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Identification of the eventual relationships between soil parameters and oil characteristics of olive oil groves cultivated in Tunisia

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Abstract - In Tunisia, olive groves are mainly made up of three reputed varieties Chemlali, Chetoui, and Chemchali. Recently, Arbosana and Arbequina varieties are introduced. In this work, we aim to i) characterize soils of these groves ii) characterize and compare the produced olive oil of each variety iii) and elucidate the eventual correlations between various soil properties and olive oil biochemical and sensory characteristics. Thus, soil and olive oil samples were gathered (10 from Chetoui variety, 4 to the Chemlali variety, 2 from Chemchali variety, 6 to the Arbosana and Arbequina varieties, and 2 to the Rkhami variety). The obtained results show that mainly, olive groves soils are moderately salty, with alkaline pH, with low organic matter content, and have high limestone content. Carotenoids concentrations were the highest for Chemchali and Chemlali varieties and the lowest for Arbosana and Arbequina varieties. Chlorophylls concentrations are the highest for the Chetoui variety and the lowest for the Chemchali variety. For fruity taste intensity, we did not find significant variation between varieties except for Chemchali oil which is slightly lower. Regarding the fatty acids composition, oleic acid is the most dominant with a proportion over 60% for all the olive oils and it is close to 70% especially for the Arbosana and Arbequina varieties, it was followed by linoleic and palmitic acids. The lowest value of palmitic acid was identified in the Chetoui variety. Linear regression tests between soil parameters and olive oil characteristics have shown significant correlations between total limestone and palmitic acid for local varieties with a negative correlation; organic matter and carotenoids and chlorophylls contents for all varieties and for Arbosana and Arbequina, with a positive correlation. Finally, a positive correlation between electrical conductivity and palmitic acid and a negative correlation between electrical conductivity and linoleic acid was identified.

Keywords: olive oil, chemical composition, soil analyzes, correlation, Tunisia.

1. Introduction

Despite the impressive volume of their aerial organs, olive trees are generallysatisfied with little nutrients and wateramounts. They arerecognized as a good land cover in arid areas, offering agreen land all over the year. Besides this primordial ecological role, the olive tree produces oil. Tunisia is a well ranked olive oil producer and it is the third worldwide exporter. Olive farming activity offers30 to 40 million working days per year, which equal to 20% of agricultural employments (Karray et al, 2011). Olive oil contributes to around 50% of national exports of agri-food products (Grati-Kammoun and Laroussi, 2013). Besides, itis widely consumed locally and appreciated for its nutritional value and health benefits for the human body. In fact, it contains, 99.9% of lipids, mainly composed of monounsaturated fatty acids which give it, along with phenols and vitamin E, its antioxidant properties (Merouane et al, 2014). From north to south, the olive trees are mainlycultivated, underrain fed conditions, over an area of 1.8 million hectares (Jackson et al, 2015). Olive trees are planted on various types of soils; most of them are highly carbonated and could not besuitable for other fruit trees crops. Nevertheless, cultivated olive varieties differ from one region to another. Indeed, the Chetoui variety is particularly cultivated in the north region. The Chemlali variety is mostly cultivated in the center of the country and in the south-east, and thisvariety is basically encountered in the south-west region. It is also interesting to note the reputation of the Rkhamivariety which is cultivated locally in Cap Bon region. In addition, two Spanish varieties, Arbosana and Arbequina, have been introduced and cultivated mainly under irrigated conditions and in crop mix system.

Olive oil's commercial value is mainly assessed based on its sensory and biochemical characteristics.

The ecological environment, with its bioclimatic and edaphic components, should have a direct impact on the olive oil quality. Soil has, for example, a direct effect on the growth of olive trees and on the olivefruit production (Ben Rouina et al, 2007). Thus, the variation in soil properties dealing with the levels of limestone, salinity, pHand soilorganic matter where olive oil trees are growing, could affect the quality of the end product. This study aims to i) characterize various olive trees groves soils, ii) characterize and compare between the produced olive oil of each variety iii) elucidate the eventual correlations between various soil properties and olive oil biochemical and sensory characteristics.

2. Materials and methods

Various olive groves throughout the country were ground sampled for soil analysis. Besides, produced olive oils from these groves were analyzed for their biochemical and sensory characteristics.

2.1. Soil sampling

Soils were sampled at 24 pointsdistributed as follows: 10 among them correspond to the Chetoui variety cultivated in the north of the country, 6 for the Chemlalivariety, 4for theArbosana and Arbequina varieties cultivated in mix crop system, 2 for the Chemchali variety and 2 for the Rkhamivariety. Soil sampling was carried out systematically at four depths, which are: 0-20 cm, 20-40 cm, 40-60 cm and 60-80 cm. From these depths, an average composite sample was made up and analyzed for all parameters except organic matter, which was determined only based on the upper layer horizon (0-20 cm).

2.2. Soil analyzes

Soil pH was determined in 1:2.5 soil/water extract (Petard, 1993). Electrical conductivity (EC) was measured with a conductivity meter in a saturated paste extract. Besides, total limestone content was determined using the Bernard calcimeter method (Chaney and Slonim,1982). Moreover, organic matter (OM) was evaluated by a cold extraction of organic carbon (Walkley and Black method, 1934) and colorimetric determination at the 600 nm wavelength.

2.3. Olive oil analyzes

2.3.1. Pigment Content

Carotenoids and chlorophylls (mg/kgof oil) were determined at 470 and 670 nm, respectively, in cyclohexane using the specific extinction values according to the method of Minguez-Mosquera et al. (1991).

2.3.2. Fatty acid composition

The composition of fatty acids was evaluated after preparation of fatty acid methyl esters (FAMEs) using a cold saponification according to the method described by IOC (2018). the FAMEs were prepared by vigorous shaking of a solution of oil in hexane (0.1 g in 2 mL) with 0.2 mL of 2 N methanolic potassium hydroxide (KOH) solution and analyzed by GC with a Hewlett-Packard (HP 5890) chromatograph equipped with a FID detector. A fused silica column, HP-Innowax (30 m x 0.25 mm, i.d 0.25 µm), was used. Nitrogen was employed as a carrier gas, with a flow rate of 1 mL/min. Temperatures of the injector and detector were set at 250 and 270°C respectively. An injection volume of 1 µL was used. The operating conditions were as follows: oven temperature was held at 180°C for 1 min and then increased by 10°C min-1 to 220°C, held for 1 min at 220°C, increased again to 240°C at 2°C min-1 and finally isothermedat 240°C for 1 min. Results were expressed as percent of relative area.

2.3.3. Panel test

Sensorial evaluation of the oils was performed according to the panel test method by a fully trained analytical taste panel recognized by the International Olive Oil Council (IOOC). The panel consisted of 11 judges (1 woman as head of the panel and 10 men, age range 28 – 55 years, mean age 45 years). The panel test was established using a standard profile sheet of the IOOC method (IOC, 2011).

2.4. Precipitations data

Annual rainfall datawere collected from the various meteorological stations the most close to the various sampled olive groves.

2.5. Statistical analyzes

Comparative statistical analysis tests have been carried out to elucidate eventual relationships between soil parameters and oil characteristics. Interpretation of the data required the calculation of means and standard deviations for the total sites and for each variety apart.

It is interesting to underline, that forthe Rkhami variety, due to its limited extension at the country scale, they wasonlyincluded for the calculation of the overall means for all the varieties. Finally, the effect of edaphic parameters on the oil quality characteristics was evaluated based on simple linear regression tests using the Excel® 2016software.

3. Results

3.1. Soil analysis results

The average salinity of the sampled soils varies between 1.32 dS/m for the sites of the Chetoui variety and 3.72 dS /m for the Chemchali variety. Indeed, most often Chetoui variety, occupies soils located on encrusted glacis or on limestone piedmontswhere soils are not highly salty, this fact is confirmed by the low measuredvalues of the electrical conductivity.

Olive trees of the Chemchali variety, grown near Gafsa cityin the southwest of the country, would be irrigated. This fact would have contributed to the deposition of salts in the soil, orthese trees would have been planted in soils slightly affected by soluble salts, of natural way. The soils planted with the introduced varieties Arbosana and Arbequina have an average electrical conductivity of 2.29dS/m, a value which is moderate, but having a high standard deviation meaning the existence of very different salinities due to irrigations by waters of different qualities. In general, the salinity of the soils is not very high and this constitutes a favorable condition for the cultivation of the olive tree, this is what is reflected by the general average, which is about 1.88 dS/m (figure 1).

The soils pH values are all around eightmeaning that all these varieties are cultivated on carbonated soils. A slight decrease of the pH of the Chemchali variety soils below 8 is observed (figure 2), it could be explained by a slight acidification of these soils by the presence of sulphates and chlorides originating from the irrigation water.

The organic matter contents are generally low to very low. They vary between 0.47% for soils where the Chetoui variety is cultivated and 1.07% for soils where theArbosana and Arbequina varieties are cultivated in crop mix system. The general average for all soils is equal to 0.68% (figure 3).

The low values relative to the soils of the Chetoui and Chemlali varieties are mainly due to the absence of sources of organic matter. These soilsare constantly ploughed, and weeds are systematically eliminated there. Indeed, thesetwo varieties are generally cultivated under rainfed conditions, which would contribute to the scarcity of sources of organic matter. At the opposite, Arbosana and Arbequina varieties are cultivated under irrigated conditions, soil organic matter contents are the highest thankseither to the fact that these soils areused in intercropping or to the fact that they are more covered by spontaneous herbaceous plants providing organic matter to the superficial upper horizons.

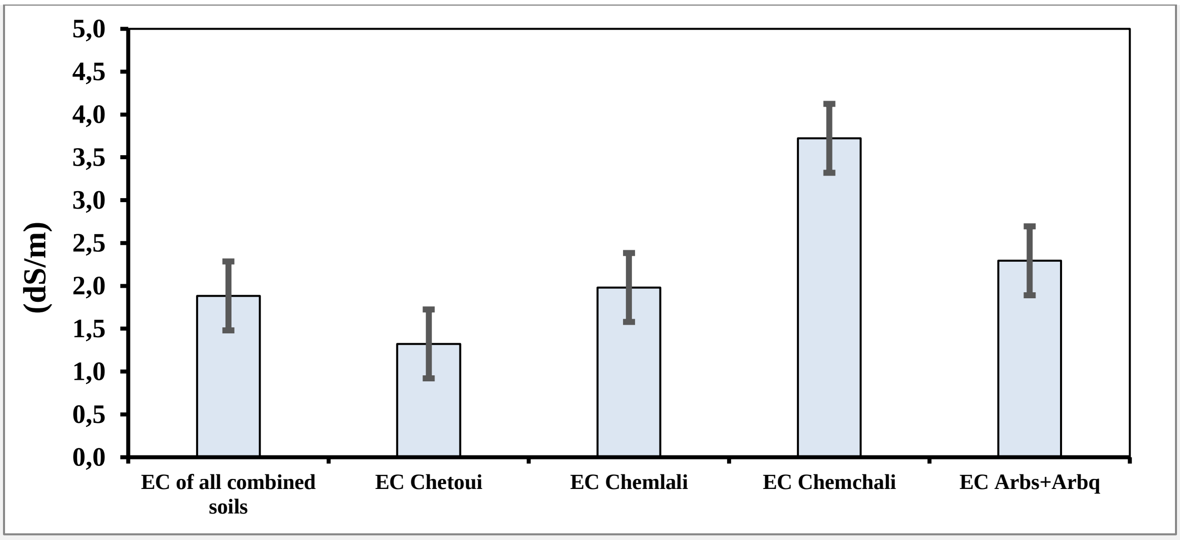


Figure 1 : Average electrical conductivities (EC in dS/m) of soils classified according to olive trees varieties

The average of limestone contents varies between 22.2% for soils of the Chemchali variety in the southwest and 46.5% for soils of the Arbosana and Arbequina varieties (figure 4). The average content for all soils is 35.6% with a fairly high standard deviation meaning a great variability among soils. The

Chemchali variety is cultivated in a large range of limestone. In fact, the limestonecontent dataof this varietyis raging between 10.15% and 34.29%. The mineralogical composition of the soils cultivated with the Arbosana and Arbequina varieties is similar to that of alluvial soils derived from marl because almost half of the total mineral matter is limestone. Their groves are located, in fact, in the Miliane plain in the northern region of Tunisia, whose soils are generally of fine texture and have mostly equal fraction of clay and limestone. The soils of the Chetoui variety have an average limestone content of 39.4% with a high standard deviation indicating a high variability between the sites located mostly in the north of Tunisia. Nevertheless, Chemlaligroves, belonging to the eastern coast and the center of the country, have moderate limestone content (18.2%) with a moderatestandard deviation.

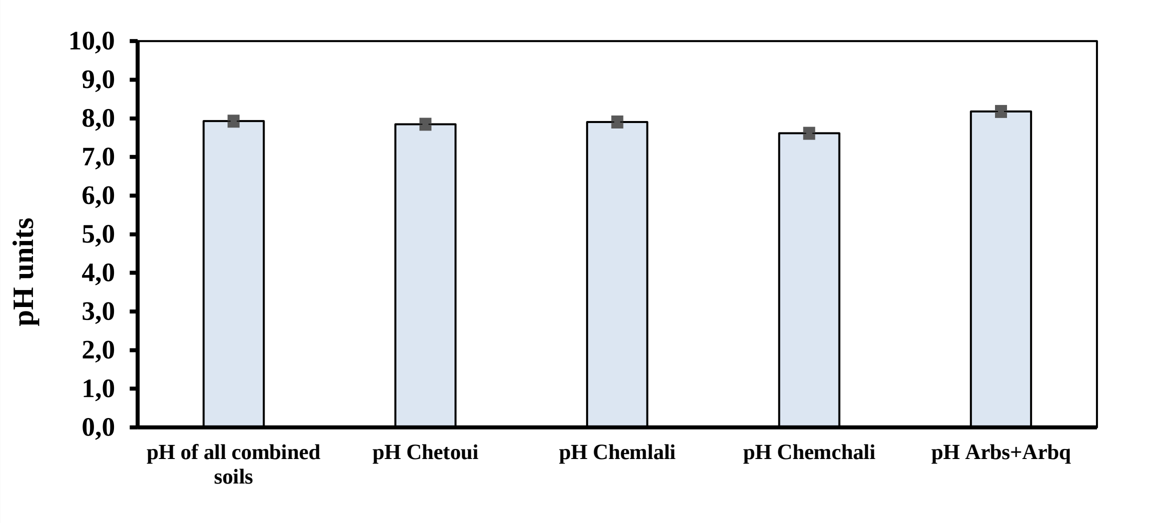


Figure 2 : Average pH values of aqueous extracts from soils classified according to olive trees varieties

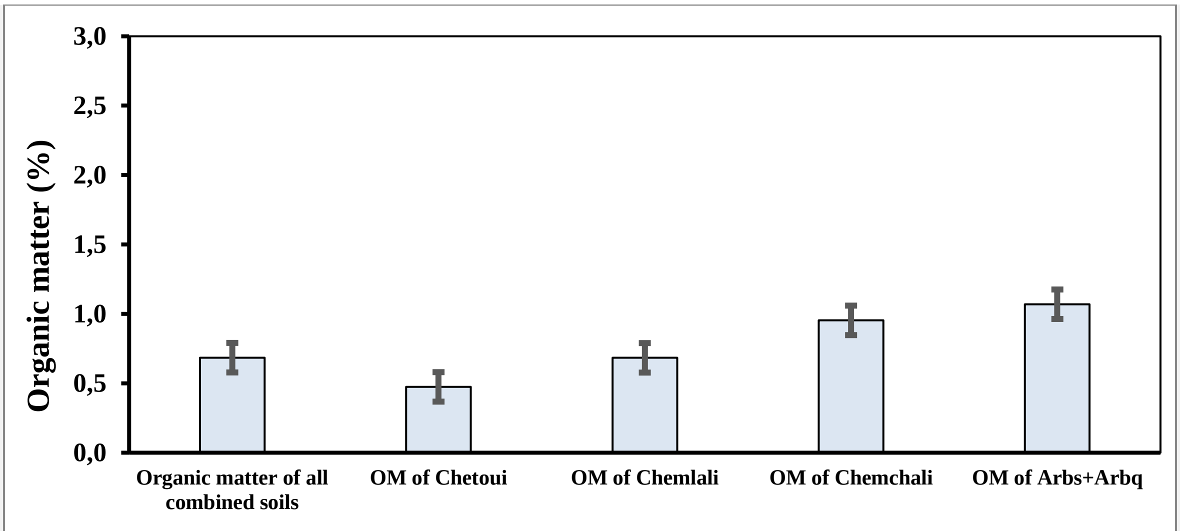


Figure 3 : Average organic matter content (OM %) of soils classified according to olive trees varieties

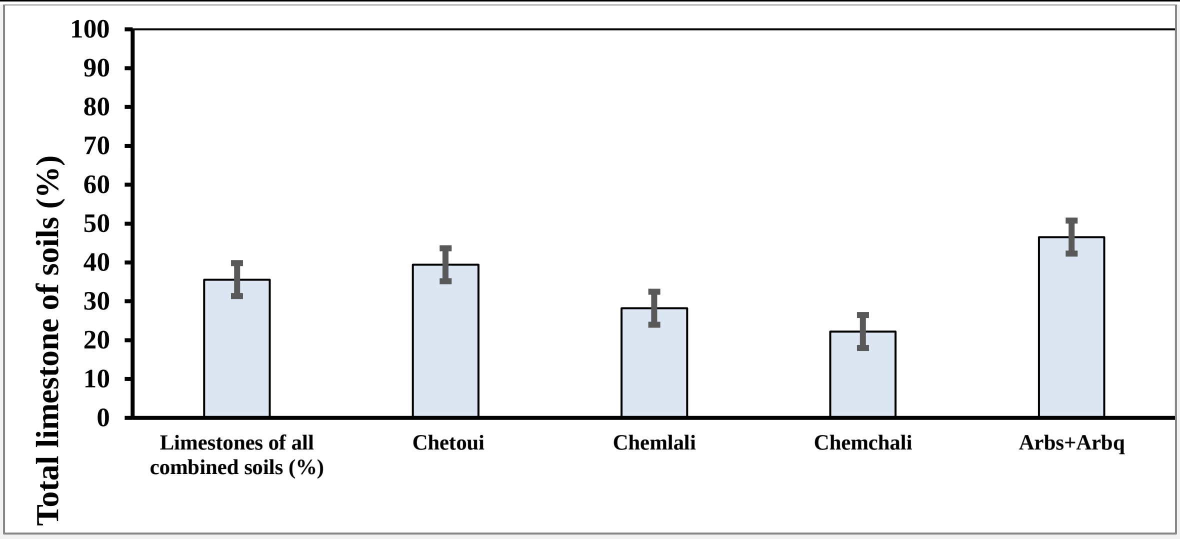


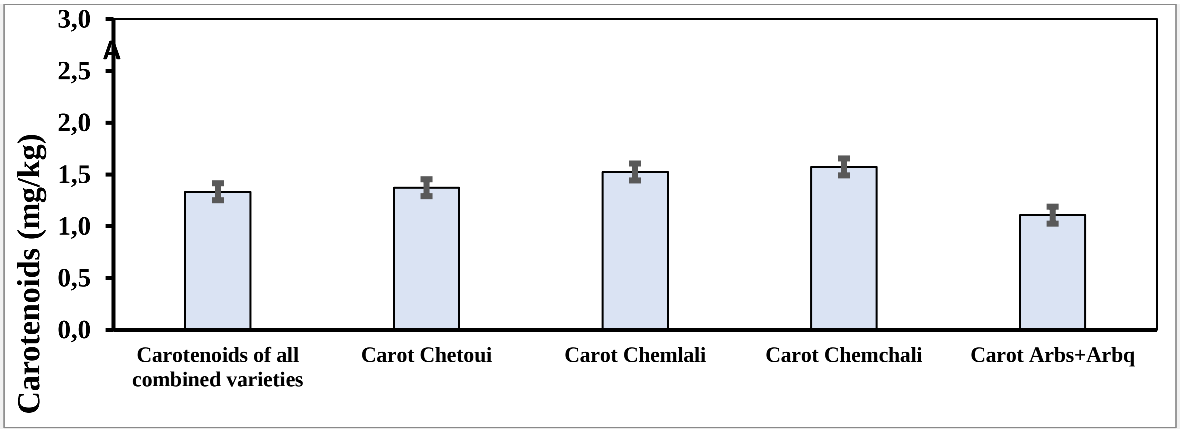
Figure 4 : Average total limestone content of soils classified according to olive trees varieties

3.2Analysis results of olive oil parameters

In this study, the olive oils were analyzed for threeparameters notably carotenoids content, chlorophylls content and the fruity sensory attribute. Carotenoids are accessory pigments in photosynthesis, they play an important role in health, because many of them are A provitamins and someof themhave antioxidant properties (Stahl and Sies, 2005; Phan, 2014). The Chemchali and Chemlali varieties contain the most content of carotenoids, with 1.67 and 1.52 mg/kg respectively. The oil contents of the Chetoui variety are almost equal to the average of all varieties with 1.38 mg/kgwhereas, the introduced varieties (Arbosana and Arbequina) seem to have the lowest content with 1.11 mg/kg in average (figure 5A).

The presence of chlorophylls plays an important role, with carotenoids, in the oxidative stability of olive oils during storage (Ben Mohamed et al, 2015). The general average of all the merged varieties is 2.6 mg/kg. The highest value is attributed to theChetoui variety with 2.92 mg/kg followed by the Chemlali variety with 2.72 mg/kg. The lowest value is associated to the Chemchali variety with 1.73 mg/kg, while that of the introduced varieties (Arbosana and Arbequina), and is equal to 2.07 mg/kg (figure 5B).

The fruity taste of the oil is a kind of aromatic flavor linked to the genetic potential of the variety but also it depends on the date of picking and ofkeeping olivesfresh before crushing (Kiritsakis, 1998). The majority of the varieties studied have a value of fruity taste close to 3.5, which is also close to that of the average of all the varieties merged. Nevertheless, the fruity taste of the Chemchali variety is slightly lower (figure 5C).



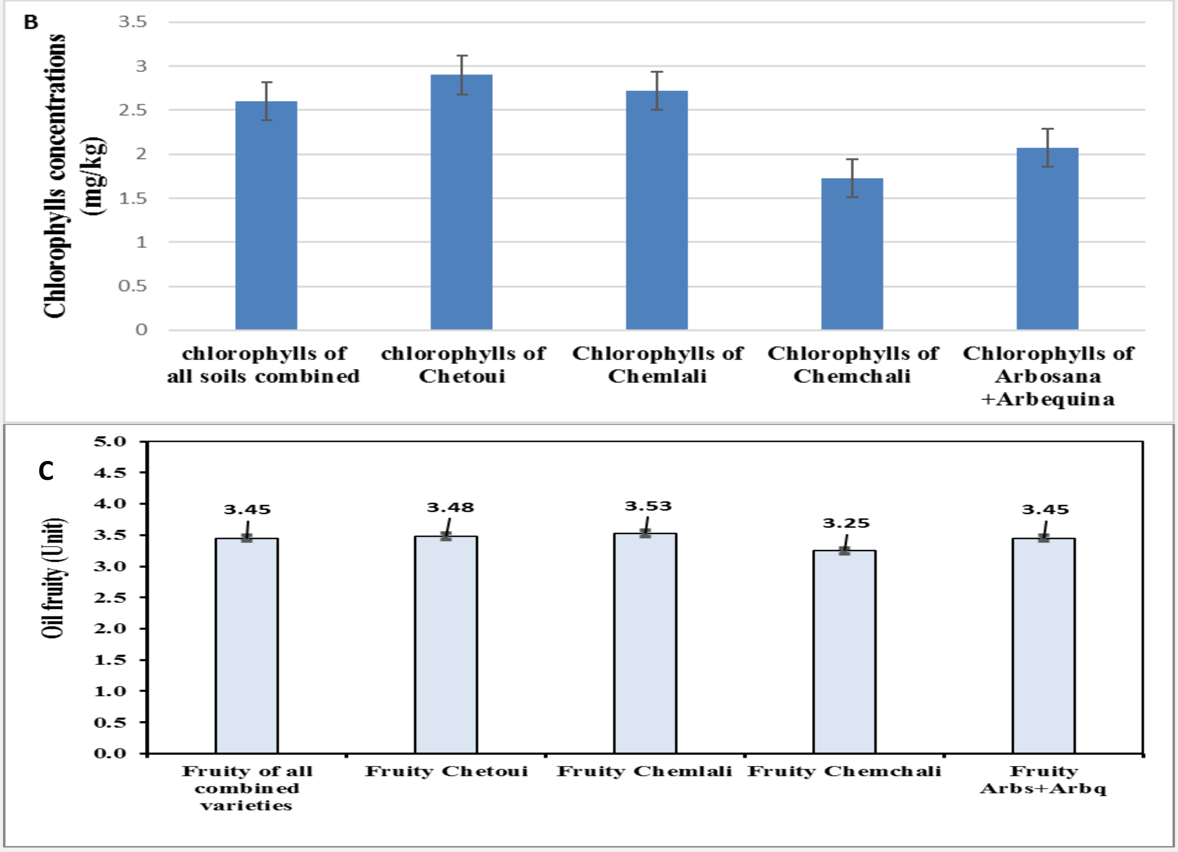


Figure 5 : Average carotenoids content (A), Average chlorophyll content (B) and Average values of the fruity taste (C) of the studied oil olive tree varieties.

3.3.The fatty acid composition

The averages of the amounts of fatty acids composing the oils of all the varieties studied (figure 6A) indicate that the most dominant acid is oleic acid (C18:1) with 65.6%, followed by linoleic acid (C18:2) and palmitic acid (C16:0) with 15.3% and 13.7% respectively. Far behind are stearic (C18:0) and palmitoleic (C16:1) acids with 2.3% and 1.05%, respectively. All other acids are only with very tiny proportions which was less than 1%. For instance, the α-linolenic acid (C18:3) represents 0.67%.

For the Chetoui variety, the most represented fatty acids are oleic acid with 65%, linoleic acid with 17.4%, palmitic acid with 12.2% and stearic acid with 2.6%. All other acids reach the 1% threshold each (figure 6B). Palmitoleic acid has a value of 0.75%, which is lower than the average of all varieties. What sets the oil of this varietyapart from others is the highproportion of linoleic acid and the low proportion of palmitic acid compared to the averages of all varieties. It is also characterized by the concentration of α-linolenic acid equal to 0.64%, which is close to the average for all varieties.

The olive oil of the Chemlali variety has the following fatty acid composition (figure 6C): 61.4% for oleic acid, 17.6% for linoleic acid, 15.8% for palmitic acid, 2.07% for stearic acid,1.37% for palmitoleic acid and only of 0.3% for α-linolenicacid percentage. The rest of the fatty acids do not exceed 0.5% for each acid. Compared to Chetoui oil, Chemlali oil is less provided with oleic acid and more enriched in palmitic acid; linoleic acid is present in the same percentage in both varieties.

For the Chemchali variety, its average fatty acid composition is as follows: 65.06% for oleic acid, 14.98% for palmitic acid, 14.35% for linoleic acid, 2.27% for stearic acid, 1.05% for palmitoleic acid and0.74% for α-linolenic acid (figure 6D). All other fatty acids are present with very low values less than 0.5%. This composition looks like that of Chetouioil especially for oleic acid, but it contains less linoleic acid and more palmitic acid.

For the Arbosana and Arbequina varieties, their fatty acid composition is as follows: 69.07% for oleic acid, 14.77% for palmitic acid, 10.79% for linoleic acid, 1.76% for stearic acid, 1.42% for palmitoleic acid and 0.65% for α-linolenic acid (figure 6E). This oil is the richest in oleic acid and is the most depleted in linoleic acid. Itspalmitic acid percentages close to those of the other varieties. In addition, we noted down that α-linolenic acid keeps roughly the same proportion as the other oils except for the Chemlali variety thatα-linolenic acid isthe lowest with only 0.3%. This oil is characterized by a high concentration of monounsaturated acid (oleic acid) and a low concentration of polyunsaturated acid (linoleic acid).

3.4. Correlations between soil parameters and oil characteristics

The soilparameters correlated with the olive oil parameters (the fruity taste and the carotenoid and chlorophyll contents) were evaluated according to the values of the coefficients of determination (R^2) and correlation r; the highest values of these coefficients made it possible to select the strongest correlations (table 1). The significant correlations are those first linking the soil organic matter (OM) parameter to carotenoids content of the oil for all varieties and to the most common local varieties notably: Chetoui, Chemlali and Chemchali.

Then the same OM parameter as that of the chlorophyll content of the oil for the Chetoui, the introduced varieties Arbosanaand Arbequina. The most significant correlation obtained at the 0.01 threshold is that linking OM to the chlorophyll content of the oil of the Arbosana and Arbequina varieties (figure 7). Other correlations came close to the significance level but remained insignificant; we cite in particular the EC - Carotenoids and EC - Chlorophyll correlations of the Arbosana and Arbequina varieties (table 1), which are negative with values of r less than - 0.7 meaning that these two varieties are sensitive to the effects of salts, sensitivity illustrated by the high level of carotenoids and chlorophylls in their oils. This EC parameter would, however, have a positive effect on the fruity taste of the oil of the same varieties. In addition, total limestone ($CaCO_3$) would have a positive effect on the fruity taste of local varieties: Chetoui, Chemlali and Chemchali which are adapted to the Tunisianlimestone soils. There is also a positive relationship close to the significance level between the total limestone in the soil and the chlorophylls content of the introduced varieties ArbosanaandArbequina.

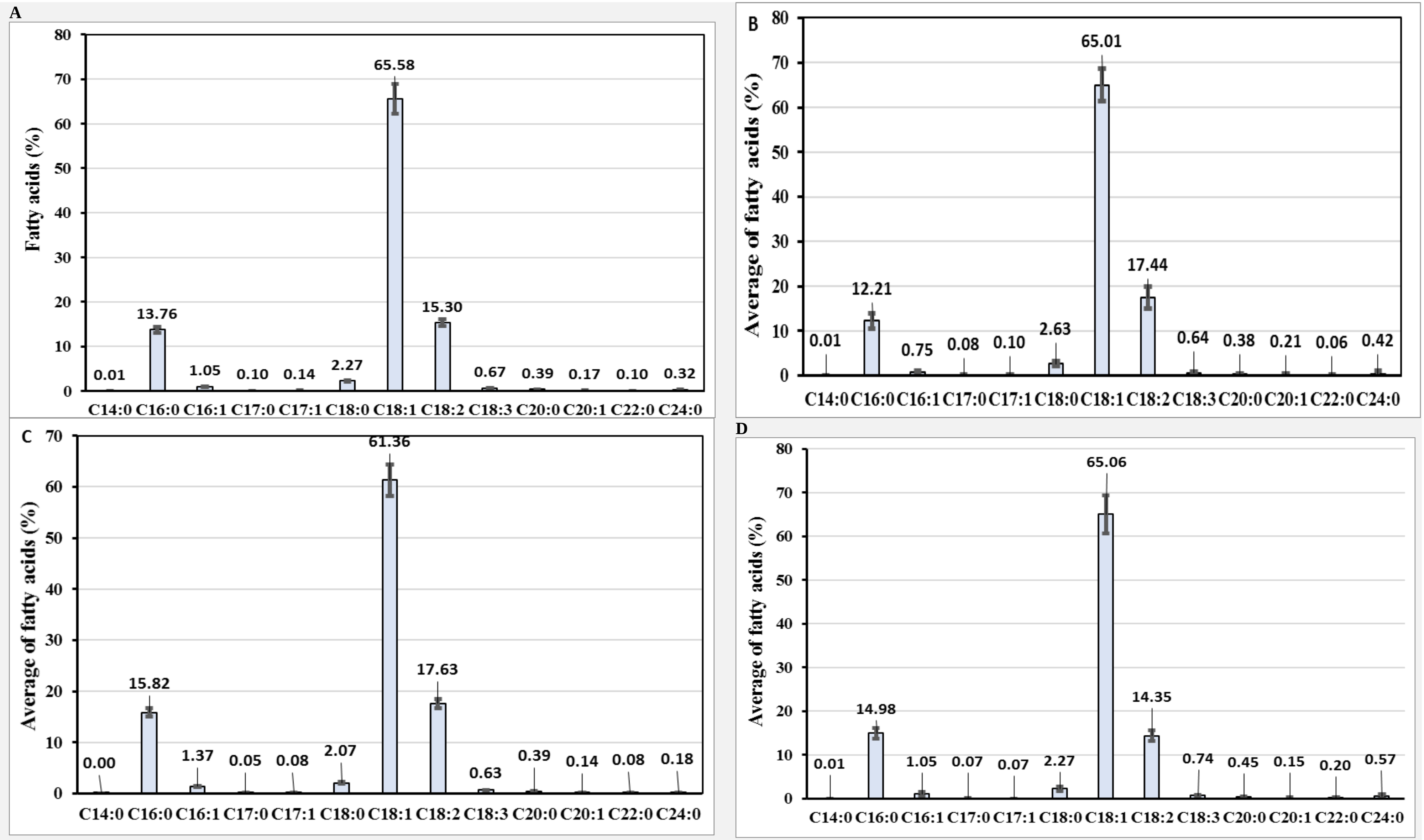


Figure 6 : Average of fatty acid composition of olive oils: Combined varieties (A), Chetoui (B), Chemlali (C) and Chemchali (D).

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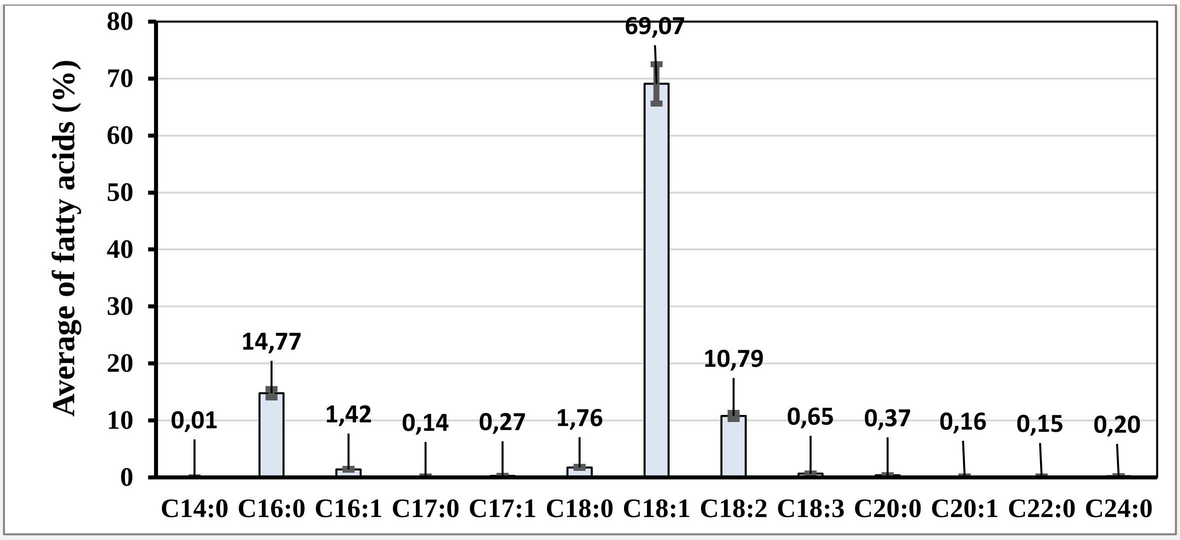

Figure 7: Average fatty acid composition of olive oils of Arbosana and Arbequina varieties.

Table 1 : Correlations between soil properties and oil quality parameters

Correlated parameters	Equation	Determination coefficient R^2	Correlation coefficient r	Degrees of freedom (dof)	Meaning threshold (n-1 dof)
EC - Fruity (Arbosana + Arbequina)	y = 0,1741x + 3,051	R^2 = 0,2058	r = 0,4536	n = 6	NS
pH - Fruity (Chetoui)	y = 1,2641x- 6,4395	R^2 = 0,2464	r = 0,4964	n = 10	NS
OM - Fruity (Arbosana+Arbequina)	y = -0,528x + 4,0148	R^2 = 0,4621	r = - 0,6798	n = 6	NS
Tot $CaCO_3$– Fruity (All the varieties)	y = 0,0124x +3,0084	R^2 = 0,107	r = 0,3271	n = 24	NS
Tot$CaCO_3$ - Fruity (Local varieties)	y = 0,0177x +2,8514	R^2 = 0,207	r = 0,4550	n = 16	NS
CE – Carotenoids (Arbosana+Arbequina)	y = -0,4277x + 2,088	R^2 = 0,5147	r = - 0,7174	n = 6	NS
pH - Carotenoids (Chetoui)	y = -0,3942x+4,4645	R^2 = 0,1653	r = - 0,4066	n = 10	NS
OM - Carotenoids (Arbosana+Arbequina)	y = 0,8294x +0,2203	R^2 = 0,4724	r = 0,6873	n = 6	NS
OM - Carotenoids (local varieties)	y = 0,5848x +1,0913	R^2 = 0,2201	r = 0,4691	n = 16	p = 0,05
OM - Carotenoids (all the varieties)	y = 0,4858x +0,9994	R^2 = 0,1782	r = 0,4221	n = 24	p = 0,05
Tot $CaCO_3$ - Carotenoids (Chetoui)	y = 0,0061x + 1,13	R^2 = 0,1634	r = 0,4042	n = 10	NS
Tot $CaCO_3$ - Carotenoids (Arbosana+Arbequina)	y = 0,0319x - 0,3785	R^2 = 0,1631	r = 0,4039	n = 6	NS
EC - Chlorophyll (Chetoui)	y = 0,853x + 1,7927	R^2 = 0,1778	r = 0,4217	n = 10	NS
EC - Chlorophyll (Arbosana+Arbequina)	y = -0,836x + 3,9878	R^2 = 0,4995	r = - 0,7068	n = 6	NS
pH - Chlorophyll (Arbosana+Arbequina)	y = -1,7375x+16,281	R^2 = 0,1482	r = - 0,3850	n = 6	NS
OM - Chlorophyll (Chetoui)	y = 2,4866x+1,7418	R^2 = 0,4644	r = 0,6815	n = 10	p = 0,05
OM - Chlorophyll (Arbosana+Arbequina)	y = 2,1371x - 0,215	R^2 = 0,7964	r = 0,8924	n = 6	p = 0,01
OM - Chlorophyll (All the varieties)	y = 0,7734x+2,0674	R^2 = 0,1172	r = 0,3423	n = 24	NS
Rainfall - Chlorophyll (Local varieties)	y = 0,0057x+0,7907	R^2 = 0,1251	r = 0,3537	n = 16	NS
Tot $CaCO_3$ - Chlorophyll (Arbosana+Arbequina)	y = 0,1002x - 2,5918	R^2 = 0,4078	r = 0,6386	n = 6	NS

NS : not significant

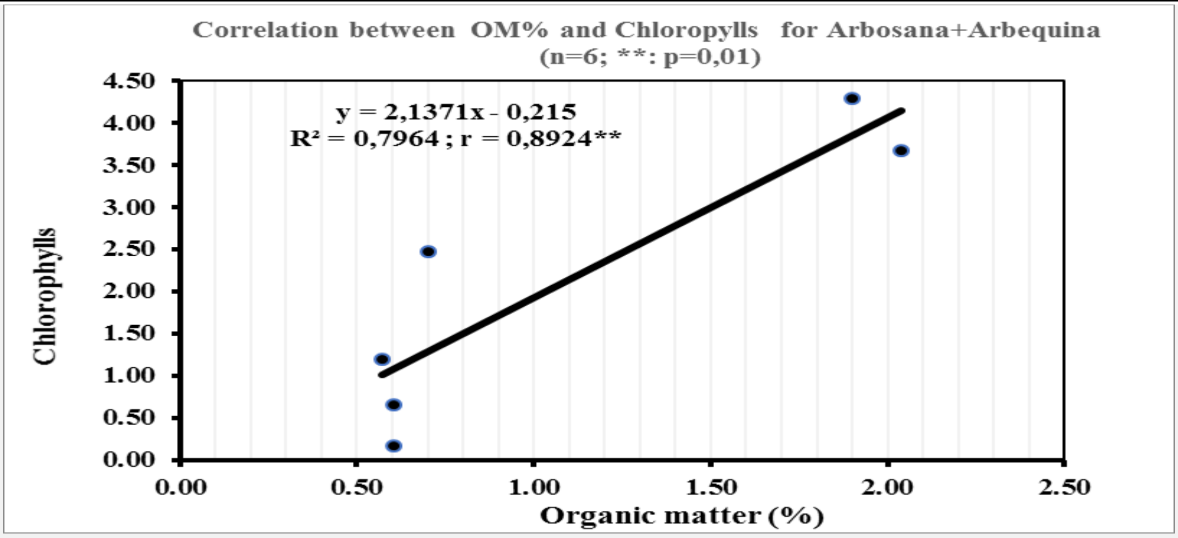

Figure 8: Simple linear correlation line between the OM parameter of the soil and the chlorophyll content of the oil of the introduced varieties (Arbosana + Arbequina).

3.5. Correlations between soil characteristics and the fatty acid proportions of oils

The soil EC, which represents its salinity, would act negatively on the linoleic acid content of the oils of local varieties (Chetoui + Chemlali + Chemchali) as shown by the significant correlation obtained between these two parameters at the 0.01 threshold (figure 8). At the opposite, this same parameter would act positively on the palmitic acid content of the oils of all varieties; the correlation is significant at the 0.05 level (table 2). Thus, according to these results, the more salty the soil, the higher is thecontent of linoleic acid is and the lower is thepalmitic acid. In addition, EC parameter shows a strong negative correlation, but not significant, with the α-linolenic acid content of the introduced varieties (ArbosanaandArbequina); the correlation coefficient r found is equal to - 0.7031. For the local variety Chetoui, salts would have a stimulating effect on the α-linolenic acid in the oil because the correlation coefficient r approaches the significance level with a value of 0.5012 for a number of samples n = 30.

The soil organic matter (OM) content is negatively correlated with the proportion of linoleic acid for all varieties (table 2). It would act in the same way on the palmitic acid content for the introduced varieties (Arbosana + Arbequina). It would, however, tend to act positively on the oleic acid content for all varieties and introduced varieties, even though the identified r coefficients are below the significance level.

Total soil limestone would have a negative effect on the palmitic acid content of the oils of the three local varieties (Chetoui, Chemlali and Chemchali) with a correlation coefficient equal to - 0.4932 and significant at the 0.05 threshold. The same trend is observed for the Chetoui variety on its own. This parameter would have a simple trend to increase the proportion of α-linolenic acid in oils of local varieties and in particular for the Chetoui variety.

Finally, rainfall would decrease the α-linolenic acid content of oils of local varieties and particularly the Chetoui variety.

Table 2 : Correlations between soil parameters and the amounts of fatty acids in oils

Correlated parameters	Equation	Determination coefficient R^2	Correlation coefficient r	Degrees of freedom (dof)	Meaning threshold (n-1 dof)
EC - Oleic acid (Arbosana+Arbequina)	y = -1,5954x+72,728	R^2 = 0,2593	r = - 0,5092	n = 6	NS
EC – Linoleic acid (Local varieties)	y = -1,5209x + 19,818	R^2 = 0,383	r = - 0,6188	n = 16	p = 0,01
EC – Linoleic acid (Arbosana+Arbequina)	y = 0,6146x + 9,379	R^2 = 0,1268	r = 0,3561	n = 6	NS
EC–Linoleicacid (Chetoui)	y = -2,0352x + 20,13	R^2 = 0,2985	r = - 0,5464	n = 10	NS
EC - α-linolenic acid (Chetoui)	y = 0,0499x+0,3641	R^2 = 0,2512	r = 0,5012	n = 10	NS
EC - α-linolenic acid (Arbosana+Arbequina)	y = -0,1611x + 1,016	R^2 = 0,4944	r = - 0,7031	n = 6	NS
EC – Palmitic acid (All the varieties	y = 0,8537x+12,153	R^2 = 0,1881	r = 0,4337	n = 24	p = 0,05
EC – Palmitic acid (Arbosana+Arbequina)	y = 0,582x + 13,439	R^2 = 0,404	r = 0,6360	n = 6	NS

EC–Palmitic acid (Local varieties)	y = 0,8866x+11,875	R² = 0,1367	r = 0,370	n = 16	NS
pH - Oleic acid (Local varieties)	y = -3,5625x+92,005	R² = 0,1429	r = - 0,3780	n = 16	NS
pH - Oleic acid (Chetoui)	y = -3,7732x + 94,616	R² = 0,1418	r = - 0,3766	n = 10	NS
pH - α-linolenic acid (Arbosana+Arbequina)	y = -0,4808x+4,5784	R² = 0,3024	r = - 0,5499	n = 6	NS
OM - Oleic acid (All the varieties)	y = 3,0479x+63,498	R² = 0,1313	r = 0,3623	n = 24	NS
OM - Oleic acid (Arbosana+Arbequina)	y = 3,616x + 65,202	R² = 0,3251	r = 0,5702	n = 6	NS
OM - Linoleic acid (All the varieties)	y = -2,8598x+17,262	R² = 0,1959	r = - 0,4426	n = 24	p = 0,05
MO –Linoleicacid (Chetoui)	y = -2,6332x+18,687	R² = 0,1536	r = - 0,3919	n =10	NS
OM - α-linolenic acid (Arbosana+Arbequina)	y = 0,2057x+0,4266	R² = 0,1965	r = 0,4433	n = 6	NS
OM - Palmiticacid (Chetoui)	y = 1,8465x+11,338	R² = 0,1424	r = 0,3774	n = 10	NS
OM–Palmitic acid (Arbosana+Arbequina)	y = -1,4115x+16,284	R² = 0,5799	r = - 0,7615	n = 6	p = 0,05
Tot $CaCO_3$ - linoleic acid (Chetoui)	y = 0,0366x+15,995	R² = 0,1294 ;	r = 0,3597	n = 10	NS
Tot $CaCO_3$ - α-linolenic acid (Chetoui)	y = 0,0048x+0,4488	R² = 0,1409	r = 0,3753	n = 10	NS
Tot $CaCO_3$ -α-linolenicacid (Variétés locales)	y = 0,0047x+0,4861	R² = 0,1194	r = 0,3455	n = 16	NS
Tot $CaCO_3$ - Palmitic acid (Chetoui)	y = -0,0373x+13,684	R² = 0,2531	r = - 0,5030	n = 10	NS
Tot $CaCO_3$ - Palmitic acid (Local varieties)	y = -0,0528x + 15,28	R² = 0,2432	r = - 0,4932	n = 16	p = 0,05
Tot $CaCO_3$ - Palmitic acid (Arbosana+Arbequina)	y = -0,0464x+16,932	R² = 0,1459	r = - 0,3820	n = 6	NS
Rainfall - α-linolenic acid (Chetoui)	y = -0,0029x+1,696	R² = 0,2417	r = - 0,4916	n = 10	NS
Rainfall - α-linolénicacid(Local varieties)	y = -0,0013x+1,0839	R² = 0,1003	r = - 0,3167	n = 16	NS

NS : not significant

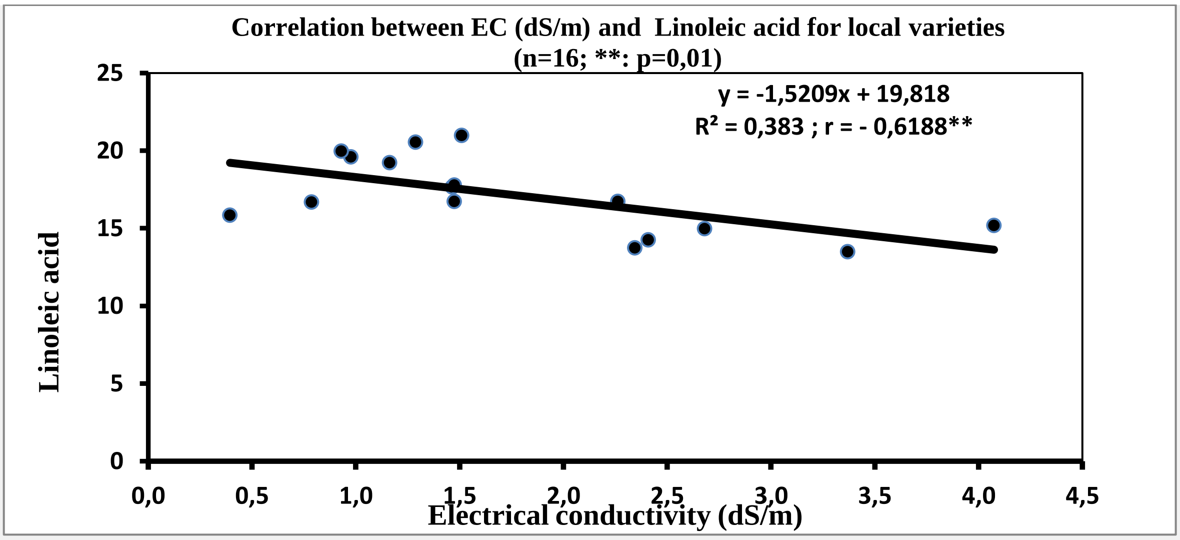

Figure 9: Simple linear correlation line between the EC parameter in dS/m of the soil and the linoleic acid content of the oil of local varieties (Chetoui + Chemlali + Chemchali).

3.6. Discussion

Soils sampled in this study are wide spread over several Tunisian regions and over different types of relief. Thus, in the northern regions, the Chetoui variety spreads and generally occupies the forms in glacis or those located on foothills or hill slopes. Indeed, in these areas plains and valleys, characterized by finesoil texture, are most often usedfor cereal crops. Chetoui variety, occupies soils that were characterized by their high limestone content, alkaline pH, moderate to low organic matter content and low salinity. This was confirmed by the results obtained: the limestone contents varied between 2.98% and 73.42% for soils of this variety; the lowest value was recorded in the less carbonate soils of Cap Bon and the highest content was identified

in the region of El Fahs which is located near the northern slopes of the Tunisian Ridge (Dorsale), known by the outcrop of its limestone and marl rocks. For the soils of the other varieties, the limestone content seems more moderate for the varieties Chemlali and Chemchali with one exception for the variety Chemlali located near Nadhour whose soils show similarities to those of El Fahs. The effects that this parameter may have on the compositions and qualities of olive oils were demonstrated by regression tests: relationships which appear to exist but without reaching the threshold of significance. This fact confirms the effect of soil limestone content on the fruity taste and the content of carotenoids and chlorophyll of the produced oil. Regarding fatty acids, limestone seems to have a positive and partial influence on the content of linoleic and α-linolenic acids, especially for the Chetoui variety. In contrary, its effect on the content of palmiticacid, which is a saturated acid, is negative in almost the majority of varieties.
The olive tree is most often cultivated in rain fed conditions and on land with no or very little salt in most of the areas of its expansion. However, irrigation activities, of a local and non-generalized character, may concern the soils where it is cultivated either when there are intercropping, or for introduced and non-native varieties such as Arbosana and Arbequina. These irrigations generally provide salts, which accumulate in soils, especially those with medium or fine texture. The measurement results of this parameter indicate that they are the soils bearing the local variety Chemchali and the introduced varieties Arbosana and Arbequina which are most affected by salts. For the other varieties, the average values of the electrical conductivity turned around 2 dS/m, a value that is relatively moderate for arid and semi-arid zones; for the Chetoui variety, the value is even lower. This parameter shows a partial effect (not significant) on the chlorophyll and carotenoids contents, particularly for the varieties Arbosana and Arbequina. The low salt contents of the soils of the Chetoui variety would mean that the presence of the ions composing the total salts would rather contribute to nutrition than to the inhibition of the absorption of the elements. In terms of fatty acid composition, this parameter would decrease the contents of oleic, linoleic and α-linolenic acids, the last two acids are considered as essential fatty acids for human nutrition (Benrachou, 2013), and would increase those of palmitic acid, in almost all varieties. Bedbabis et al (2010) confirmed this for the Chemlali variety.
For the water extract pH of the soils, its values have usually been close to eight, which could not induce obvious discriminations between the varieties and show direct effects on the quality parameters and the fatty acid composition of the oils of the studied varieties. We just found insignificant relationships, one positive between this factor, the fruity taste, and the other negative between the same factor and the chlorophyll and carotenoids contents, particularly for the Chetoui variety.
The role of soil organic matter, which was relatively more abundant in the soils of the Arbosana and Arbequina varieties, without however exceeding 1.5%, was quite obvious on the quality parameters and the fatty acid composition. These two varieties are cultivated under irrigation on soils that have often a fine-texture, which would create more favorable conditions for the stabilization of organic matter by clays. According to the obtained results, the more organic matter the soil contains, the more the concentrations of carotenoids and chlorophyll are in the oils. The correlations were significant at the 0.05 level and even 0.01 for the Arbosana and Arbequina varieties. Organic matter improves soil fertility and the chemical nutrition conditions of plants; this would have a positive effect on the synthesis of these two parameters in the fruits, which would yield them to the oil after trituration. A negative effect of organic matter on the fruity taste has been identified for the Arbosana and Arbequina varieties. For fatty acids, its presence in soils would significantly decrease the proportions of linoleic and palmitic acids for all varieties and especially Arbosana and Arbequina.
The last parameter tested is the annual rainfall; it would act negatively, but not significantly, on α-linolenic acid. By the way, this variable does not have a wide range of variation and the majority of its values are around 350 - 450 mm/year, which did not favor the identification of significant correlations.
For the oil quality parameters and by comparing between the different varieties, it was found that for the fruity taste, the values are almost equivalent except for the Chemchali variety from the Gafsa region, which has a lower value. For the carotenoid content, the Chemchali and Chemlali varieties offer the highest concentrations; in contrast, the oil of the Arbosana and Arbequina varieties is the least concentrated in this substance. Finally, for chlorophyll, the Chetoui variety is the most concentrated, followed by that of Chemlali; in contrast, the Chemchali variety has the least concentration. These two components have antioxidant properties and their levels can vary with the stage of maturity of the olives (Baccouri et al, 2008; Lazzez et al, 2008).
For fatty acids, all the varieties studied are characterized by oils where oleic acid is the most dominant followed by far and with variable values, by linoleic and palmitic acids. Oleic acid was most abundant in Arbosana and Arbequina varieties with almost 69% and least abundant in Chemlali variety. Linoleic acid has the highest values with almost 19% in the Chetoui and Chemlali varieties, but the introduced varieties contain the lowest fraction. Finally, for palmitic acid, which is a saturated acid unlike the previous ones, the Chetoui

variety is the least endowed (around 11%); for the three other varieties, the proportionshave variedbetween 15% 16%. The variations in these proportions distinguish well between varieties, which have been confirmed by Grati-Kammoun and Zarrouk (2012). We should remind that the α-linolenic acid contents did not exceed 1% and did not even reach 0.9%, which was the maximum level tolerated by the European Union regulation (Olivier et al, 2003).

4. Conclusion

Soils on which the varieties selected in this study are cultivated and which represent the most widespread cultivars in the country, have all been carbonated and have relatively moderate soluble salt concentrations despite their diversity and their distribution over a large geographical area. The limestone contents showed almost no obvious effects on the quality parameters of oils. For fatty acids, a significant negative correlation between this edaphic parameter and palmitic acid could be demonstrated. Salinity, in contrast, had a significant negative effect on linoleic acid and a positive effect on palmitic acid. In addition, the organic matter of the soils was significantly and positively correlated with the oil contents of carotenoids and chlorophyllsfirstly and negatively with linoleic and palmitic acids secondly. The oil of the Chetoui variety, more widespread in the north of the country and most often cultivated under rain fed conditions, exhibited the highest content of chlorophylls, while the Chemchali variety, more cultivated in the southwest, showed the highest concentration in carotenoids, slightly ahead of the Chemlali variety more widespread in the center and near the eastern coasts of the country. Finally, what distinguished the fatty acids composition of the studied varieties is the higher proportion of oleic acid in the oil of the Arbosana and Arbequina varieties and the lower fraction of palmitic acid in the oil of the Chetoui variety.

Dedicate

Dr. KaoutherBchir Ben Hassine and Dr. Habib Ben Hassine dedicate this work to the memory of the agricultural Engineer “Houcem El Mabrouk” who died in 2020. Rest in peace, dear excellent student. You are in our heart and your soul will guide us. You are with us forever.

5. References

Abaza L., Msallem M., Daoud D. et Zarrouk M. (2002). Caractérisation des huiles de sept variétés d'olivier tunisiennes. Revue OCL (Oilseeds and fats, Crops and Lipids). 9(2): 174-179. DOI :https://doi.org/10.1051/ocl.2002.0174.

Allaya M. et Karray B. (2000). Avantage comparatif de la production d’olives à huile dans la région de Sfax (Tunisie). Revue MEDIT. 2: 24-29.

Baccouri O., **Guerfel.M., BaccouriB., Cerretani L., Bendini A., Lercker G., Zarrouk M. and Daoud Ben Miled D.(2008)**. Chemical Composition and Oxidative Stability of Tunisian Monovarietal Virgin Olive Oils With Regard to Fruit Ripening.Food Chem.15;109(4):743-754.doi: 10.1016/j.foodchem.2008.01.034.

Bedbabis S., Clodoveo M.L., Ben Rouina B. and Boukhris M. (2010). Influence of irrigation of moderate saline water on « Chemlali » extra virgin olive oil composition and quality. Journal of food quality.33 (2): 228-247.https://doi:org/10.1111/j.17454557. 2010. 00310.x

Ben Mohamed M., Boudiche S., Kachouri F. etBornaz S. (2015). Impact de la production biologique sur la qualité des produits agricoles et agro-alimentaires : cas de l’huile d’olive et des tomates. Journal of New Sciences, Volume JS-INAT(16): 932-936.

Benrachou N.(2013). Etude des caractéristiques physicochimiques et de la composition biochimique d’huiles d’olive issues de trois cultivars de l’Est algérien. Thèse en biochimie appliquée, Université Badji Mokhtar Annaba, Algérie, 112p.

Ben Rouina B., Trigui A., d’Andria R., Boukhris M. and Chaïeb M. (2007). Effects of water stress and soil type on photosynthesis, leaf water potential and yield of olive trees (*Oleaeuropaea* L. cvChemlaliSfax). Australian Journal of Experimental Agriculture. 47(12): 1484–1490.

Chaney R. and Slonim S. (1982) Determination of calcium carbonate content in soils, In: Demars, R Chaney (Eds.) Geotechnical properties behaviours and performance of calcareous soils, ASTM STP. Philadelphia 777:3-15.

Grati-Kammoun N.et Laroussi S. (2013). L’expérience tunisienne dans l’élaboration des signes de qualité dans l’huile d’olive. In: Ilbert H. (ed.), Tekelioglu Y. (ed.), Çagatay S. (ed.), Tozanli S. (ed.). Indications Géographiques, dynamiques socio-économiques et patrimoine bio-culturel en Turquie et dans les pays méditerranéens. Montpellier : CIHEAM, 2013. p. 107-115 (Options Méditerranéennes : Série A. Séminaires Méditerranéens ; n. 104).

Grati-Kammoun N. and Zarrouk W, (2012). Exploratory chemometric analysis for the characterization of Tunisian olive cultivars according to their lipid and sterolic profiles.International Journal of Food Science & Technology. 47(7): 1496–1504.https://doi: 10.1111/j.1365-2621.2012.02997.

Jackson D., Paglietti L., Ribeiro M. etKarray B. (2015). Tunisie : Analyse de la filière oléicole. FAO Investment Centre, Rome, 165p.

Karray B., Msallem M., Ksantini M., MahjoubBoujnah D. et Grati-Kammoun N. (2009). Programmes et acquis de recherches pour la rénovation de la filière huile d'olive et l'amélioration de ses performances. Document technique, Institut de l'olivier, Tunisie, 27p.

Kiritsakis A. K. (1998). Flavor components of olive oil-A review. Journal of the American Oil Chemists' Society.75:673–681.

Lazzez A., Perri E., Caravita M.A., KhlifM.and Cossentini M. (2008). Influence of olive maturity stage and geographical origin on some minor components in virgin olive oil of the Chemlali variety. J. Agric. Food Chem. 56(3): 982–988.https://doi:org/10.1021/jf0722147.

Olivier D., Artaud J., Pinatel C., DurbecJ.P.and Guérère M. (2003). Triacylglycerol and Fatty Acid Compositions of French Virgin Olive Oils.Characterization by Chemometrics.Journal of Agricultural and Food Chemistry.J. Agric. Food Chem. 5723–5731. https://doi:org/10.1021/jf034365p

Petard J. (1993) Les méthodes d'analyse, tome 1, Analyses des sols ORSTOM, Nouméa, septembre 1993. 192 p.

Merouane A., Noui A., Medjahed H., Nedjari Benhadj A. et Saadi A. (2014). Activité antioxydante des composés phénoliques d'huile d'olive extraite par méthode traditionnelle. International Journal of Biological and Chemical Sciences, 8(4): 1865-1870.

Montpellier C. (2019). L'huile d'olive: intérêts alimentaire et cosmétique. Thèse de doctorat en pharmacie, Faculté de pharmacie de Marseille, Université d'Aix-Marseille, 67p.

Phan T. H. (2014). Utilisation des caroténoïdes naturels de *Momordicacochinchinensis* (GAC) comme composés santé. Extraction et bioactivité en fonction de l'origine et du procédé. Thèse de doctorat, Université de Bourgogne, Agrosup, Dijon, 182p.

Stahl W. and Sies H. (2005). Bioactivity and protective effects of natural carotenoids. Biochim Biophys Acta. 1740(2):101-107. https://doi: 10.1016/j.bbadis.2004.12.006.

https://www.iso.org/obp/ui/#iso:std:iso:5508:ed-2:v1:fr. (Corps gras d'origines animale et végétale. ISO 5508:1990.

Walkley, A. and Black I.A., (1934). An examination of the Degtjareff Method for Determining Soil Organic Matter, and a proposed Modification of the Chromic Acid Titration Method.Soil Science. 37(1): 29-38.

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