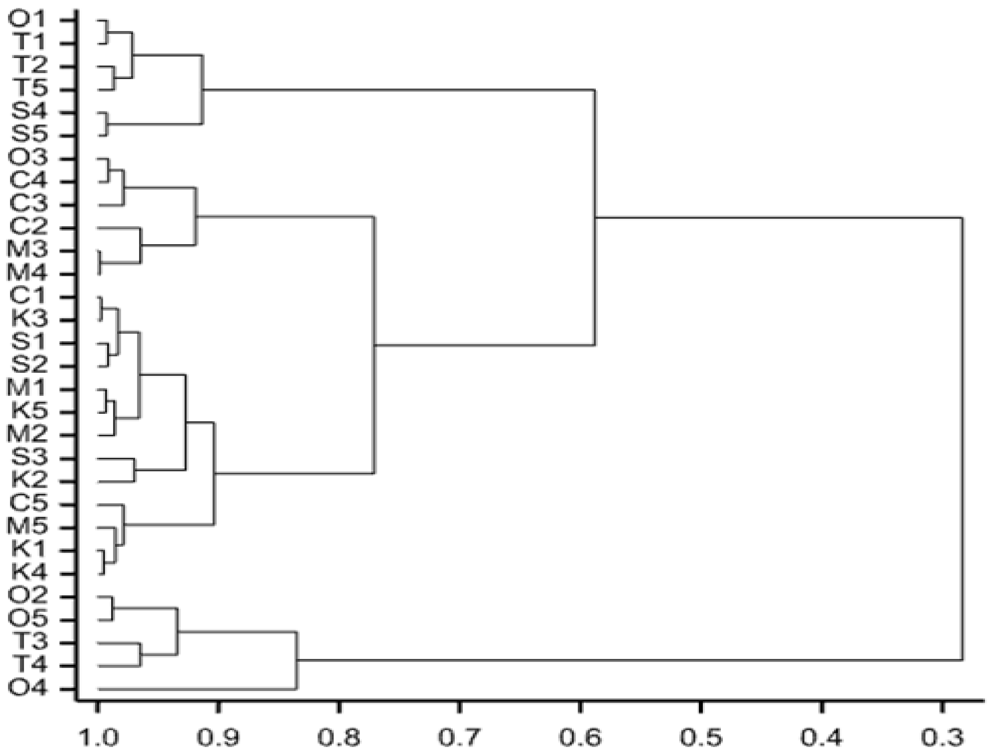

Figure 17: Hierarchical Classification Dendrogram of the Various Stations

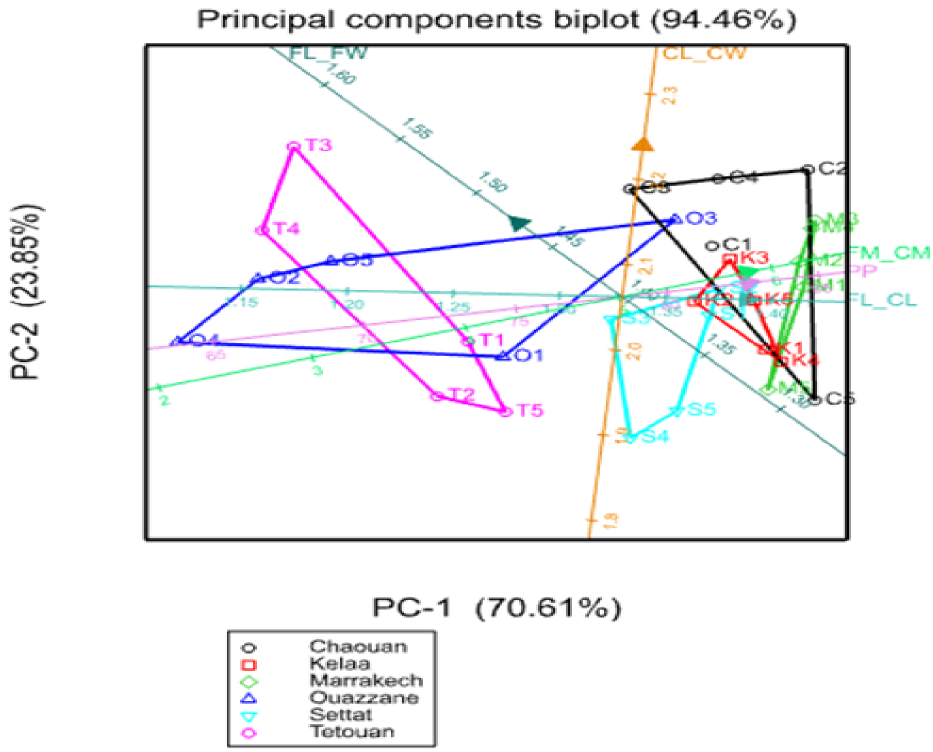

Figure 18: The Discriminating Factor Analysis of the Different Stations

4. DISCUSSION

The average weight of the fruit is a varietal character. The genetic heritage of a variety largely influences the weight, shape, and size of fruits and kernels, followed by the degree of maturity, as well as the cultural conditions involved in determining these parameters [10, 27].

In the northern region (Tetouan, Chaouan, Ouazzane and Taounate) Morocco, [5] found that the fruit weight of Moroccan Picholine does not exceed 3.44 g with a core weight of 0.53 g which is consistent with our results in this region which generally varies between 2.48 and 3.81 g for fruits and between 0.63 and 0.68 g for the weight of stones. In the Meknès region, in an irrigated plot [26] found that the fruit weight of the Moroccan Picholine variety is 3.94 g with a core weight of 0.61 g. These results are consistent with our findings in the northern region where fruit weights ranged from 2.48 to 3.81 g and nucleus weights ranged from 0.63 to 0.68 g. [14] found that the variety Haouzia, Menara and Dahbia (which are clones of Moroccan Picholine) in the Ouazzane region in a rain-growing system these varieties have a fruit weight of between 2,7 and 3,8g and in Taounate, in an irrigated system, the weight of the fruit varies between 3 and 3,7g concerning the weight of the stones in rain system the weight of these varieties varies between 0.46 and 0.53 g and in irrigated between 0.45 and 0.56 g. According to [12], Moroccan Picholine is characterized by an average weight (weight varies between 2 and 4 g) in terms of fruit and kernel weight, which is consistent with our results found at most of the stations studied.

[13] In Tunisia for the Chemlali variety found that the average weight of fruit ranged from 0.6 g for plots where irrigation was interrupted for 5 years to 1.4 g for plots irrigated continuously. Indeed [11] found that irrigation has a positive effect on the weight of olives and essentially on the weight of the fleshy part; however, they noted

an increase of 20 to 25 per cent in the weight of the samples in the irrigated system. [19] Found in a rainfall growing system that the Boof variety (indigenous) in Albania has a fruit weight of 4.14 g and 0.58 g for the kernel and variety Freng (indigene) has a fruit weight of 2.28 g and 0. 31 g for the kernel weight, both of which are older than 500 years. [39] Found in Turkey, in an irrigated cultivation system during the dry period, that the variety Ulamş ş and Gölcük has a fruit weight of 3.30 g and 2.50 g respectively.

Also in this context, [31] found that the best values were recorded for Moroccan Picholine and Haouzia with weights of 4,35g and 3,35g respectively for fruit and 0,91 g and 0,80 g for the weight of stones, whereas the Arbéquine variety had the lowest fruit weight (1.95g) and a core weight of 0.45 g. The other varieties had intermediate values of 2.95g and 2.06 g for fruit weight and 0.73 g and 0.45 g for stones weight for Menara and Arbosana in the Beni Mellal region. These results are rather similar to those found at the Marrakech and Kelaa Sraghna irrigated sites with fruit weights ranging from 4.52 to 4.76 g and nucleus weights ranging from 0.78 to 0.79 g.

For the FM/CM ratio, [14] found values ranging from 6.1 to 6.3 in the Haouzia, Menara and Sigoise varieties in a rain-growing system (Ouazzane); these values are also recorded for the Haouzia and Menara varieties in the Taounate irrigated system, unlike the Sigoise variety, where this ratio is estimated at 5.1. [26] Found in the Meknès region in a drip irrigated cultivation system a ratio not exceeding 5.43 for Moroccan Picholine. In another study in the Settat region, this ratio was 5 for the Arbequine variety, 5.3 for Koroneiki and 5.7 for Moroccan Picholine under rainfall conditions [22]. Elsewhere, in Tunisia, [2] found that the Degache variety shows a ratio of fruit mass to kernel mass (FM/CM) between 4.03 and 11.46. Also, [15] found that the four varieties, Chétoui, Chemlali, bi and Gerboui, located at three different sites in Tunisia have an FM/CM ratio that varies from 4.47 to 9.65, 2.85 to 2.75, 3.61 to 5.41 and 2.56 to 7.66, respectively. These results differ from one variety to another.

The length of the fruits and nuclei is an important criterion for pomological characterization. In Tunisia, [15] found in a rain-growing system that the Chétoui variety has a length of fruit ranging from 13,49 to 19,38 mm and a core length of 11,43 to 14,09 mm, whereas the Variety bi has a fruit length of between 13,16 and 15,22 mm and a kernel length of 10;26 to 12.16 mm and the Gerboui variety with a fruit length varies between 13.64 and 17.62 mm and the core length varies between 9.22 and 10.52 mm. [1] having worked in Algeria, found that the Limeli variety has a fruit length of 15.58 mm and a nucleus of 13.75mm and the Sigoise variety has a fruit length of 19.31 mm and a nucleus of 14.30 mm. In Morocco, [31] found in the Beni Mellal region in rainfed growing system that the Moroccan Picholine and Haouzia variety recorded the best fruit length values up to20 mmwhile Abequina and Arosana showed the lowest values 15,01 and15.43 mm respectively. For the length of the kernel, Haouzia has the highest value16, 89 mmwhile Moroccan Picholine has average values13.35 mmand Arbequin shows the lowest values10.51 mm. Furthermore, [14] found that Haouzia and Menara varieties grown in rainfall in the Ouazzane region have a fruit tongue of 21 and 21.6 mm respectively, while the nucleus length is 16.8 and 17.1 mm respectively. The same varieties grown under irrigation in the Taounate region have a fruit length of 21.8 mm for Haouzia and 23.7 mm for Menara, while the core tongue is 16.7 mm for Haouzia and 17.1 mm for Menara. These results are consistent with the results found at all sites in our study area where fruit length varied between 19.04 and 23.74 mm and nucleus length varied between 15.62 and 16.82 mm.

The length/width ratio of fruit and kernel is a criterion to be taken into account in the pomological characterization. In Tunisia, [2] found that Degache has a length/width ratio of fruit (FL/FW) of 1.34 and kernel (CL/CW) of 1.93. In Algeria, [1] found that the Limeli and Sigoise varieties had FL/FW values of 1.95 and 1.34 and CL/CW values of 2.14 and 1.84, respectively. In Morocco, [22] found in the Meknès region in an irrigated culture system that this ratio varied between 1.12 and 1.15 in the Haouzia variety and between 1.23 and 1.30 in the Dahbia variety. In addition, [26] found in the same region of Meknès in a system of taste-irrigated cultivation that the Moroccan Picholine variety has a length-to-width ratio of 0, 73 and 0.63 for the Dahbia variety, while the ratio for the Moroccan Picholine nucleus is 0.46 and 0.39 for Dahbia. Also in Morocco, a study by [14] in two stations, one in the rain system (Mjaara) and the other irrigated (Taounate), showed that in the first station the L/l ratio of the fruits varies between 1.20 and 1.26 for the two varieties Haouzia and Menara and the L/l ratio of the stones is estimated to be 2 also for the two varieties. However, in the irrigated system (Taounate), the L/L ratio of the fruit is 1.37 and 1.43 for the Haouzia and Menara varieties, respectively, and the L/L ratio of the stones is 2.2 for the two Haouzia and Menara varieties. These results are consistent with our results for all sites studied where the fruit length/width ratio (FL/FW) varies between 1.34 and 1.48 and the kernel length/width ratio (CL/CW) between 2.01 and 2.13.

The percentage of flesh (PP) is a parameter that indirectly evaluates the oil content. [5] Found that Zeitoune, Haouzia and Menara have 84%, 86% and 87% flesh in the northern Moroccan region in a rain-fed system. These results are consistent with ours, especially at Chaouan (rain), Kelaa (irrigated) and Marrakech (irrigated), where the percentage of flesh generally varies between 82.69 and 83.10%.

Under irrigation conditions, production increased significantly, with all varieties reacting positively. In fact, production showed an average yield improvement of about 14.5% [33]. The relatively low yields observed for certain varieties such as Frantoio, Hojiblanca, and Sigoise are attributed to water insufficiency, thus inducing water stress that can influence flower formation through pistillary abortions [33, 35-40].

[23] Found in an irrigated growing system that the oil contents are 25% for the Arbequine variety, 24% for Koroneiki and 21.0% for Moroccan Picholine. [24] Found in a rain-growing system that the levels are 23% for Haouzia and Menara and 18% for Arbequine. According to [14] the average oil content during 5 years of study is 20.7% for the variety Sigoise, 22.5% Haouzia and 23.5% Menara which has the highest oil contents that explain its use as a nutrient and also as a therapeutic compounds for several diseases [41,42].

5. CONCLUSION

This study contributes to the pomological characterization of Moroccan Picholine olives grown in two major regions of Morocco. Our results reveal a clear link between olive size and the cultivation system. Olives from the central stations (irrigated) were larger, heavier, and had a higher flesh-to-pit ratio compared to those from the northern stations (rain-fed). While the northern region receives more rainfall than the south, its distribution is irregular, and dry seasons are lengthening. This reliance on unpredictable rainfall patterns likely explains the smaller olive size and potentially lower oil content observed in the north. Conversely, irrigation in the central stations compensates for limited rainfall, resulting in larger fruit size, higher weight, and a greater flesh percentage. These findings suggest the potential benefits of implementing an irrigation system adaptable to the mountainous terrain of the northern region. Optimizing water use through such a system could significantly improve olive yields, thereby supporting local populations whose livelihoods depend heavily on olive cultivation. This improvement in yield could ultimately contribute to better living conditions for these communities.

References

1) Abdessemed, Boudchicha, A., Rh, & Benbouza. (2018). Agriculture Journal Characterization and identification of some Olea europaea L olive ecotypes in *Algeria*. Agriculture Journal. February 2019. http://revue-agro.univ-setif.dz/

2) Amar, F. Ben Maachia Sihem. (2015). Morpho-pomological diversity of the olive tree (OLea europaea L.) in the Degache oases (Tozeur, Tunisia). Gate, December 2014, 2-7. https://www.researchgate.net/publication/271837996

3) Ater, M., Barbara, H., & Kassout, J. (2016). Importance of local varieties, oleaster and traditional olive cultivation practices in the Chefchaouen region (northern Morocco). 121, 109–121.

4) Ater, M. Hmimsa, Y. (2013). Agrodiversity of traditional agro-ecosystems of the country Jbala (Rif, Morocco) and land products I - Introduction. Research Gate. June 2014, p. 13. https://www.researchgate.net/publication/257330182

5) Barbara, H., Terral, J.-F., & Ater, M. (2020). First Pomological Characterization of Local Olive Varieties (Olea Europaea L.) Traditional Olive Groves Of The Mountains Of Northwest Morocco. European Scientific Journal ESJ, 16 (6), 21. https://doi.org/10.19044/esj.2020.v16n6p556

6) Bellini E, Genetic Variability and Heritability of Certain Traits in Crossbred Olive Seedlings, Olivae 49 (1993) 21-34.

7) Boulouha B, R. Loussert, R. Saad, Study of the phenotypic variability of the Moroccan Picholine variety in the Haouz region, Olivae 43 (1992) 30-33.

8) Charafi J., El Meziane A., Moukhli A., Boulouha B., El Modafar C., Khadari B. (2008). Menara gardens: a Moroccan olive germplasm collection identified by a SSR locus-based genetic study. Genetic Resources and Crop Evolution, vol. 55, n. 6, p. 893-900. http://dx.doi.org/10.1007/s10722-007- 9294-6.

9) Choukrani G, Hamimsa A, Saidi ME, & Babqiqi A. (2018). Diagnostic Et Projection Future Du Changement Climatique En Zone Aride. Cas De La Region Marrakech-Safi (Maroc) Diagnosis and Future Projection of Climate Change in Arid Zone. Case of Marrakech-Safi Region (Morocco). Larhyss Journal, 36(January 2019), 49–63.

10) Cimato A., 1990. The quality of virgin olive oil and agronomic factors. Olivae,31, 20-31.

11) Dettori S, Russo G. (1993). Influence of cultivar and water regime on the volume of production and quality of olive oil. Olivae, 49, 36-43.

12) El-antari and Sikaoui. (2022). Catalogue des variétés d'olivier cultivées et autochtones du Maroc Institut national de la recherche agronomique (p. 76).www.inra.org.ma

13) Gharsallaoui, M., Zaanouni, N., & Gabsi, S. (2018). Study of variations in pomological characteristics of olive fruits following irrigation by treated wastewater (EUT) Study of variations in the pomological characteristics of olive fruits following irrigation by treated wastewater (EUT). 52(1), 3479–3487.

14) Hadiddou, A., Oukabli A., Moudaffar C., Mamouni A., Gaboun F., Mekaoui A., H'ssaini L., E.F.M. (2013). Evaluation of the production performance of 14 varieties of olive (olea europaea L.) National and Mediterranean in two contrasting cultivation systems (rain and irrigated) in Morocco. Al AwAmiA, 127, 21-43.

15) Hannachi, H., Msallem, M., Ben, S., & El, M. (2007). Influence of the geographical site on the agricultural and technological potential of the olive tree (Olea europaea L.) in Tunisia. Direct, 330, 135-142. https://doi.org/10.1016/j.crvi.2006.11.005

16) Hilali S, S. El Antri, Study of varietal polymorphism in fruiting olive cultivars in Marrakech Morocco, Olivae 50 (1994) 45- 47.

17) I.O.C (International Olive Council). (2015). International study on the production costs of olive oil. (International Olive Council), 1-40.

18) I.O.C., (1997). Methodology for Primary Characterisation of Olive Varieties, Project RESGEN-CT (67/97), EU/IOC, International Olive Council (IOC).

19) Ismaili, H. (2016). Pomological characteristics of main indigenous varieties of olive. IPA Cross Border Conference 2014 Albania - Greece, Pomological September 2014. https://doi.org/10.13140/RG.2.1.1026.9045

20) Khaloui, M. EL, & NOUR, A. (2007). Processes for the production of table olives based on Moroccan Picholine and Dahbia varieties National Programme for the Transfer of Technology in Agriculture (PNTTA), DERD, B.P: 6598, Rabat, www.agriculture.ma Bulletin produced at the Institut Agronomique et Vét. Agriculture, 037, 77-80.

21) Laouina A. (1998). The northern mountain environment: Strengths, constraints and degradation processes. In: Berriane M., Laouina A. (ed.). The development of northern Morocco: points of view of geographers. Gotha (Germany): Justus Perthes Verlag. p. 15-59. (Nahost und Nordafrika; n. 4).

22) Mahhou, A., Jermmouni, A., & Mamouni, A. (2014). Harvesting period and characteristics of olive oil of four varieties under irrigation in the Meknès region. Moroccan Journal of Agricultural and Veterinary Sciences, 5-15.

23) Mahhou A., Taiebi Z., Hadiddou A., Oukabli A., and Mamouni A. (2011). Performance and quality of production of olive varieties Arbequine, Koroneiki and Moroccan Picholine irrigated in the Settat region (Morocco). Olives, 116: 44- 58.

24) Mahhou A., Nabil Y., Hadiddou A., Oukabli A., and Mamouni A. (2012). Performance of olive varieties: Arbéquine, Haouzia and Menara in rainy conditions in the Meknès region of Morocco. Olives, 118: 03-21.

25) Medail F., Quézel P. (1997). Hot-Spots analysis for conservation of plant biodiversity in the Mediterranean basin. Annals of the Missouri Botanical Garden, Vol. 1, pp. 112-127.

26) Mekkaoui mohamed (1991). Study of Morphological, Physiological and Floral Characteristics of Two Varieties of Olivier (Dahbia and Moroccan Picholine) in the Meknes Region. AL AWAMIA (MA) ISSN: 0572-2721, (1991), No. 73, P. 64-85.

27) Michelakis N., 1992. Improving the quality of olive oil in Greece: Passing, Present and Future. Olivae,42, 22-30.

28) Ministry of the Interior, Kingdom of Morocco, D.G. des C. (2015). The Region of Marrakech-Safi MONOGRAPHIE GENERALE.

29) Mokhtari, N., Mrabet, R., Lebailly, P., & Bock, L. (2013). the bioclimate of Morocco. Review. Moroccan. Science. Agronomics. Veterinarians. (2014) 2 (1):50-66

30) Mouhtadi, I. El, AGOUZZAL, M., & GUY, F. (2014). OILCROPSANDSUPPLYCHAININAFRIA The oil sector in Africa The olive tree in Morocco. Oilseeds and Fats, Crops and Lipids, 21 (2), 21-23.

31) Omar, F., Oulaid, T., & Abdelaziz, A.I.T. M. (2019). Evaluation of the Pomological Characteristics of Olive Fruits (Olea Europaea L.) of Five Varieties Grown in the Beni-Mellal Region (Morocco). 6(1), 23–28. nternational Journal of Research in Agriculture and Forestry Volume 6, Issue 1, 2019, PP 23-28. ISSN 2394-5907 (Print) & ISSN 2394-5915.

32) Osrirhi A. ElOumri M. Moussadek R. Moatamid Z. Ambri A. Goebel W. Agricultural use of land in Settat-Rapport and Cartes- 2007.

33) Rallo, l., Martin, G.C., Lavée, S., 1981. Relationship between abnormal embryo sac development and fruitfulness in olive. J. Amer. Soc. Hort. Sci. On 1981, flight. 106, pp. 813-817.

34) Rallo L, D. Barranco, Perugia olive cultivars in Andalusia, Acta Hortic. 140 (1983) 169–170

35) Riera, F.J., 1941. Pleomorfismo y esterilidad ovaria del olivo. Anales de la E. de P.A. y de E.A.. Vol.1.Facs. I y II Barcelona.

36) Saidi, M.E., Boukrim, S., Finguire, F., & Ramromi, A. (2012). The surface flows on the high atlas of Marrakech case extreme flows. Larhyss Journal, 10 (June 2014), 75-90.

37) Talantikite M, H. Ait Amar, acid composition of olive oils of the three cultivars in Algeria, Olivae 23 (1988) 29-31

38) Trigui A, M. Msallem, Olivier de Tunisie, Catalogue of Indigenous Varieties and Local Types, V1, IRESA, Institut de l'Olivier, Tunisia, 2002.

39) Uçkun, A. A. (2021). Investigation Of The Effects Of Seferihisar Region Climatic And. Gate, December, 16. t: https://www.researchgate.net/publication/356904555

40) Zouggari A., Vignet-Zunz J. (coord.). (1991). Jbala: History and Society. Paris: CNRS, Casablanca Maroc: Wallada.

41) Chakit M, El Hessni A, Mesfioui A. Ethnobotanical Study of Plants Used for the Treatment of Urolithiasis in Morocco. Pharmacognosy Journal. 2022;14(5):542–547. doi: 10.5530/pj.2022.14.133.

42) Website https://fr-be.topographic-map.com/map-1zzxm2/Ben-Guerir/?center=32.11515%2C-7.54761&zoom=10&popup=32.12329%2C-7.57851