Research Article

Comparative Study of the Physiological, Phenological and Agronomic Characteristics of Algerian Olive (*Olea europeae sativa* L.) Varieties in Semi-Arid Conditions

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Abstract | The olive tree (*Olea europaea*. L), is a characteristic species of the Mediterranean landscape, which has many varieties with significant phenotypic diversity. In our work we studied 6 varieties: Azéradj, Frontoio, Neb Djmel, Limli, Sigoise and Chemlal, at the level of the area of El-Annasser, wilaya of Bordj-Bou-Arréridj, this study is based on phenological, physiological and agronomic characterizations established by COI (1997).The results obtained indicate that the large number of stomata in the leaves of the Azeradj variety (1.22 stomata/1mm^2), Limli variety has the highest value of the chlorophyll rate with 99.23%, Azeradj and Frontoio varieties are the earliest (February 25), Chemlal and Limli varieties are the latest (March 16),all the varieties studied are self-fertile. The six varieties tested present differences for the different physiological, phenological and agronomic characteristics, but they are all self-compatible.

Received | February 19, 2023; **Accepted** | April 26, 2023; **Published** | May 18, 2023
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Citation | Fayçal, B., C. Nacira, S. Amel, B. Mohammed, M. Khelifa, K. Cherifa, D. Melak, A. Younes and A. Fares. 2023. Comparative study of the physiological, phenological and agronomic characteristics of Algerian olive (*Olea europeae sativa* L.) varieties in semi-arid conditions. *Pakistan Journal of Agricultural Research,* 36(2): 106-114.
DOI | https://dx.doi.org/10.17582/journal.pjar/2023/36.2.106.114
Keywords | Olive tree, Varieties, Characterization, Pheno-physiology, Semi-aride

Introduction

The olive tree is the second most important fruit and oilseed crop grown worldwide after the oil palm. The olive tree presents a considerable number of varieties, this great polymorphism is due to the influences of the soil and the microclimate which are likely to bring modifications which can

be phenotypic and genotypic (Ouazzani*et al*., 1995; Belaj *et al*., 2001). This wealth of genetic material is due in particular to the great longevity of the tree, its secular history and the nature of its pollination. The olive tree is a woody plant with opposite leaves and fleshy fruits (Flahault, 1986; Morettini *et al*., 1972). The flowers are hermaphroditic have male (two stamens) and female (pistil) organs, very small (3-5mm) (Villa, 2003). The olive is ovoid, green at first then turns black when fully ripe, variable dimensions depending on the variety (Saad, 2009). Nowadays, the olive tree has spread widely beyond its original air following its dispersal by humans in the United States, Australia and New Zealand (Green, 2002). The olive tree is present throughout all the wilayas of the North of the country because of its ability to adapt to all bioclimatic stages (Achour, 1995). Thus, in certain semi-arid and arid zones which value suitably by its hardiness and flexibility of adaptation.

In Algeria, the cultivation of the olive tree dates back to ancient times, our peasants devoted themselves to it with art for several centuries (Abdessemed, 2017). The olive tree is the most cultivated fruit tree in Algeria, this culture occupies a very important place with more than a third of the Algerian arboreal orchard (Boukhari, 2014).

Algeria is one of the main Mediterranean countries whose climate is more favorable to the cultivation of the olive tree, where it is one of the main fruit species at the national level. According to FAO statistics (FAOSTAT, 2021), the olive tree in Algeria is grown over an area of 440008 ha, or 34.09% of the national tree orchard, with a production of 704619 Tons, the yield is estimated at 1.6014 t/ha.

Olive oil production in Algeria is estimated at 80.000 tons during the 2017-2018 campaign, an increase of 27% compared to the previous period, while the area reserved for olive growing consists of 56.3 millions olive trees including 32.3 millions productive olive trees, a rate of 57%. Olive growing is concentrated in seven main wilayas (Bejaïa, Tizi-Ouzou, Bouira, Bordj-Bou-Arreridj, Jijel, Sétif and Mascara). the olive-growing areas cultivated in Algeria have increased almost three times over the past seventeen years; from 170.000 hectares in 2000 to 487.000 hectares in 2017 (Oreggia *et al*., 2017). The total olive-growing area of the wilaya of Bordj-Bou-Arréridj is 27.457 ha, and the number of olive trees 2.534.710 trees (DSA, 2021).

Two main objectives condition this work: the first objective is to contribute to the characterization of 06 varieties of olive trees in the region of Boumerghed wilaya of Bordj-Bou-Arreridj, based on the phenological, physiological and agronomic description described in the descriptor of the International Olive Council (IOC). The second objective is to assess the existing variability between these varieties (Table 1).

Table 1: *Representation of origin, use and the main properties of the varieties of olive trees studied (Mendil and Sebi, 2006).*

Varieties	Origin	Use	Properties
Azeradj	Algerian (Béjaia)	Oil and table olive	A hardy, drought-resistant tree; fruit of heavy weight and elongated shape; used for the production of oil and table olives, oil yield from 24 to 28%.
Frontoio	Italian	Oil	tree grows well in milder climates, but it is not as tolerant of heat and cold. The average oil yield is 23-28%. It is self-pollinating and is excellent for politicizing other cultivars. White flowers, dark green leaves.
Neb Djmel	Algerian (several regions)	Oil and table olive	Tree of average vigor, with an average development, the habit is spread, the foliagewith a hemispherical shape, the density of the foliage is loose, presence of vents whichlet in light
Limli	Algerian (Sidi Aich Béjaia)	Oil	It represents 8% of the Algerian olive grove. Its fruits are small (1 g to 2 g) and its oil content is 15%, the oil is slightly acidic, its maturity and quite early.
Sigoise	Algerian (Mascara)	Oil and table olive	Originally from the plain of Sig, occupies 25% of the Algerian olive orchard. Thisvariety is used for the production of excellent canning olives in green or black with a production of 50 kg/tree. It is also appreciated for the production of oil whose yield is 18 to 22%. The tree has a medium height, which facilitates picking by hand. The average fruit weight ranges from 4.5 to 5.5 g, and the pulp-to-stone ratio is 6.44.
Chemlal	Algerian (Kabily)	Oil	Vigorous, large trees with a spherical and semi-hanging habit. Its fruit branches are long and flexible. The fruits are small with an elongated shape and a weight of 2.5g and are intended for the production of oil of excellent quality. The oil yield is 16% to 18%. Self-sterile variety due to the absence of pollen. In Kabily, it is always associated with Azeradj which ensures its pollination, a hardy and late variety.

Materials and Methods

Plant material

The plant material used in this study consists of six varieties of olive trees (Azeradj, Frantoio, Neb Djmel, Limli, Sigoise and Chemlal) planted in the semi-arid zone of the Bordj-Bou-Arréiridj region, 4 trees per variety are chosen to follow the different phenological stages and the different morphological and agronomic characters.

Location of the experience

Our study was carried out at the level of a private farm, a place called Boumerghad, area of El-Annasser, the practical part is done and at the level of the educational laboratories of the University Mohamed El-Bachir El-Ibrahimi, Bordj-Bou-Arréridj and the laboratory of the University, Mohamed Boudiaf, M'sila.

The location of experiments for this study is located in the municipality of El Anasser, area of Bordj Bou Arreridj following the coordinates: lat 36.04 249°N and long 4.50 290°E, altitude: 930 m in the north-eastern region of Algeria in the East High Plains closer to the Saharan Atlas the country (Figures 1, 2).

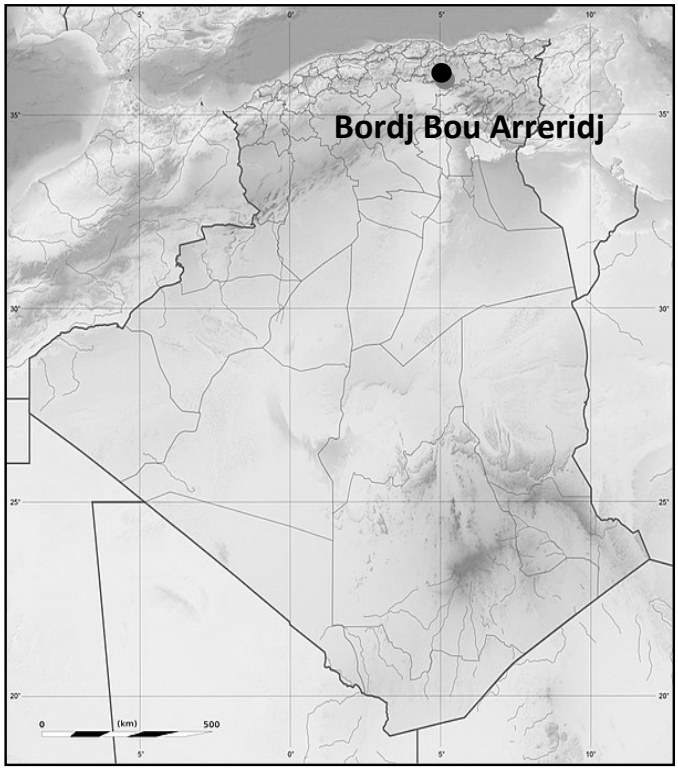

Figure 1: *Study area situation.*

Soils are relatively shallow with heavy texture and low organic matter and (Bouzerzour and Dekhili, 1995). The average temperature is 15 ± 0.9 °C and negative temperatures and frosts occur from January to April, whereas high temperatures, generally associated with a strong dry wind (called sirocco), are recorded in early summer (Chourghal *et al.*, 2016). Annual precipitation varies between 350 and 450 mm, and climatic hazards, such as drought and frost, are critical for production systems (Baldy, 1986).

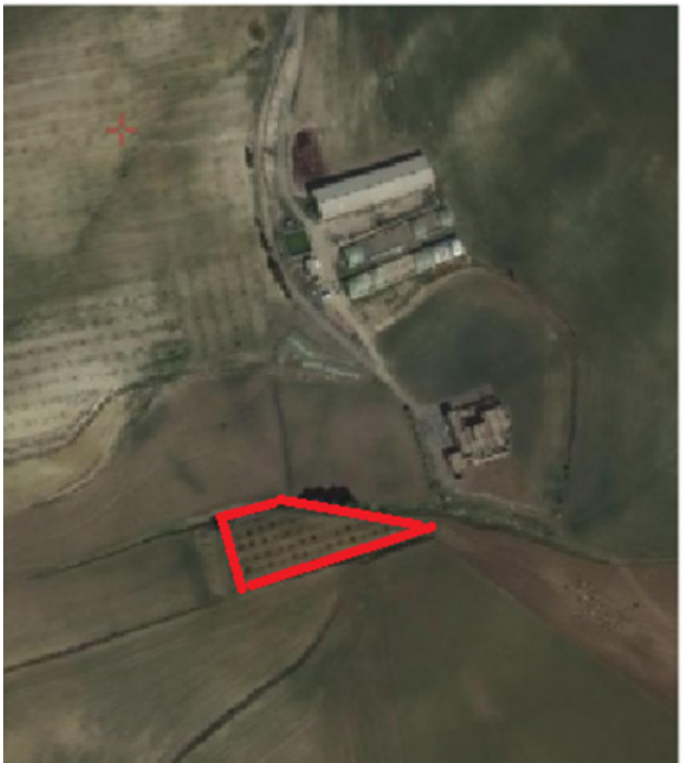

Figure 2: *Location of the experiments.*

Olive growing has always existed in Bordj Bou Arreridj in mountainous areas to the north but has spread throughout all the region. Yields are low and remain dependent on climatic conditions, but the olive, due to its adaptation to the agro-climatic context of the region, is part of the speculation that can contribute greatly to the diversification of the economy (Lamani and Ilbert, 2016).

Experimental device

This study was carried out on trees, aged 19 years, from the period of bud burst until fruiting, according to a device in total randomization, 4 trees were selected for each variety, 28 trees in total were sampled and labeled.

Sampling

The different parameters studied according to (C.O.I., 1997).

Methodology

The working methodology followed for the

physiological, phenological and agronomic characterization was taken as proposed in the catalog of varieties (Mendil and Sebai, 2006) and the world catalog of olive varieties.

The measurements taken

Physiological characteristics: Stomatal density: A sample of 12 leaves was taken for each variety (3 leaves/tree), to determine the stomatal density by the epidermal fingerprint method. The leaf stomata in the olive tree are completely covered by hairs, so they must be removed with tape several times to be able to observe the stomata. The prints were obtained by the application of a layer of transparent nail polish, once dried, this layer of varnish is removed with the help of an adhesive tape and placed on a slide. The observations were made using a telephone camera, then observed under an optical microscope such as OPTIKA MICROSCOPES, DM-25. The density of the trichomes (DT) was determined from counting the number of their imprints/mm^2 of epidermis, while their diameter is determined by measuring the µm of each imprint.

Chlorophyll rate: A sample of 3 leaves per tree was chosen, 12 leaves per variety, the chlorophyll rate was calculated using the Chlorophyll Content Meter CCM-200. The CCM-200 Chlorophyll Content Meter is a portable, battery-powered instrument designed for the rapid, non-destructive determination of chlorophyll content in intact leaf samples. Measurements are instantaneous and can be made in the field under normal lighting and growing conditions. The CCM-200 uses absorbance to estimate leaf chlorophyll content, two wavelengths are used. One wavelength is in the absorbance range while the other serves to compensate for mechanical differences such as tissue thickness. The multimeter measures the absorbance of both wavelengths and calculates a chlorophyll concentration index (CCI) value proportional to the amount of chlorophyll in the sample, (*Safe Parameters: Optical transmission ratio at 931 nm at emission optics at 653 nm. *Measurement area: 71 mm^2 (9.5 mm diameter). *Resolution: ± 0.1 Chlorophyll content index unit).

Phenological characters: Study of the phenological stages (from bud burst to fruit drop) and determination of the dates of each period.

Agronomic characters

Earliness and lateness: Early and late varieties were identified by monitoring phenological phases.

Incompatibility: Flowering shoots of 25 cm to 50 cm in length were chosen, with sufficient inflorescences and which were covered with perforated bags so that no external pollination will take place.

Data analysis methods

Data processing was carried out in two stages: (a) data collection; (b) their presentation in tables and finally their analysis using statistical tests. The different results of the morphological characterization are presented in the text in the form of averages. The one-factor analysis of variance (ANOVA1) using STATISTICA 8 software. Was carried out with the aim of detecting the character effect on the leaf, the fruit. This analysis is essentially intended to detect existing differences between the different values obtained for the different COI descriptors used.

Results and Discussion

Physiological charters

Stomacal density: We used analysis of variance to test the significance of the difference between varieties in the parameter stomatal density. At a probability threshold of 0.01, our analysis of variance results reveal a highly significant difference between varieties concerning the character stomatal density (Table 2).

Table 2: *Analyse of variance of the character stomacal density.*

Average and standars deviation					
Azeradj	**Frontoio**	**NebDjmel**	**Limli**	**Sigoise**	**Chemlal**
1.22±0.29	0.98±0.15	1.13±0.19	1.11±0.14	1.12±0.21	1.09±0.13
Analyse of variance					
	Degr. of	**SCE**	**CM**	**F**	**Prob**
Intercept	1	80,47504	80,47504	2468,448	0
Variety	6	0,80689	0,13448	4,125	0,001483
Error	63	2,05389	0,0326		
Total	69	2,86078			

According to the results revealed, we notice a large number of stomata in the leaves of the Azeradj variety (1.22 stomata/1mm^2), against a low number for the Frantoio variety (0.86 stomata/1mm^2). On the other hand, the varieties Neb djmel, Sigoise, Limli and Chemlal gave intermediate values which are respectively of the order of (1.13, 1.12, 1.11 and 1.09), (Figure 3).

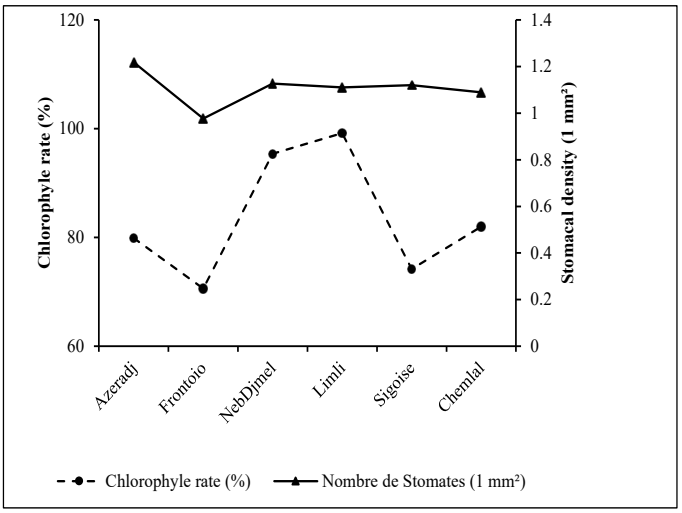

Figure 3: *Stomacal density and chlorophyll rate in the studied varieties.*

The increase in stomatal density favors the survival of plants in particularly harsh environments, moreover this increase would be an alterative to a good supply of CO_2 for the realization of photosynthesis.

Chlorophyll level

Analysis of variance to test the significance of the difference between varieties in the character chlorophyll level was done, at a probability threshold of 0.001 the analysis of variance results reveal very highly significant differences between the varieties (Table 3).

According to the results, we notice that the Limli variety has the highest value of the chlorophyll rate with 99.23%, the Frontoio variety presents the lowest value (70.58%). On the other hand, the varieties Neb djmel, Chemlal, Azeradj and Sigoise, present average values with, respectively: 95.36%, 82.04%, 79.89% and 74.24%, (Figure 3).

Leaf age and physiological condition are important determinants of chlorophyll content, these factors will positively affect CCI, which is commonly promoted to measure leaf nitrogen considered as an indicator of elemental status. plant nutrients, much of the nitrogen in the plant is bound to chlorophyll and other photosynthetic compounds. Nevertheless, chlorophyll is highly regulated by the plant and can change with light levels as well as nutrient status (Hoel and Solhaug, 1998).

Phenological characteristics

The phenological stages correspond to the evolution of buds from vegetative rest to fruit set. Bud burst begins to elongate, which begins on 25/02/2022 for the Azeradj and Frontoio varieties, which are the earliest varieties, after three days the Neb djmel variety begins around 03/03/2022, and after three days the Sigoise variety during 09/03/2022 and finally the Limli and Chemlal varieties around 16/03/2022 which constitute the latest varieties (Table 4).

The buds turn into flower buds which begin on 19/04/2022 for the Azeradj variety then the Frontoio and Neb djmel varieties on 27/04/2022, after a week the formation of clusters begins for the rest of the Limli, Sigoise and Chemlal around 04/05/2022 (Table 4, Figure 4).

Table 3: *Analyse of variance of the character chlorophyll level.*

Average ans standars deviation					
Azeradj	**Frontoio**	**NebDjmel**	**Limli**	**Sigoise**	**Chemlal**
79.89±4.4	70.58±4.81	95.36±5.6	99.23±5.73	74.24±4.42	82.04±3.94
Analyse of variance					
	Degr. of	**SCE**	**CM**	**F**	**Prob**
Intercept	1	1224662	1224662	576,1166	0
Variété	6	84790	14132	6,648	0,000002
Error	203	431521	2126		
Total	209	516311			

Table 4: *Phenological phases of the olive tree, early and late varieties according to phenological periods.*

Variety	Budburst	Formation of clusters	Flowering	fruit set
Azeradj	25/02/2022 (Early)	19/04/2022 (Early)	25/05/2022 (Early)	09/06/2022 (Early)
Frontoio	25/02/2022 (Early)	27/04/2022 (Early)	25/05/2022 (Early)	11/06/2022 (Early)
Neb djmel	03/03/2022 (Seasonal)	27/04/2022 (Early)	29/05/2022 (Late)	15/06/2022 (Late)
Limli	16/03/2022 (Seasonal)	04/05/2022 (Late)	29/05/2022 (Late)	13/06/2022 (Late)
Sigoise	09/03/2022 (Seasonal)	04/05/2022 (Late)	01/06/2022 (Late)	12/06/2022 (Seasonal)
Chemlal	16/03/2022 (Late)	04/05/2022 (Late)	28/05/2022 (Seasonal)	11/06/2022 (Early)

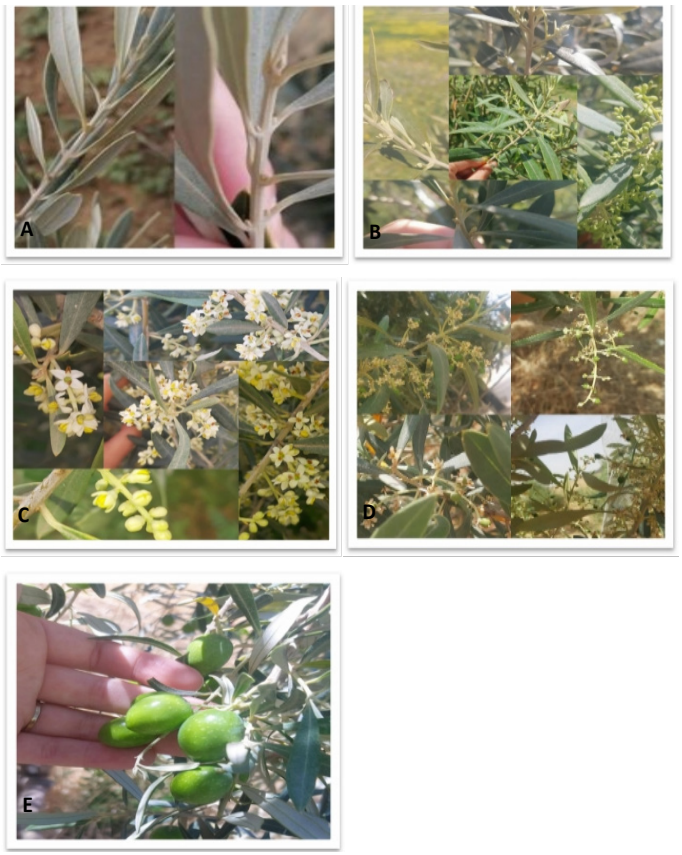

Figure 4: *Different phenological stages of the olive tree. A: Bud burst ; B: Cluster formation; C: Flowering; D: Fruit set; E: Fruit magnification.*

The flower buds turn into flower parts which give flowers on 23/05/2022 for the Azeradj and Frontoio varieties, after two days, it is the Neb djmel variety which flowers, around 27/05/2022 after two days, it is the turn of the Limli variety. Finally, around 29/05/2022, the Chemlal and Sigoise varieties will flower last (Table 4, Figure 4).

The fruit set is the formation of the olives which begins on 09/06/2022 for Azeradj for the Frontoio and Chemlal varieties the fruit set begins on 11/06/2022 after the Sigoise variety on 12/06/2022 the Limli variety on 13/06/2022 and the latest Neb djmel variety around 15/06/2022 (Table 4, Figure 4).

The stage of the evolution of the young fruits until obtaining their optimal size which is started on 09/06/2022 until the complete maturation of the fruits (Table 4, Figure 4).

Earliness and lateness

We note that the Azeradj variety is the earliest, while the Neb Djmel and Limli varieties are the latest during all the phenological stages studied, the Chemlal and Sigoise varieties which were late during bud burst became early during fruit set, these differences are due to varietal characteristics specific to each variety (Table 4).

Incompatibility

Self-compatibility in which the fertilization of the ovules of a flower can be ensured by the pollen of the same flower or by the same variety. For all the varieties studied in our experiment, the flower shoots that we covered with a bag all self-pollinated, they gave fruit without the intervention of another variety (Figure 5).

Figure 5: *Incompatibility.*

The study region is a semi-arid zone characterized by a cold winter and a hot summer, the varieties of olive trees grown must adapt to this type of harsh climate in rainy conditions, the various parameters measured allow us to conclude that the autochthonous varieties of olive trees are the most suitable, such as the Azeradj, Chemlal and Limli variety, grace to a high stomatal density and a high chlorophyll rate, which will further increase the rate of photosynthesis, therefore a good yield and a good production of quality olive oil.

Contrary to the varieties introduced such as Frontoio which gives an average yield with an average quality of oil, and which presents a precocity in the different phenological stages, which exposes it to the negative effects of the late spring frost, these constitute signs of weak adaptation.

Following these results, he concluded that the local varieties must be well maintained is that by several cultural practices such as: soil maintenance, which improves the permeability of the soil decreases the evaporation of water from the soil (Warlop, 2010), as well as maintenance at the foot of olive trees using manual hoeing (Bouvard *et al*., 2000). Chemical weeding is not recommended for young plantations because it is expensive and not respectful of the environment (Afidol, 2012). In dry orchards, in the event of high olive production, harvest-related exports must be compensated by an increase in nitrogen and potash manure (Gazeau *et al*., 2012). The practice of pruning is essential, the fundamental principles of pruning are: Architectural balance, light and ventilation and avoiding the phenomenon of production alternation (Wallali *et al*., 2003).

Flood irrigation is the most practiced method despite the great losses due to this traditional method. Irrigation frequencies are irregular because of the lack of water, due to the drought that has affected the region for several consecutive years. As diseases and pests must be controlled, the two most common pests in orchards are the psyllid and the olive fly (Siouda *et al*., 2020). As the timing of the harvest must be respected, the harvest of table olives takes place at the end of September, while that of the black olives reserved for the production of oil begins in December and ends at the end of winter, around mid-February.

The local variety Chemlal is the most dominant and most cultivated olive oil variety with more than 60% of the orchards, the local variety Sigoise is considered as a table olive. All these cultural operations will improve the state of the orchards in Algeria, by increasing the yields of olive and oil of local varieties.

Conslusions and Recommendations

The olive tree has been part of our environmental landscape for thousands of years, grace to its great interspecific diversity and cultural value. The experimental work was carried out at the level of the zone of El Anasser (exploitation of Boumerghad) to determine the pheno-physiological and agronomic characters of six varieties of olive tree: Azeradj, Frontoio, Neb Djmel, Limli, Sigoise and Chemlal, we led to the following results:

- The analysis of variance shows a highly significant difference between the varieties for the stomatal density and the chlorophyll rate.
- The physiological characters measured indicate that the Azeradj variety has the highest number of stomata with 1.22 stomata/1mm^2, while the Limli variety contains the highest chlorophyll rate with 99.23%.
- The study of the phenological stages revealed significant differences between the varieties tested, for all the phases studied, the Azeradj and Frontoio varieties begin their development early around February 25; after a week, it is the turn of the Neb Djmel variety around March 01, then the Sigoise variety around March 09 and a few days later, the Chemlal and Limli varieties start around March 16, which are considered the latest.
- This study allowed us to conclude that all the varieties studied have self-fertility (self-compatibility), so trees of the same variety can self-pollinate without the intervention of another pollinating variety.
- At the end of this study, farmers are recommended to cultivate local Algerian varieties in rainfed conditions, where the trees are more adapted to semi-arid climates, grace to the adequate physiological characteristics. The introduced varieties present an average oil production and quality and poor adaptation to the northern Algerian climate.

Acknowledgment

We thank Sir Benouili Amar, the owner of the olive orchard where the experiment was carried out, for his

help and practical guidance.

Novelty Statement

This study is based on a physiological (number of stomata and chlorophyll rate), phenological (phenological stage) and agronomic (compatibility rate) characterization of some varieties of olive trees in the semi-arid zone of Algeria.

Author's Contribution

Bahlouli Fayçal: Supervision, conceived the idea, technical input at every step, overall management of the article.
Chourghal Nacera: Statistical application, data analysis. Wrote and worked on tables and graphs.
Salamani Amel, Benaini Mohammed, Maamri Khelifa, Atek Younes and Aissat Younes: Methodology, provided technical and guidance input.
Kachaou Cherifa and Djaballah Melak: Provision of samples and field activities, support in manuscript write-up.

Conflict of interest
The authors have declared no conflict of interest.

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