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Effects of Topography, Soil Texture and Climatic Factors on the Growth Rate of Olive Trees (*Olea europaea* L.) in Albaha Region, South-Western Saudi Arabia

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

A field study was conducted to study the effects of topography, soil texture and climatic factors on the growth rate of olive trees (*Olea europaea* L.) in Albaha region, south-western Saudi Arabia. Results indicated that there was no variation observed in soil texture among the studied locations. The maximum amount of rain fall and relative humidity recorded in the study areas was– 28.7 mm and 59%, respectively. Temperature was ranged from 16 – 29.6°C while surface wind speed reached a maximum value of 47 Kts. At the studied locations which had steeper topography and characterized by scattered small, huge and steep Rocky Mountains the elevation was in the range of 1245 – 2052 m while the slope was ranged from 00 to 75. Most of the healthy very green vigorous trees were found in the bed of the Wadi while the stunted ones were scattered on the mountain edges. This indicated that the altitude and slope have remarkable effects on the growth rate of the olive trees.

Keywords: Olive trees; Olea europaea; topography; climatic factors; Albaha; Saudi Arabia.

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1. INTRODUCTION

Saudi Arabia is characterized by a semi-arid environment with high temperature variability, low annual rainfall, no natural perennial flow and limited groundwater reserves [1]. Albaha region is a part of Sarawat Mountains and characterized by cool climate, high precipitation and high humidity. It is designated as a semiarid climate that situated in the south-western part of Saudi Arabia [2,3].

Studies carried out on climatic changes Zabin at different regions of Saudi Arabia indicated that the southwest region was different from the central and north regions. In the southwest region, mean values in summer and winter were 24.3°C and 19.4°C respectively. The intra-seasonal difference was less than 5°C while in the central and north regions, the differences were up to 20°C. The wet summer was likely to reduce the temperature difference in the southwest [4].

Olea europaea (Oleaceae), is belonging to the olive complex, is largely distributed in Asia and Africa. **T**he most known subspecies is subsp. europaea, a typical, ancient and economically important crop in the Mediterranean basin that includes both wild and cultivated olive [5]. Both wild and cultivated olive trees are largely distributed in Albaha region. Olives are considered a new crop in Kingdom of Saudi Arabia. During the last fifteen years national production of olive oil has increased rapidly and there is an enormous potential for olive oil and table olive production in the Saudi Arabia [6].

The growth of olive trees and productivity are greatly affected by the climatic condition and the soil texture especially in the arid and semi-arid countries such as Saudi Arabia. The aim of this study was to correlate the effect of topography, climatic factors and soil texture on the growth rate (vigour's shoot growth) of olive trees (*Olea europaea* L.) grown in Albaha region.

1.1 Study Areas

The study was carried out at twelve location sites (Farm No.1a, Farm No.1b, Amdaan Forest, Barhrah Forest, Albudani area, Al Khulb Park, Mishari Prince Park, Farm No. 2a, Farm No. 2b, Almrasa area) in Albaha province during Jan – Dec, 2016 and Jan – Dec, 2017. The area is characterized by its variation in environmental factors such as topography, geomorphology, climate and soil.

2. MATERIALS AND METHODS

2.1Topography and Climate

Data of monthly variation in air temperature (°C), relative humidity (%), precipitation (mm) and wind speed were obtained from Albaha meteorological station, Saudi Arabia, during Jan – Dec 2016 and Jan – Dec 2017.

2.2 Soil Texture

Soil samples were collected randomly from each location then mixed together before analysis. The method described by Gupta [7] was adopted for determining the soil texture of each sample using a Bouyoucos hydrometer (TM-85, SHTG, Shanghai, China).

3. RESULTS AND DISCUSSION

3.1 Topography

3.1.1 Farm no.2

The farm (20.04'N, 41°34'E) is located in Bouhar village, approximately 30 km north-eastern of Albaha city with an area of 150544 sq m. It is at an average elevation of 1918 m above mean sea level and has a sharp sloping topography towards the west. The highest part of the farm is a hill located to the eastern side of the farm, at 1949 m above mean sea level. The western side of the farm is at an altitude of 1992 m above sea level with gentle slope. General slope (33%) is toward the west side. Most of the soils in the farm are sandy loam or loamy sand to clay texture and mostly blocky or massive while granular structure at surface layers. According to the elevation gradients, the farm was divided into different locations. More than 30 cultivars of *Olea europaea* subsp. *europaea* were planted in rows 6 m apart and 2 m between plants in the row.

3.1.2 Almrasa

Almrasa (20°05′N, 41°33′E) is a gentle slope area (21%) lies at western side of Bouhar – Almrasa road and the area is composed of mountains and Valleys (Wadis). The altitude of the central region of the Wadi is about 1909 m and the relative height of the mountains varies from 300-600 m. The Wadi covers an area of

about 50 sq. km. and the soil texture at the bed of the Wadi is loam, clay, and silty clay. The dominant tree in the Wadi was *Olea europae* and the region holds a variety of plants, such as *Acacia etbaica* Schweinf*., Acacia etbaica* ssp. *uncinata* Brenan*, Acacia gerrardii* var. *najdensis* Chaudhary, *Ficus cordata* ssp. *salicifolia* (Vahl) C.C. Berg, *Ziziphus spina-christi* (L.) Desf, *Juniperus procera* Hochst. Ex Endl. Most of the healthy very green and vigorous *Olea europaea* trees were found in the bed of the Wadi while the stunted ones were scattered on the mountains edges.

3.1.3 Barhrah forest

Barhrah Park (20°20′N, 41°21′E) is located about 64 km north-western of Albaha city in Almandaq province. In general, the area has steeper topography and characterized by scattered small and huge and steep Rocky Mountains. The peaks of these mountains reach elevations of over 1800 m in the vicinity of Barhrah. The average slope of the area is about 45% and is characterized by cool climate, high precipitation and high humidity. *Olea europaea* subsp. *cuspidata* (Wall. & G. Don) Cif was found scattered on the edages of mountains and shared dominancy in the area with *Ziziphus spina-christi* (L.) Desf. The most common companion species to *Olea europaea* subsp. *cuspidata* were *Opuntia ficus-indica*, *Ficus palmata* Forssk., *Ficus cordata* subsp. Salicifolia (Vahl) C.C. *Berg, Nuxia oppositifolia* (Hochst.) Benth and *Rhus abyssinica* Hochst. Ex Oliv.

3.1.4 Algema forest

The park (19°81′N, 41°71′E) is about 25 km South of Baljurashi town and the Mountains on this are generally discontinuous, less rugged and much drier as compared with the other locations. The eastern part of the area is a little hilly at an elevation of 1400 m or above and partially mountainous at the elevation of 1700 m or above. The western part slopes gently to the coastal plain. The climate is cooler, with temperatures rarely rising above 35°C. The ground surface is covered with boulders and various sharp angled rocks while the soil is shallow. The plant cover is thin and *Olea europaea* subsp. *cuspidata* (Wall. & G. Don) Cif was found abundantly in upstream region of Algema Dam. Other associated species such as *Acacia gerrardii* var. *najdensis* Chaudhary, *Tamarix aphylla* (L.) Karst., *Juniperus phoenicea* L., *Juniperus procera* Hochst. Ex Endl, *Pistacia falcata* Becc. Ex Martelli, *Nuxia oppositifolia* (Hochst.) Benth, *Trema orientalis* (L.) Blume, were relatively few and recorded mainly near the Dam.

It has been reported that topographic and edaphic factors play a critical role in controlling community structure and species distribution [8,9,10,11,12].

3.2 Climatic Factors

Albaha region (south-western part of Saudi Arabia) is characterized by unique climatic and topographic features with rugged topography and elevation ranging between 1700 m eastwards, and 2400 m westwards above sea level. The region is divided by huge and steep Rocky Mountains into two main sectors, a lowland coastal plain at the west, known as “Tihama”, and a mountainous area with an elevation of 1500 to 2450 m above sea level at the east which form a part of Al - Sarawat Mountains range Several authors have reported that plant growth and plant community are well affected by climatic factors [13,14,15].

3.2.1 Temperature and precipitation

Figs. 1 and 2 display the monthly variation in air temperature and precipitation at Albaha region in 2016 and 2017, respectively. During Jan – Dec 2016 the mean temperature varied between 16 – 29.5°C while the rainfall was in the range of 0.2 – 25.6 mm. The monthly mean temperature recorded in 2017, was in the range of 16.4 – 29.6°C while the rainfall was in the range of 1 – 28.7 mm.

However, the chemical and quality characteristics of a virgin olive oil are influenced by the site of cultivation [16,17,18] showed that the climatic conditions particularly the rainfall during growing and ripening of olive fruits; influence the concentration of phenolic compounds.

3.2.2 Relative humidity

The mean monthly relative humidity ranged from 26 to 59% during the year 2016 (Fig. 3). The highest level of relative humidity was recorded on January while the lowest level was recorded on July. As shown from Fig. 4, the relative humidity in the year 2017 was in the range of 26 – 59%. No clear variation was observed between the two years in their monthly mean temperature, rainfall and relative humidity. Overall temperature in the area was lower due to the effects of elevation,

while the other regions of the country were affected by tropical air mass in spring, summer and autumn. In all seasons, the area received irregular and variable rains of frequent occurrence, with a maximum in spring.

However, the spatial variation of the precipitation, temperature and relative humidity in the region could be due to elevation gradients, topographically driven convective rain, Indian monsoons, wet summer monsoon and other factors. The region receives rainfall in almost all months of the year, whereas the northern region receives most of its rainfall during the winter and spring seasons.

The high winter temperature in the region as compared with the central and north regions of the Kingdom could be attributed to the effects of the moist air mass from the Red Sea in the equatorial side. The annual thunderstorms are most frequent and, in general, decrease towards the west and east. In general, thunderstorm frequency does not appear to vary in any consistent way with precipitation.

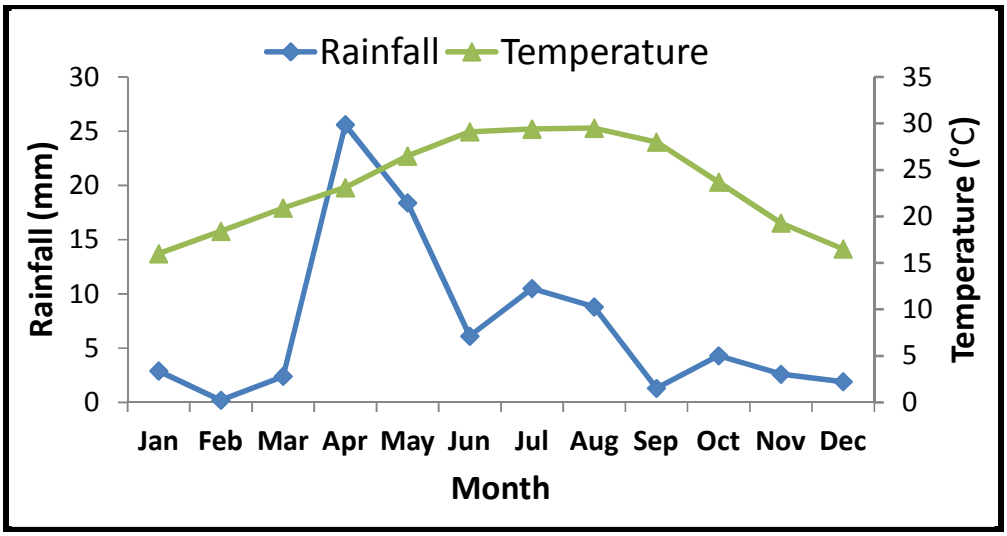

Fig. 1. Monthly mean temperature and precipitation pattern over the period from Jan to Dec 2016

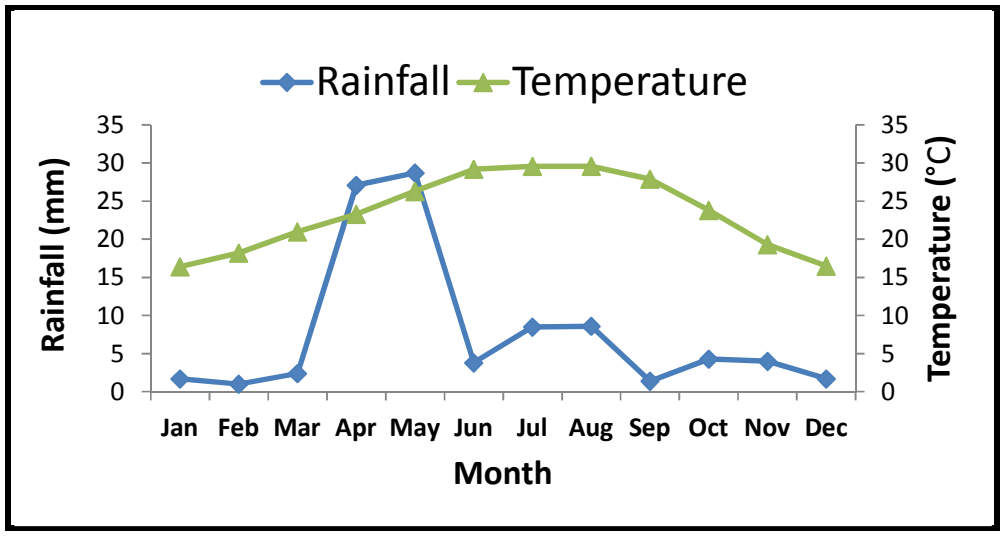

Fig. 2. Monthly mean temperature and rainfall pattern during Jan – Dec 2017

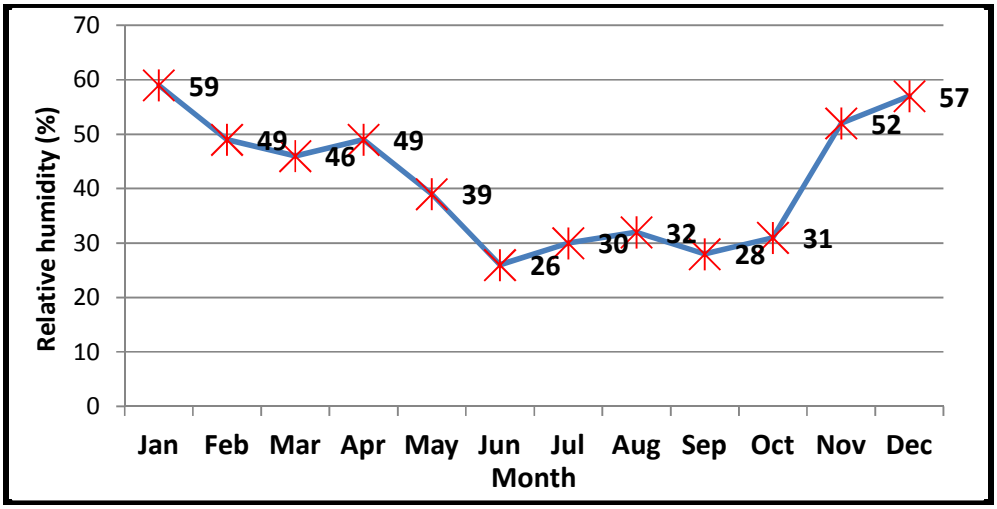

Fig. 3. Monthly mean relative humidity over a period from Jan to Dec 2016

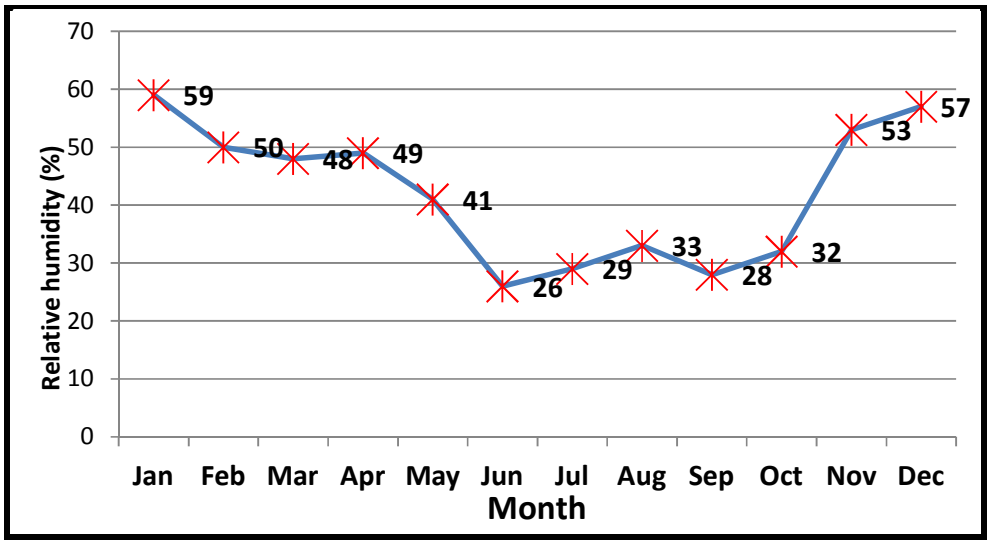

Fig. 4. Monthly mean relative humidity during Jan – Dec 2017

3.2.3 Wind speeds

Monthly mean and maximum wind speeds measured on the ground surface at Albaha region are presented in Figs. 5 and 6. Wind speed is given here in the units of "Knots" (kts). A "Knot" is a nautical mile per hour (1 knot = 0.51444 m s^{-1} = 1.15078 mile h^{-1} = 1.853 km h^{-1} = 1.689 ft s^{-1}). The monthly mean wind speeds in the year 2016 were in the range of 5 to 9 Kts while the average maximum wind speeds were in the range of 25 to 47 Kts. During the year 2017 the surface wind speed reached a maximum value (47 Kts) in April while the lowest speed (22 Kts) was recorded in October. However, over land, the roughness of the ground causes a decrease in the mean wind speed compared with that which occurs over the sea, with the size of the decrease depending on the nature of the terrain. In general, wind speed increases with height, with the strongest winds being observed over the summits of hills and mountains.

Many studies have revealed that the importance of environmental variables not only in affecting plant growth and plant community structure and species distribution variability at a spatial scale but also in providing insight into the environmental requirements of the tree species

needed for successful ecological restoration and biodiversity protection [19,20,21].

3.3 Soil Texture

No clear variations were detected in soil texture among the studied locations. Most of the collected soil samples were either sandy clay loam or sandy loam and a few were silt loam. The percentages of sand clay and silt were significantly varied among the studied locations (Table 1). The highest level of sand percentage (75.8 ± 4.3%) and the lowest value of the clay content (13.7 ± 0.87%) were detected in the soil samples of Algema Forest. The collected soil from Al Khulb Park area contained significantly high amount of silt (42.8 ± 10.3%) as compared with the other locations (10.5 ± 4 - 28.3 ± 2.9%). Mishari Prince Park soil had relatively high amount (31.7 ± 2.5%) of clay and low (40 ± 5.2%) amount of sand when compared with the other locations. It was clear that all the soil samples from all locations had high percentage of sand and low amount of silt except Al Khulb Park soil which contained high level of silt.

Mahmoud et al. [22] have reported that the soil texture of Albaha region is classified into three classes: loam, clay, and silty clay. The loamy soil represents 85.8% of the area, whereas, 8.4% of the area is silty clay and 5.7% of the total area is clay soil. Soil texture has a large influence on water holding capacity, water conducting ability and chemical soil properties and greatly affected the growth of the studied olive trees. It plays a big part in the plant's ability to extract water and nutrients. However, the particle size distribution is one of the essential controls of soil structure and functioning. Soil processes, properties and

Table 1. Soil texture at the studied location sites

Location	Sand (%)	Clay (%)	Silt (%)
Farm No.1a	57.4 ± 5.2^{cd}	20.4 ± 3.8^{bcd}	22.2 ± 2^{bc}
Amdaan Forest	65.3± 3.3^{abcd}	17 ± 2.6^{cde}	17.7 ± 1.3^{cd}
Barhrah Forest	70.3 ± 4.2^{ab}	17.4 ± 3.8^{bcde}	12.3 ± 4.9^{d}
Albudani area	70.1 ± 5.5^{ab}	17.5 ± 4.5^{bcde}	12.3 ± 1^{d}
Al Khulb Park	34.1 ± 10.4^{e}	23 ± 1.3^{bc}	42.8 ± 10.3^{a}
Mishari Prince Park	40 ± 5.2e	31.7 ± 2.5^{a}	28.3 ± 2.9^{b}
Farm No. 2a	65.5 ± 2.6^{abcd}	20.4 ± 3.4^{bcd}	14.2 ± 3.3c^{d}
Farm No. 2b	61.1 ± 5^{bcd}	20.4 ± 5.8^{bcd}	18.5 ± 0.9^{cd}
Almrasa area	68.3 ± 5.2^{abc}	17.9 ± 3.4^{bcde}	13.8 ± 2.3^{cd}
Algema Forest	75.8 ± 4.3^{a}	13.7 ± 0.87^{e}	10.5 ± 4^{d}
Alchukran Forest Park	64.1 ± 11.5^{abcd}	15.7 ± 0.87^{cde}	20.2 ±10.7^{bcd}
Farm No.1b	54.1 ± 2.9^{d}	23.4 ± 1.4^{b}	22.5 ± 4.3^{bc}

Values are mean ± SD, n = 3. Values in columns with different letters are significantly different (p < 0.05)

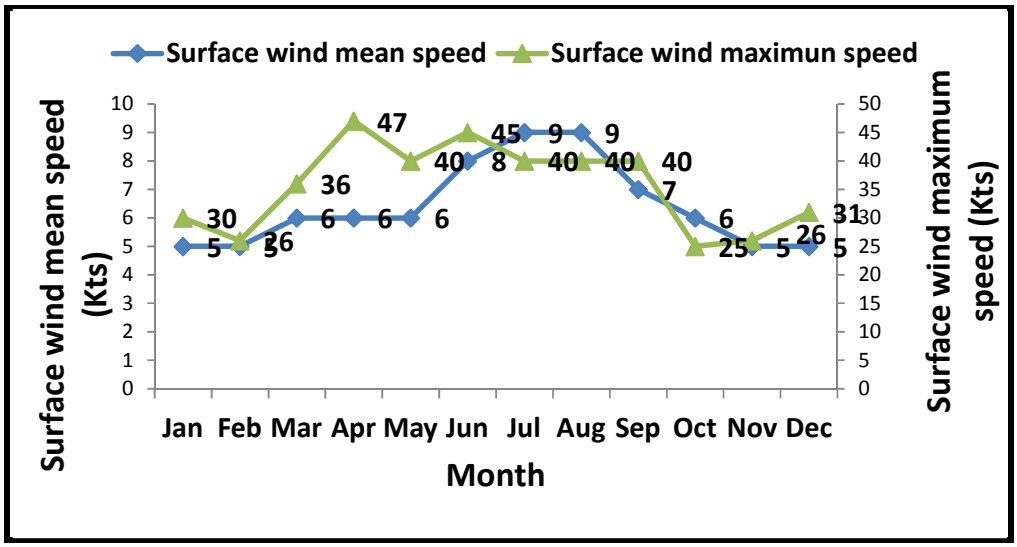

Fig. 5. Monthly mean and maximum wind speed over a period from Jan to Dec 2016

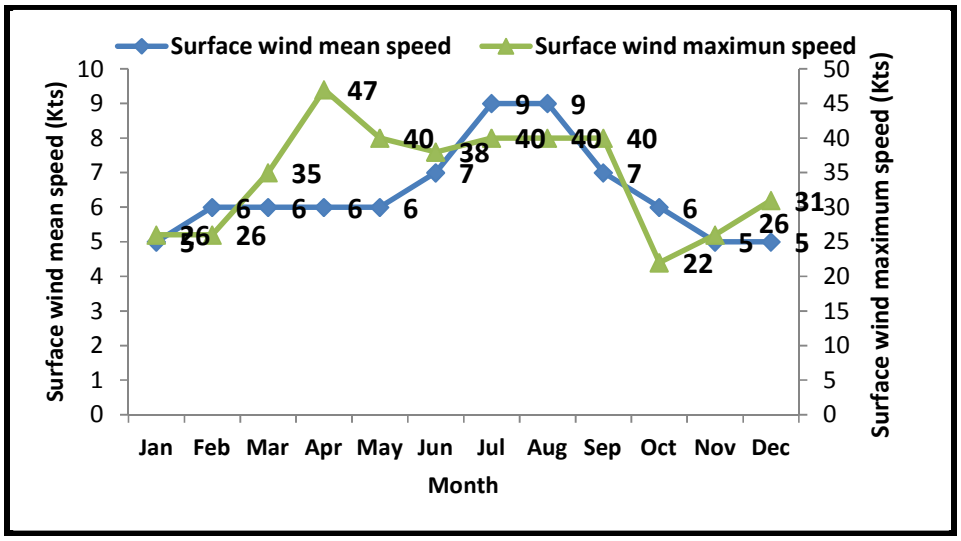

Fig. 6. Monthly mean and maximum wind speed during Jan – Dec 2017

specific features are usually related to these distributions [23]. Servili et al. [24] found that the soil texture was correlated positively with phenol content in olive oil (possibly because it influences negatively the soil moisture of soil). It is recommended to study the individual effect of these variable parameters on the growth as well as the oil yield of the studied olive trees in each location.

4. CONCLUSION

The obtained results revealed that there was a clear effect of topography and climatic factors on the growth rate of the studied olive trees. Elevation gradients, slope, mountain edges and bed of the valleys were the main factors that affect the heath and shoot growth of the trees. Future work should be conducted to study the effects of other topographic and climatic factors and human disturbance on olive trees.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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