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Ecological characterization of ancient olive trees in Lebanon-Bshaaleh area and their age estimation

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Abstract: *In order to characterize the pedological characteristics of Bshaaleh area and to assess the suitability of this area to olive cultivation, the climate conditions and the soil characteristics were evaluated as well as the tree's age estimation by using the growth rate method. The comparison of the climatic data of Bshaaleh with those of the Koura area, which is considered an optimal area for olive cultivation in north of lebanon, showed that Bshaaleh is much colder than Koura area during winter (5.1 degrees less) and cooler during summer (3.9 degrees less). Moreover, Bshaaleh received much more precipitations; indeed, on a per year basis they were about 90% higher than in Koura area (1390 mm vs. 730 mm). According to the USDA Soil Textural Triangle, the soil samples tested from Bshaaleh had a sandy loam texture, which is a suitable texture for olive trees.The average value of 1.7% of organic matter found in the samples tested can be considered an adequate content. The total phosphorus found in the soil was around 0.22 ppm, which is a value that can be considered good to support the plant growth.The Electrical Conductivity (EC) resulted around 0.69 dS/m.The level of calcium carbonate resulted high. Concerning the tree's age estimation, our results show a slower growth rate that could be explained by the environmental conditions of Bshaaleh, especially the high rainfall rate and the long cold period. We concluded that the first olive plantation in Bshaaleh,that goes back to 1350 years, is still productive.Moreover, the ecological characteristics revealed that the soil of Bshaaleh is well suitable for olive trees which tolerate relatively low temperature conditions.*

Keywords*: Bshaaleh, Lebanon, olive tree,age estimation, climate and soil characteristic.*

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I. Introduction

Olive trees are the oldest and most important fruit trees in history. They are a symbol of peace, fertility, luck, wisdom, prosperity, and victory. They are indigenous to the Mediterranean, as well as through Africa and Asia. The olive tree has adapted to cope with extreme conditions, grows on arid and rocky soils and occupies important parts of mountains and hills; and survives under drought conditions and strong winds. They also need very little attention and have an average lifespan of approximately 500 years[1; 2; 3].

The high survival potential of the olive is due to a number of morphological developmental adaptations, such asspecial leaf anatomy, sectorial shoot-root relation, environmental root system adaptation, and its high morphogeneticregeneration potential.

On the other hand, the species *Olea europaea* L. has the genetic ability to respond to luxury conditions. Inrelatively warm regions with high rainfall or extensive summer irrigation, large trees with high trunks and rich vegetative growth tend to develop. This would rarely be the case in northern regions with a cooler temperate climate in spite of the summer rains in such regions [4].

The orchard site strongly affects its capacity to produce. Olives are subtropical trees, sensitive to hard freezingtemperatures [5; 6]Olive tree can withstand temperature as low as of -8˚C or -9˚C as long as it is notsubjected to them for many hours provided that trees are not in the active growing period [7].Conversantly, during vegetative stages, olives are much more sensitive to low temperatures, which may cause damage to twigs, branches and even to the trunk.

Although olive trees adapt to a wide variety of soils, production is best where the trees can develop roots without chemical or physical restriction, the soil's physical and chemical condition being critical to olive production[7]. The physical condition of a soil depends on its texture, depth and stratification. Olives prefer moderately fine textured soils, including sandy loam, loam, silt loam, clay loam and silty clay loam soils, which provide aeration for root growth, are quite permeable and have adequate water holding capacity. Sandier soils do not have good nutrient and water holding capacity. The heavier clay soils often do not have adequate aeration for root growth and than are difficult to manage for maximum production [5].

Olive trees are shallow rooted and do not require very deep soils to produce well. Soils with an un-stratified profile of 1.2 m are suitable for olive [5]. Nutrientavailability varies depending on the soil's parent material and the different soil layers present [8; 9].

Olives tolerate soils of varying chemical quality. Although trees grow and produce at optimal level, at a pH of 6.8-7.5, olive can adapt and produce also in moderately acid soils or basic soils (from pH 5.0 to 8.5) [8].The pH is important because of its influence on availability of soil nutrients, solubility of toxic elements, physicalbreakdown of root cells, cation exchange capacity, in soils whose colloids (clay/humus) are pH-dependent, andbiological activity [10; 11]Medium fertile soils (having 1-2 % of OM) receiving an average rainfall of at least 500- 550 mm peryear may guarantee good productions [7].

Tree age determination can be a fairly complicated process. The best way of determining a tree's age is to find out when it was planted. Obviously, this is difficult, but it occasionally works if the tree was planted by humans in a context where historical information can provide us a date. Wood density is frequently cited as being a principal determinant of life history variation in woody plant. It is correlated with stem water storage and transport capacity, resistance to decay and leaf characteristics such as toughness and deciduousness [12].

There are basically two major methods that can be used for tree age estimation: (1) tree rings, (2) and growth rate. The principle used in tree rings method is that in most trees that form rings, the rings are formed annually, so the number of rings in the tree will provide a fairly close approximation of the tree's age [13]. In practice, there are a number of problems with this principle listed by [15]. Age can only be estimated by external measurement and then by direct comparison with other trees of similar species, size and known planting date on comparable sites elsewhere**.**

Dating a tree without rings can also be done by measuring its growth rate. Growth rate measurements tend to assume that the growth rate measured over a given recent time period can be extrapolated to the entire lifespan of the plant. As we will see when discussing tree rings, such estimations can be wildly inaccurate. Nonetheless, it has been used to estimate ages of 1000 to 4000 years for quite few yew trees in England and to infer an age of 2000 years for a cycad based on counting the number of leaf scars on the trunk and multiplying by an estimation of how long it took the plant to produce a new leaf [15].

Data on circumference, tree‘s height, tree‘s rings and growth rate has been used to estimate the olive tree age by [13]. Growth rings have been used as a determinant of age for many evergreen or Mediterranean/subtropical trees [16]. [17] found a strong correlation between age estimated on the basis of tree ring counts, radiocarbon dates, or growth rate data.

According to the Lebanese Ministry of Environment (1998), the geomorphologic regions of Lebanon overwhelmed by the high variability in soil, rainfall and temperature have resulted in a variable and inclusive biodiversity richness, relatively small ecosystems and numerous crops. Among them, olive orchard occupies the third rank [18] and olive production, is estimated at 37000 tons in 2017 [19]. Olive constitutes an integral and significant part of the Mediterranean environment of which Lebanon and culture, however, its ecological importance has only recently been acknowledged [20]. Olive trees can live for long period and in Lebanon, some trees were estimated very old, especially in the area of Bshaaleh. However, studies related to olives are mainly based on pest, diseases, olive waste,…. Therefore, the objectives proposed are to study the climate conditions, the soil characteristics, to estimate age of trees and to assess the suitability of Bshaaleh area to olive cultivation, to try to draw a historical scenario regarding the possible population responsible for the plantation of these olive trees in Bshaaleh

II. Materials and Methods

2.1Climate conditions

The Lebanese Agricultural Research Institute (LARI), is a governmental organization under Minister of Agriculture supervision. This institute has installed many meteorological weather monitoring stations around the country. Two stations located in the north part of the countrywere chosen for data weather. Temperatures and precipitations recorded for the period 1949-1970 were provided by a station in Quartaba village(Altitude: 1140 m, 34˚50'45"N, 35˚50'59"E) as it is the nearest station to Bshaaleh region and it that can reflect the climate conditions of this area. The second station chosen was in Amioun, koura district, the most cultivated area with olive trees in Lebanon North (Altitude: 330 m,34° 17' 56"N, 35° 48' 32"E) where sampleswere collected for the period 1946-1966 in order to compare them with those of Bshaaleh.

2.2 Soil sampling

The soil samples taken were composed of several sub-samples representing a seemingly uniform area or field withsimilar cropping and management history. Taking samples directly after fertilization or amendmentapplication was avoided.Soil sampling was performed using a bucket auger to a depth of 0 - 30 cm and 30 - 60 cm. The soil of the Bshaaleh area, from where the samples were collected, appeared uniform. Four samples at two depths each were taken. The sub-samples were collected at random from the whole Bshaaleh area. "Fig. 1" showed the position of each sampling point (red point).All information about samples were recorded. Samples were stored in a cooler for minimizing microbialactivity and were air-dried or dried in an air-forced oven at 30^oC.Physical soil property analyses were conducted according to the methods reported previouslyby [10]. Forstandard particle size measurement, the soil fraction that passes a 2-mm sieve was considered.Laboratory procedures normally estimate the soil percentages represented by sand (0.05 - 2.0 mm), silt (0.002 -0.05 mm) and clay (0.002 mm). Hydrometer method was used for particle size analysis as described previously(Day, 1965 cited by [21];[22]).The following soil chemical properties are those that were assessed:soil pH, Electrical Conductivity (EC), calcium carbonate, soil Organic Matter (OM) and Total phosphorus (P). Chemical soil property analyses wereconducted according to the methods reported by [10].

2.3 Methods for age estimation

Three trees chosen, represent the different dimensions of 15 ancient olive trees of Bshaaleh: B1 was the largest, B4 with medium-size and B7 the smallest. According to [23], the measurement of the length of 10 rings was conducted consequently starting from different points (A, B, ...) and for 3 repetitive measurements exceeding 30 rings as shown in "Fig. 2".A trunk section was chosen from a tree of the same grove, having the same environmental conditions. An illuminated magnifier (5x) has been used to conduct the measurement. The length measured was recorded for different points.A number of 10 different marginal points was set, so thedata could be considered more representative. The average value of the marginal growth rate, the standard deviation and the coefficient of variability were calculated. The final result was used to estimate the tree age after the measurement of the tree relative dimension, especially the circumference.The circumference was measured using a tape; the measurement of tree circumference was conducted at breastheight [12].Using the measurement results, the age of the tree was estimated taking into consideration the local marginal growthrate and the trees dimensions.

The statistical comparison of data was performed by ANOVA, using the software SAS (Statistical Analysis System)Version 9.42013, to reveal significant differences at $P < 0.05$ for each sample point among the different measurements.

III. Results

3.1 Climate conditions

Meteorological data records from Quartaba station referring to the period 1949-1970, indicated that the mean annual temperature was 15.1˚C with a standard deviation of 5.3˚C.The minimum temperature recorded varied between 3.2˚C and 18.1˚C with an average of 10.6˚C. January and February were the coldest months with daily mean temperatures falling to an average of 3.2˚C-3.3˚C (Fig. 3). The warmest month was August, when the maximum average temperature reached 26.3˚C (data not shown).The lowest temperature could not be defined in the Quartaba available data. But according to LARI, in another proximate station in Wata-Houb,a minimum temperature of -6.35˚C was recorded during January 2009(data not shown).The available data from Wata-houb indicated that the average relative humidity in this region was around 62.5% (SD 19.9%) in the first 3 months of 2009 and around 46.2% (SD 16.8%) in the second 3 months of 2009. About 70-75% of the annual rainfall fell between September and February and less than 30% fell between March and August, when some violent downpours can occur and result in serious flooding and erosion (data not shown).The assessment of available climatic data of the LARI station in Amioun (data not shown) referring to the period 1946-1966, showed a mean annual temperature of 18.5˚C with a standard deviation of 4.9˚C. The minimum temperature recorded varied between 8.3˚C and 20.2˚C, with an average of 13.8˚C. January and February were the coldest months with daily mean temperatures falling to an average of 8.3-8.4˚C. The warmest month was August, when the maximum average temperature reached 30.2˚C. The average cumulative annual rainfall registered in the same period was 730 mm with a maximum of 165 mm/month, registered in the month of January.

3.2 Soil characteristics

The results concerning the physical characteristics of the soil are presented in"Table 1". According to the USDA Soil Textural Triangle[10], the soil samples tested from Bshaaleh had a sandy loam texture, which is a suitable texture for olive trees. The results regarding the chemical property of the soil are presented in "Table 2".The pH of the soil had an average value of 7.07 (+ 0.26) and so it can be classified as neutral. All pH values ranged from 6.5 to 7.5, which are optimal values for overall nutrient availability for tree roots [8]. In this range, the soil cation exchange capacity is production near 100% base saturation [24].Soil OM that derived from the transformation of plant material residues and soil organisms has amajor influence on soil aggregation, nutrient availability, moisture retention and biological activity. The averagevalue of 1.7% found in the samples tested can be considered an adequate content (>1.29%) [25]. A relatively important fluctuation in theOM level among thedifferent samples was noticed, with the lowest percentages found in the 30-60 cm depth. OM benefits the soil by aggregating soil particles as well as increasing its cation exchange capacity and water-holding capacity [8].

The level of calcium carbonate resulted high (38.3%).The EC resulted around 0.69 dS/m. The total salt content of a soil can be estimated from the measurement of EC. Soil salinity refers to the concentration of soluble inorganic salts in the soil. EC values from 0 to 2 dS/m (or mmhos/cm) are safe for all crops [10]. The low values of EC indicate that the soil of Bshaaleh area is not saline.The total phosphorus found in the soil was around 0.22 ppm, which is a value that can be considered good to supportthe plant growth [8].

3.3 Tree ages estimation

3.3.1 Marginal growth rate calculation

Ten different marginal points were chosen randomly in order to start the measurement of the first, second and third ten rings. This process was repeated three times (Table 3).The ANOVA One-way test conducted on these measurements revealed a very slight difference (*P*-value =0.044)between the three measurements because *P*-value was < 0.05 and the *F* value = 3.73. This difference was probablycorrelated to the unstable growth rate that can occur during the time [23].According to the calculation and assuming that each ring represented one year of growth, a marginal growth rate of1.633 mm/year as an average was calculated. The standard deviation calculated (0.106) can be considered low andreflects a low fluctuation rate in the data recorded among the different points with an acceptable coefficient ofvariability (Table 4).

3.3.2 Trees' age estimation from stem diameter measurement

According to the marginal growth rate (MGR) and taking into consideration the dimension of the trees, theestimation of the age was calculated by dividing the tree's Radius over the calculated marginal growth rate. The results are presented in the "Table 5".In order to correct the estimated age, 50 years of rapid starting growth were subject to be deducted. Duringthis period, the growth rate was considered as 0.63 cm/year [23]. This correction resulted in 30 cm reduction in tree radius.After correction, approximately 175 years were reduced from the estimated age of each tree, related to the first fastgrowing period.According to the calculated results, the ancient olive trees of Bshaaleh have been planted during several periods since 1400 years ago as estimated. The oldest tree (B1) has been probably planted between the year 446 and the year 746 before correction and between the years 620 and 920 after correction.

IV. Discussion

It is well known that the Mount of Lebanon (where Bshaaleh is located) forms a barrier to the movement of rains and precipitation can reach more than 1400 mm per year, including the water received as snow. For the period 1949-1970, punctual dates of frosting temperatures or of very high temperatures during the summer period have been investigated but without results because of the lack of detailed day data. According to the local farmers, the maximum amount of snowfall in Bshaaleh can exceed one meter in height and snow can persist for more than one week.Amioun, in Lebanon koura district, that is located in the North of Lebanon, is the most cultivated area with olives. The comparison of the climatic data of Bshaaleh with those of Koura area, showed that Bshaaleh is much colder than koura area during winter (5.1˚C less) and cooler during summer (3.9˚Cless). Detailed data from measurements done in nearby areas of Quartaba can be deduced that during winter temperatures can fall up to -6˚C and, probably, also to lower values. According to [5],winter temperatures fluctuating between 2˚C and 18˚C are ideal, supplying the winter chilling that many olive cultivars need for subsequent flower development. On the other hand, damage to aerial parts of the plant can reduce productivity [26], while at -12˚C damage may be serious enough to threaten the life of the tree.As shown by [6], olives are subtropical trees, sensitive to hard freezing temperatures. Critical conditions such as strong and dry winds, rain, and high temperature affect pollination and may reduce fruit. Conversely, very hot and dry conditions during bloom shorten the receptive period and desiccate the flowers[27].Our results are not in concordance with those shown previously, because the olive trees are still productive even when the temperature falls to -6˚C in winter season. Moreover, Bshaaleh received much more precipitations; indeed, on a per year basis they were about 90% higher than in Koura area (1390 mm vs. 730 mm).The rainfalls can be considered relatively high and so enough to allow a good tree growth and production also in rainfed conditions[28]. As far as the climate is concerned, the collected information showed that the environment of the Bshaaleh area is relatively cold and rainy compared with other areas where olive cultivation is important in Lebanon (i.e. Koura area).Therefore, the trees of Bshaaleh appeared to tolerate relatively low temperature conditions and, as a result of this, they seem potentially suitable to be cultivated in relatively cold environments.

The results of the pedological characteristics of this study show that the considered physical and chemical characteristics of the soil of Bshaaleh areawere well suitable within the ranges considered good for the growth of olive trees. Some studies showed that the olive tree vegetative growth, flowering and fructification were related with the soil structure [29]. As a matter of fact, a good soil composition allows a good aeration level for root growth, a quite permeable structure and an adequate water holding capacity [8;10].

The results of age estimation confirmed that the olive accessions present in Bshaaleh area are very old, butyounger than reported in previous articles by the Lebanese minister of tourism.Our results show a slower growth rate that could be explained by the environmental conditions of Bshaaleh, especially the high rainfall rate and the long cold period.An investigation conducted to determine the growth cycles of olives grown in tropical climate of Thailand showed that the growth curves tended to drop during rainy season [30].Olive crops evolvement during 60 years in three 80-year-old orchards shows that, the yield of the year (n) depend onrainfall of the same year and the year before (n-1).A radial growth regarding only the first growth phase, which is normally lasting not more than 200 years, possibly falls between 3 and 5 mm/year [23].Age attribution itself is challenging, due to irregular annual growth rings and the ubiquitous presence of cellulosedecaying dry-rots in the trunk (mainly *Polyporous* spp.). After 30 to 50 years of growth even if nothing appears fromoutside the inner trunk starts to decay with wood density loss. This loss is proportional to its initial marginal value and to wood den [31].In cultivated trees, a marginal growth rate of 4 to 7 mm/year can be extended for the duration of active cultivation that lasted from 100 to 150 years. After this phase, a progressive reduction of marginal growth rates occurs following Gompertz marginal reduction with values ranging around 1.2 mm/year with SD 0.6 mm/year. This value can be combined with initial growth rate to build a segmented approximation of trunk size time equation. A 3 years old twig and terminal rings in living trunk can serve as estimators [31]. The marginal growth rate of 1.633 mm/year as an average of olive trees of Bshaaleh can confirm the previous studies.

We are conscious that some inaccuracy in the interpretation of the age estimation might have occurred due to acumulative effect of factors such as variation in climatic conditions and cultural care over the long period, lack ofknowledge on annual growth increments between trees of different groups, etc., as also reported in other studies[13] and this is why the results have to be considered as indicative and a range of time is indicated as possible period of plantation of the old olives of Bshaaleh.We concluded that the first olive plantation in Bshaaleh goes back to not more than 1410 years (SD=150).Several articles have been published previously concerning the age of the olive trees of Bshaaleh. The possible estimated ages mentioned differed from one article to another talking about 1000 to 10000 years of age. As previously mentioned, the Lebanese ministry of Tourism has classified the olive trees of Bshaaleh as National Heritage. The Bshaaleh site has been nominated as one of the official touristic sites of Lebanon where very old olive trees (4000 years B.C.) are still healthy and productive. These trees are named Noah olive trees.

According to the researcher Father Youssef Dagher, Bshaaleh was a central place for habitation, even before theChristian period. There are many evidences showing that Bshaaleh is a very old village even before the Arabperiod [32]. Several very ancient monasteries and churches were found in Bshaaleh, including St. Thomas, St. Mema, St.Richa, St. Seba, St. Sarkis & Bakhos [33]. These churches and monasteries pooling in Bshaaleh has beenconsidered as one of the most important causes of urbanization and prosperity of agriculture in this area [34]. The St. Doumit monastery was considered as the biggest religious place in Bshaaleh, the place, that join theByzantine and the Syriac architecture, and was probably destroyed during Mamalik period in 1305 AD. SomeSyriac history specialists considered that the church of St. Doumit was built by the Syriac people, who werepresent in Bshaaleh before the Maronites [33].According to our preliminary results, probably the cultivation of olive trees in Bshaaleh started with thereligious groups, who fled to the mountains to escape from the Arab invasion, which occurred 1450 years ago. In themountains, they started to build their own monasteries and started to cultivate the most useful plants for them, i.e. olives and vines[34].

By using the marginal growth rate method to estimate the age, we were able to confirm that the olive trees of Bshaaleh are autochthonous, since this description can be used for fruit trees that have been present in the same area for more than 200 years [23]. Indeed, the age estimation study conducted on the ancient olive trees of Bshaaleh showed that the oldest tree was more than 1000 years old.

Our results could not confirm the age reported by the Ministry of Tourism for the ancient olive trees of Bslaaleh (6000 years). The age estimated in the present study, and so the reliability of the estimation, is also in agreement with the observation that the endocarps of the fruits of the ancient olive trees of Bshaaleh were longer than 11 mm and the fact that stones with length longer than 11 mm refers not to extremely ancient olive variety [23]. Indeed, in studies on the evolution of olive varieties it was observed a tendency of the stone and accordingly of the fruit to increase with time [35].

V. Conclusion

The ecological characterization revealed that the soil of Bshaaleh is well suitable for olive and that the climate is relatively cold and rainy. Therefore, the trees of Bshaaleh resulted to tolerate relatively low temperature conditions and, as a result of this, they seem potentially suitable to be cultivated in relatively cold environments.Our findings show that the most ancient olive trees, still productive, in Bshaaleh – Lebanon seem to be interesting for many reasons. These ancient trees represent an important part of the Lebanese olive autochthonous germplasm and their propagation will be important for conserving the biodiversity and for a better evaluation of these trees in comparative fields. It has been concluded that these trees seem to be able to grow up in cold areas. After propagation, this could make feasible their cultivation in different regions of Lebanon with climatic conditions similar to those of Bshaaleh where, at the moment, olive is not cultivated. Obviously, studies to verify this possibility in these regions should be performed before advising large scale plantations.We can also consider that this work is a cornerstone to start putting in order the variability of olive cultivars in Lebanon using multidisciplinary characterization approaches.The very old age of the olive trees in Bshaaleh indicate that they have been able to grow and produce in the environmental conditions of this area without substantial problems, suggesting that the trees could be interesting for their tolerance to relatively cold environments. This suggests a potential importance of these trees to be propagated and used in relatively cold environments that are present in Lebanon. The multiplication and use of these trees would also contribute to preserve the autochthonous olive germplasm of Lebanon.In this way, Bshaaleh olives can continue to offer the gifts that they have given for centuries as a benediction to the Lebanese population

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List of Figures

Figure 1. Soil sampling points (red) from the Bshaaleh site.

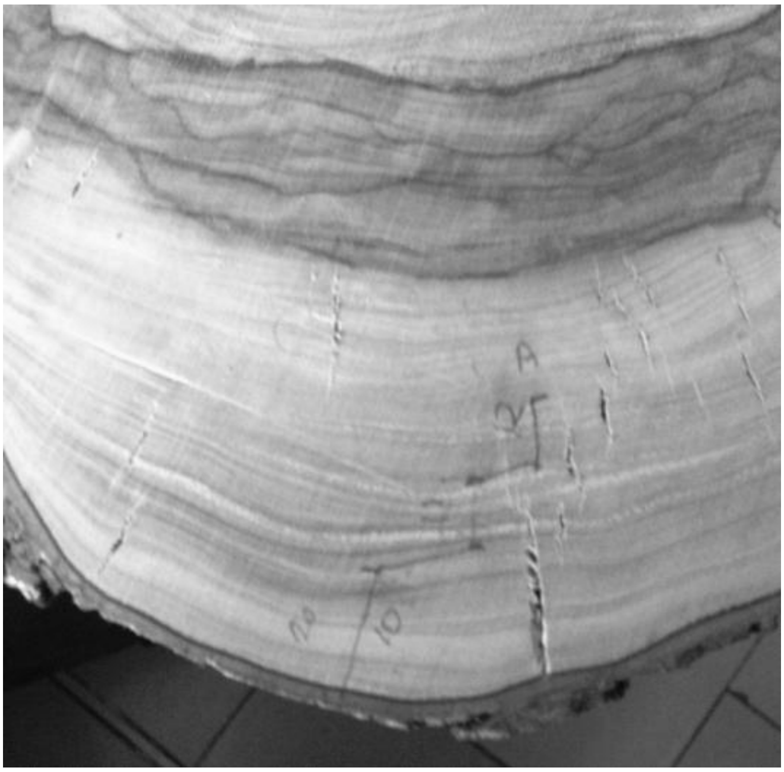

Figure 2: The count of each 10 rings length [23].

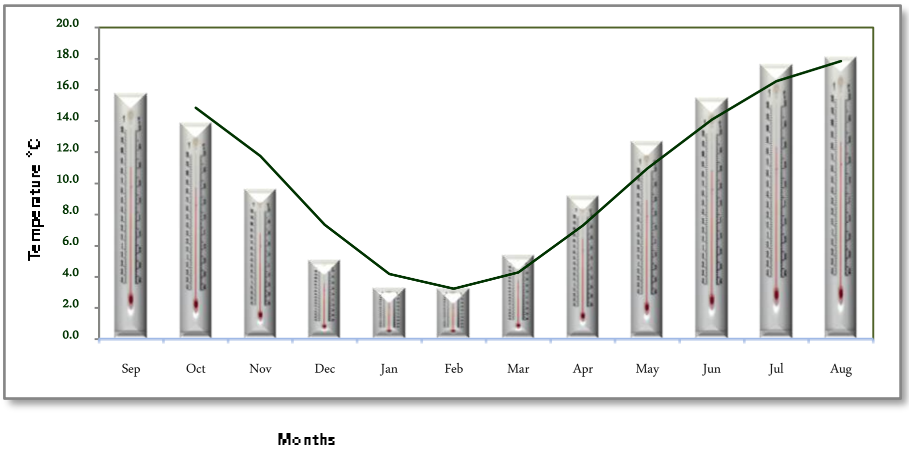

Figure 3. Monthly average minimum temperature at Quartaba station (1949-1970). {Average 10.6˚C, SD 6.2} *(LARI, 2009).*

List of Tables

Table 1: Physical properties of the soil at different positions and depths

Samples	Depth (cm)	Sand (%)	Silt (%)	Clay (%)
#01-#03-#05-#07	00-30			
	Mean	54.06	38.47	10.00
	SD	2.83	6.79	3.60
	Texture class	Sandy loam		
#02-#04-#06-#08	30-60	Sand (%)	Silt (%)	Clay (%)
	Mean	51.51	38.97	11.47
	SD	4.40	5.44	2.79
	Texture class	Sandy loam		
Total	Average	Sand (%)	Silt (%)	Clay (%)
	Mean	52.78	38.72	10.74
	SD	3.69	5.70	3.08

Table 2: Chemical properties mean values of the soil at different depths

Samples	Depth (cm)	pH (%)	Org. Matter (%)	$CaCO_3$ (%)	EC (ds/m)	P (ppm)
#01-#03-#05-#07	00-30					
	Mean	7.02	2.12	35.60	0.69	0.22
	SD	0.16	0.28	12.67	0.10	0.11
#02-#04-#06-#08	30-60					
	Mean	7.13	1.28	40.98	0.68	0.15
	SD	0.29	0.34	18.62	0.04	0.06
Total	Average					
	Mean	7.07	1.70	38.3	0.68	0.18
	SD	0.26	0.56	17.3	0.08	0.10

Table 3: Length of 10 rings measurements

	Positions											
	A	B	C	D	E	F	G	H	I	J	Mean	SD
1st measure (mm / 10 rings)	13	19	15	20	13	17	16	20	17	15	16.5	2.59
2d measure (mm / 10 rings)	13	17	14	14	15	16	17	15	17	14	15.2	1.47
3rd measure (mm / 10 rings)	17	17	19	16	17	18	16	17	19	17	17.3	1.06

Table 4: Marginal Growth Rate calculations

Average marginal growth rate (MGR) =	**16.33 mm per 10 years / 1.633 mm per year**
Minimum marginal growth rate =	**1.52 mm per year**
Maximum marginal growth rate =	**1.73 mm per year**
Standard Deviation =	**0.106**
Coefficient of Variability =	**5.86**

Table 5: Tree age estimation from stem diameter measurement (Radius (mm) / Marginal growth rate per year) (*): without correction

Tree code :	Position:		
B1	**1185 m**	**34° 12' 06 N**	**35° 49' 23 E**
Circumference (mm):	Diameter (mm):		
14500	**4615.50**		
Trunk Cross Section:	Height:		
1629.77 m²	**6.25 m**		
Estimated Age= Radius / MGR	Standard Deviation		
1413 years*	**150 years**		
Estimated planting period	**Between 454and 754 A.C.**		

Tree code :	Position:		
B4	**1181 m**	**34° 12' 06 N**	**35° 49' 23 E**
Circumference (mm):	Diameter (mm):		
6500	**2096.02**		
Trunk Cross Section:	Height:		
327.505 m²	**6.00 m**		
Estimated Age= Radius / MGR	Standard Deviation		
633 years*	**67 years**		
Estimated planting period	**Between 1316 and 1451 A.C.**		

Tree code :	Position:		
B7	**1177 m**	**34° 12' 06 N**	**35° 49' 23 E**
Circumference (mm):	Diameter (mm):		
4500	**1432.40**		
Trunk Cross Section:	Height:		
156.97 m²	**5.25 m**		
Estimated Age= Radius / MGR	Standard Deviation		
438 years*	**46 years**		
Estimated planting period	**Between 1532 and 1625 A.C.**		

Elie Bou Yazbeck "Ecological characterization of ancient olive trees in Lebanon-Bshaaleh area and their age estimation." IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 11.2 (2018): PP 35-44.