Evaluation of Some Man-Made Forests at Al-Jabal Al-Akhdar in Libya

Mohamed O. Al-Fitori[1], Ibrahim E. Kherallah[2], Ahmed M. El-Baha[2], Hosney A. Abo-Gazia[2], Ahmed A.A. El-Settawy[2]

[1]Department of Forest, Faculty of Natural Resources, Omr AL-Mukhtar University, Libya

[2] Department of Forestry and Wood Technology, Faculty of Agriculture, Alexandria University, Egypt

ABSTRACT

This study aimed to investigate the growth dynamic, litterification, wood yield and dendroclimatology of Aleppo pine (*Pinus halepensis*) trees growing in five different plantations, namely, Hemre, Marawah, Madwar Ziton East, Madwar Ziton West and Kashaf, located at Al-Gabal Al-Akhdar region, Libya.

The results obtained have demonstrated that the planation of Marawah displayed the highest diameter at breast height (dbh) (21.55 cm), mean annual increase in dbh (0.66 cm/ year), basal area (BA) (19.25 m^2/ha) , log volume (1.02 m^3/tree), mean annual increase in log volume(0.02 m^3/tree/year) , log yield /ha (307.47 m^3/ha) and mean annual increase in log yield/ ha (8.54 m^3/ ha/ year). Hemre, however, displayed the tallest tree (14.61m) crown diameter (5.23 m) , with no significant differences in dobh, (21.70 cm) , BA (21.20 m^2/ha) and log yield /ha (256.22 m^3/ ha) with those manifested in Marawah plantation. On the contrary, Kashaf plantation, however, has exhibited the lowest values of the growth and yield as mentioned above.

The average of annual litter fall gained in the plantations floor was 10.51 ton/ ha / year, as a mean for all plantations studied, with non significant differences among each other. There were also non significant differences among all plantations in specific gravity of the wood (0.45 as a mean for all plantations). The bark coefficient was also the same for all plantations inspected (0.93).

Monitoring the rainfall rate since 1960 up till now (2019), there was a slight decrease in rainfall rate with the time that averaged 394.34 mm/year, concomittant with a slight increase in temperature that averaged 18.47°C at Al-Gabal Al-Akhdar region. The dendroclimatological studies have revealed that either the width of early wood, latewood or annual ring thickness was inversely proportional with the simultaneous temperature in all sites investigated. Except for Kashaf plantation, the rainfall rate was neithersignificantly impacting on the width of early wood, latewood nor annual ring thickness developed in the stem of the trees in all plantations analyzed. Upon the prospected negative climate changes and its detrimental impacts on the forest growth, it recommended to improve silvicultureal practices to keep it fit.

Key words: *Pinus halepensis*, Plantation, Dendrology, Dendroclimatology, Litter, Bark thickness, Growth, Yield, Basal area.

INTRODUCTION

It is well known that the forests are virtually cover about one third of the global land, which cover about 3.9 billion hectares. It has been reported that about 31.6 to 30.6% decrease in forest area in 1990 and 2015, respectively, yet with slow rate recently (FAO, 2018).

The plantations (Man-made forests) are covering about 187 million ha, where the largest area (61% of the total area)is located in Asia. The annual increase in afforestation is amounted for 4.5 million ha, where Asia and South America implies 89% of such contributed increase. There has been an accomplished afforestation in an area of 3 million ha, out of 4.5 ha, the total area afforested.

One half of the plantations were exploited in industrial purpose, yet one- fourth for un-industrial ones and the rest one-fourth with no certain purposes.

The most common tree species used as a plantation were *Eucalyptus* spp., *Acacia* spp. And *Pinus* spp., that for their fast pace growth rate, so that their short rotation. The species mentioned above are used for timber and fibers for diverse industrial purposes (FAO, 2000).

In 2000, about 35% of the timber produced in Libya had been obtained from the plantation. This percentage is expected to surge for 40% in 2020, owing to an increasing demand for timber industrial purposes, since *Pinus* spp and *Eucalyptus* spp. comprised about 20 and 10% of the total species used, respectively (FAO, 2000).

Since the ancient Greece, Romanian era, AL Gabal AL-Akhdar is regarded as an important civilized center, where the agriculture and industries have been developed. The ancient civilization had been relied on the natural resources in AL-Gabal AL-Akhdar, as water, forests, ranges and settled agriculture (Johnson, 1973). In addition, dams and gradoni (terraces) have been set out (Zunni and Bayoumi, 2006).

The green cover in this region has been underwent a heavy devastation, notably felling of big trees for ship and construction industries in the ancient era for housing.

AL-Gabal AL-Akhdar region is localized between latitude 32 and 33 North and altitude 20 and 23 East., where Mediterranean located in North and El-Batnan plateau at East, Benghazi plain at West and Libyan Desert at South. Such mountain is accounted for 1% of the total area of Libya. The importance of Al-Gabal Al-Akhdar is owing to its nature as a unique evergreen natural forest in Libya, resembling south Italy, Greece Island and Turkey ecosystem (Azzawam, 1984 and Omar Al-Mukhtar University, 2005)

Accordingto Al-Zaght,(1978), the total forest area in Libya is about 6,680,000 ha, which comprised about 4% of Libyan area, yet most of such area were deforested, except for the natural forest at Al-Gabal Al-Akhdar, which covers about 0.5 million ha (0.7% of the total area of Libya), some areas have been degraded (Omar Al-Mukhtar University, 2005). The afforestation program was launched in a bid to protect arable or cropped land, building, roads and houses away from sand dune invasion, yet unfortunately, the plantation had underwent recently to devastation and contraction (Eldoumi *et al*., 2002).

The afforestation program has been launched in 1954 using only *Pinus halepensis* species to cover an area of 750 ha. Additionally, more plantation were established here and there to reach eventually 3325 ha all over Libya (Zunni *et al*., 1996). In 1970s, the plantations set up this time were composed of *Pinus halepensis* chiefly, *Eucalyptus camldulensis* and *Acacia cyanophylla* with less extent, then in 1980s with *Cupressus sempervirens*, as well. There are great intents to study the situation in some plantations already existed in Al-Gabal Al-Khdar region, implying assessment and to figure out its potential and its compatibility with the prevailing the environmental conditions in behalf of the local and exotic tree species there. *Pinus* is a paramount and worldwide coniferous tree species. According to Price*et al*.,(1998), the genus of *Pinus* embraced 111 species in two subgenera, four sections, and 17 subsections. Aleppo pine (*Pinus halepensis* Miller) tree belongs to Subgenus *Pinus* (Diploxylon or hard pines), subsection *Pinus* (Eurasia, Mediterranean, E North America, Cuba) (Gernandt *et al*., 2005). *Pinus halepensis* Miller is an evergreen coniferous tree of 15-25 m in height, 150 cmin diameter at breast height, and the leaves are needles in pairs in fascicles of intermediate length (5–12 cm × 1 mm) and bearing narrow-cone fruits (William *et al.,* 1967, Aljos, 1984, Gindel, 1944 and Weinstein, 1989). The tree thrives well in several continents, notably, North and South Africa, South and East Europe, North America and Australia in different habitats, where the tree needs annual rainfall about 14 inches (350 mm/ years) (Gindel,1955) at least. Aleppo pine is so common to colonize large parts of the eastern and western part of the Mediterranean Basin (Barbero *et al*., 1998).

Aleppo pine is one of the typical trees, which conferred both of environmental and economic benefits and fits multipurposes in afforestation programs.

The tree produces soft wood and satisfies some constructional and carpenter purposes and for pulp and paper production (Haddad *et al*., 2009), and can be used as a fuel (Earle, 2019). Italso produces resins (Spanos *et al.*, 2010), resin from the bark (Britt, 1970, Woodson,1986 and Passialis *et al.*, 1995), oleoresins and gum resin and phenolic compounds (Tisler *et al.,*1983 and Passilis *et al*., 1995), Furthermore, the tree (all parts) is rich in medicinal products (Yaniv and Dudai, 2004).

The Aleppo pine tree has been studied by many workers from several standpoints, amongst which, ecophysiology, and dendrology, silviculture, and biometry, dendrochronology as well as wood and non-wood technology.

The growth dynamic of the tree and its relation with the environmental aspects has been received a considerable attention. Furthermore,the dendrochronology of *P. halepensis* and other trees species was undertaken by many investigators, i. e., by analyzing the annual increment rings of the wood and coincidently with the environmental condition impacted its thickness, notably temperature (Salminen and Jalkanen, 2005,Hordo *et al.* 2009, Bajwa *et al.* 2015 and Gonzales-Benecke *et al.* 2017).

The precipitation or rain fall rate has an influence on the thickness of the increment growth rings (late- and early- wood thickness) in some trees (Cedro , 2001, Sabate *et al*., 2002 Pritzkow *et al*., 2014, Bogino *et al*., 2009 and Bajwa *et al*., 2015) and effect of water availability on the girth growth of *P. halepensis* Olivar *et al*., (2014) and in other pine species (Moore *et al.,* 2006 ; Vittoz *et al.,* 2008 and Bogino *et al*., 2009).

This study aimed to assessment of the growth of *P. halepensis* and its dynamic, growing in five stands (plantations) in AL Gabal AL-Akhdar region. Also, The work aimed at analyzing dendrochroclimatologically the growth of the trees to pinpoint the most important simultaneously environmental conditions impacted on the growth of the tree and putting forward documented data base for further organized research in this connection.

MATERIALS AND METHODS

This study aimed at investigating and assessment of five plantations components, in terms of growth parameters, wood increment analysis in relation to present and past environmental conditions at Al-Gabal Al-Akhdar region, Libya.

Study site

Five plantation sites, located at South side of Al-Gabal Al-Akhdar region have been selected. The height of the mountains (plantation sites) was ranged between 413m in Al-Kashaf forest, which located at Al-Ghareeb-Takniss road, 866m above sea level in Hemre forest, 20km South Al-Bayda City, during the period from Septameber, 2016 to Sep., 2017.

The profile of each site can be described as follows:

1- Hemre plantation

This is one of old plantations in Al-Gabal Al-Akhdar region, has been established in 1951 over an area of 79ha, where *Pinus halepensis* is unique species. It is located at °32.´63.872 latitude at North and °31.´79.297 latitude at East. Relative to the other sites studied, it is regarded as the highest one, i.e., 849m above sea level. Common soil there is clayey, deep to intermediate brown colored, with thin layer of litter, which to certain extent retains moisture.

In addition, it is regarded as a poor succession site. Owing to applying no silvicultural practices, the trees inspected are of short trunk except for the tree standing at the boundaries of the forest, which are characterized with big diameter. In general, this plantation has been underwent severl deterioration by unwise human activities and adverse natural factors.

2- Marawah plantation

This plantation is located at the Eastern aspect of Marawah Village, extended parallel to the main road. Soil surface is displaying some slope (3-9%), between °32.´15.032 altitude at North and °021.´41.334 latitude at East, This plantation has been established in 1972 in an area of 43.5ha, at 505m above sea level.

The stand inspected is of intermediate to low stocking and 2 categories can be described, the first is a group of trees standing on slight-sloped plateau with poor-growth trees, yet it is free of epidemic diseases and some have crooked trunks, probably owning to wind throw over there. The second category is stand over the boundary of the way in form of strand, with high crown and big trunk trees. The soil is of a medium depth, red and turn yellow in dry condition and reddish brown at wet condition.

3- Eastern Madwar Ziton plantation

It is regarded as one of the important plantation in Al-Gabal Al-Akhdar region, which has been established in 1980, located at the main road between Marawah and Madwar Ziton Village in a form of longitudinal strip parallel to the road. The plantation is at °32.´44.498 altitude Northern, °021.´28.516 latitudeEastern, over a height of 440m above sea level. The plantation is relatively new, mostly with *Pinus halepensis* trees, with an area of 232ha. Slope of soil surface is slight toward north (2-5%) and the soil is of medium depth clayey, brown colored soil, composed of limestones and rich in organic matter.

4-Western Madwar Zaiton plantation

This plantation is five km apart of the Eastern one, °32.´44.903 altitude Northern, °021.´18.810 latitude Eastern, covers a mountain of 512m height above sea level. It has been established in 1992 in an area of 8.5 ha.

The characteristics of the soil is resembling that of site 3, because it is nearby, with slope of 3.5%.

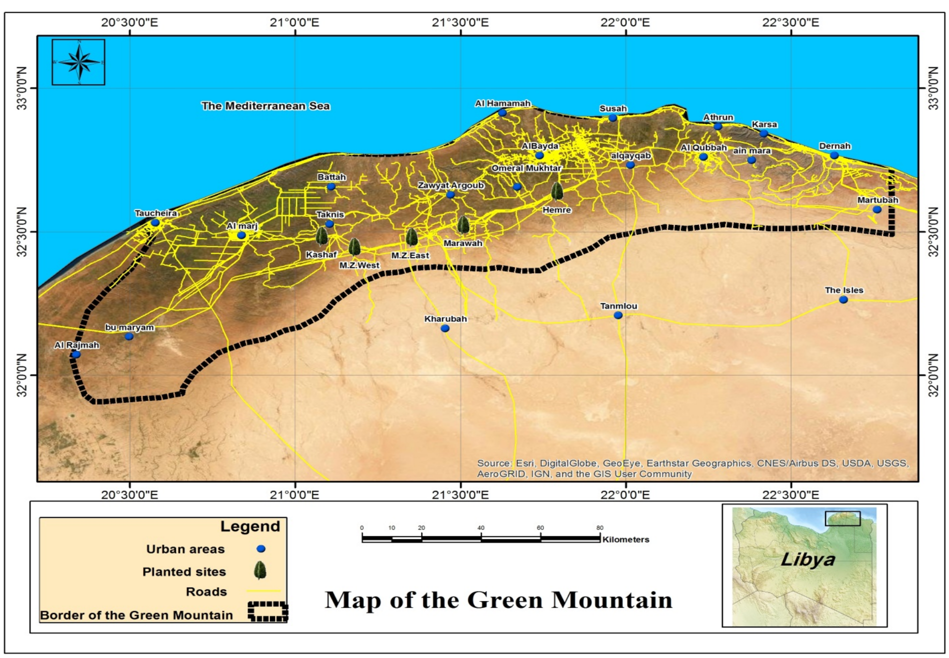

Fig. 1: Al-Gabal Al-Akhdar plan, indicated the 5 study sites selected for investigation.

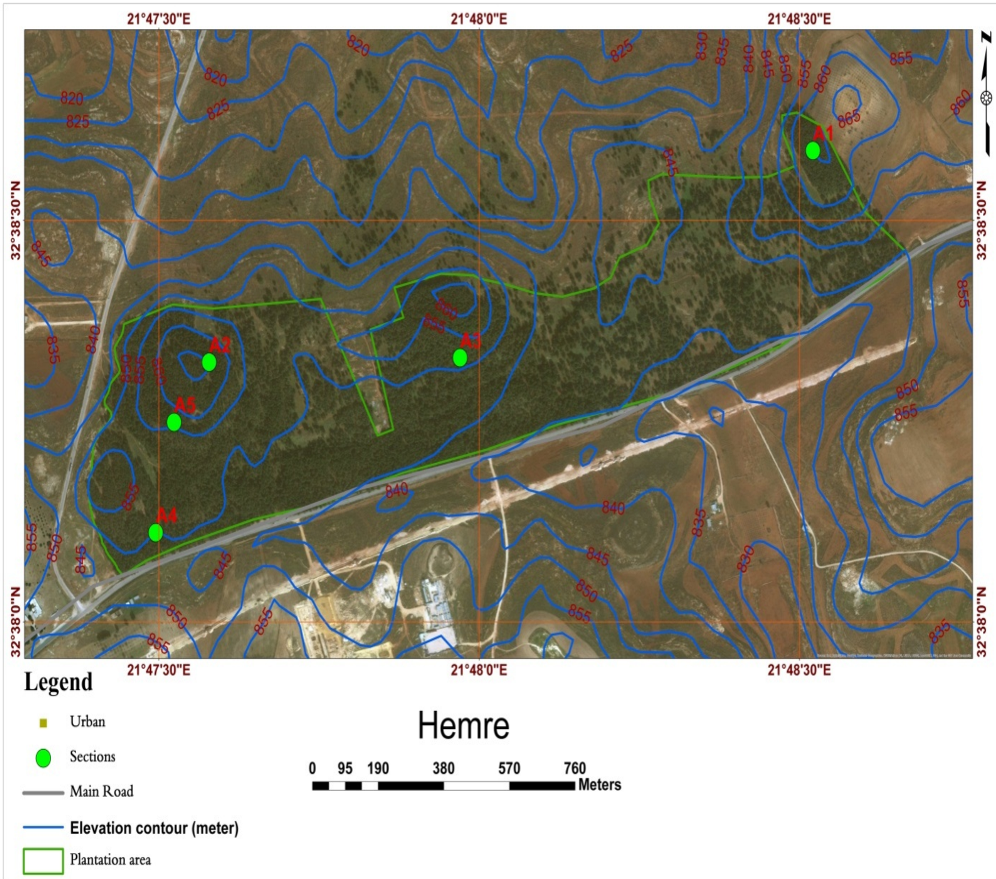

Fig. 2: Map of Hemre plantation indicated From remote sensing image.

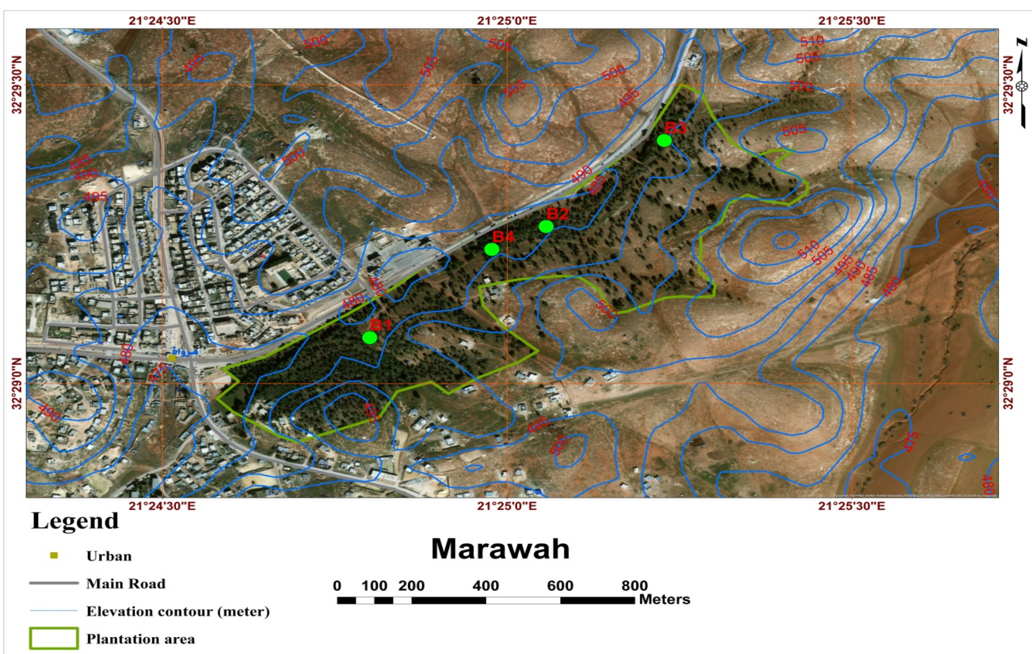

Fig. 3: Map of Marawah plantation indicated From remote sensing image.

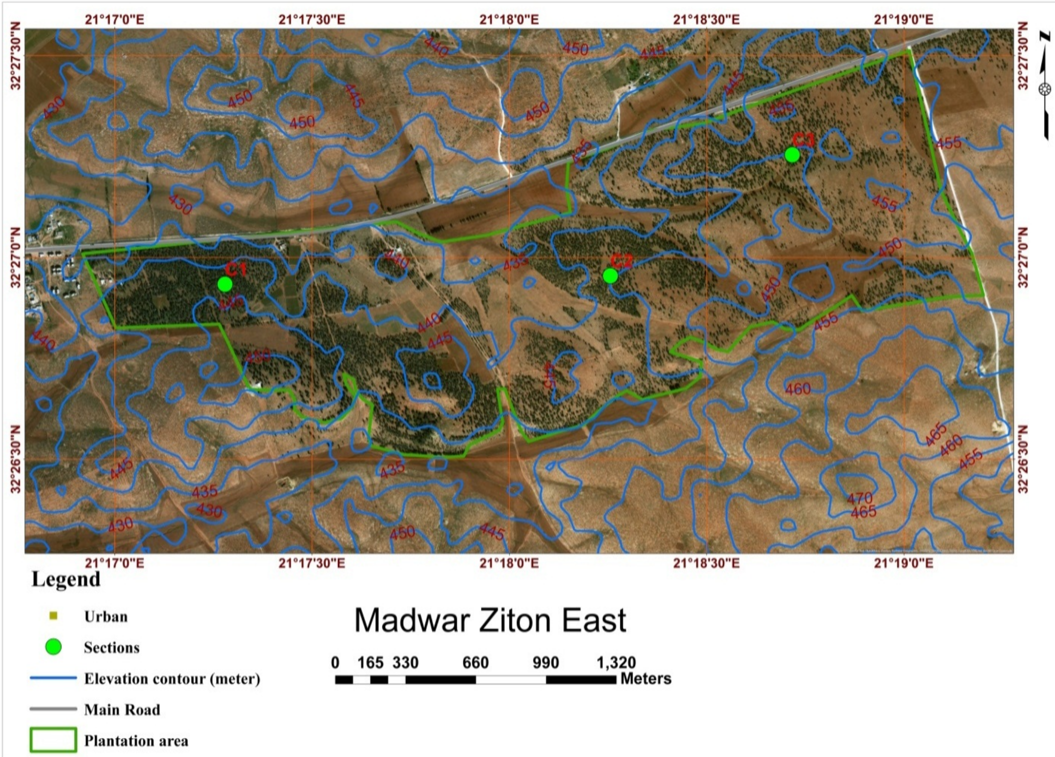

Fig. 4: Map of Eastern Madwar Ziton plantation indicatedFrom remote sensing image.

5- Kashaf (Takniss) plantatio

At altitude of °32.´51.187 Northern and latitude of 021°.12.121 Eastern, Kashaf (Takniss) plantation was established in early of 1960s.

It is regarded as a one of the old plantations, located at Al-Ghareeb-Takniss Road. It has been established in semi-even- levelled surface soil, with little slope (4.3%), in an area of around 105 ha, 442.2m above sea level.

This plantation is composed of *Pinus halepensis* chiefly, in addition to some species, amongst which, *Juniperus phoenicea* ,*Pistacia lentiscus*, *Arbutus pavarii, Rhamnus oleoides, Phillyrea angustifolia, Asphodelus microcarpus, Phlomis floccose, Globularia alypum,Cistus* sp, *Asphodelus microcarpus.* Furthermore, some less-height vegetation are existed under pine canopy. The soil, generally is red-colored over limestones and to somewhat is being deep.

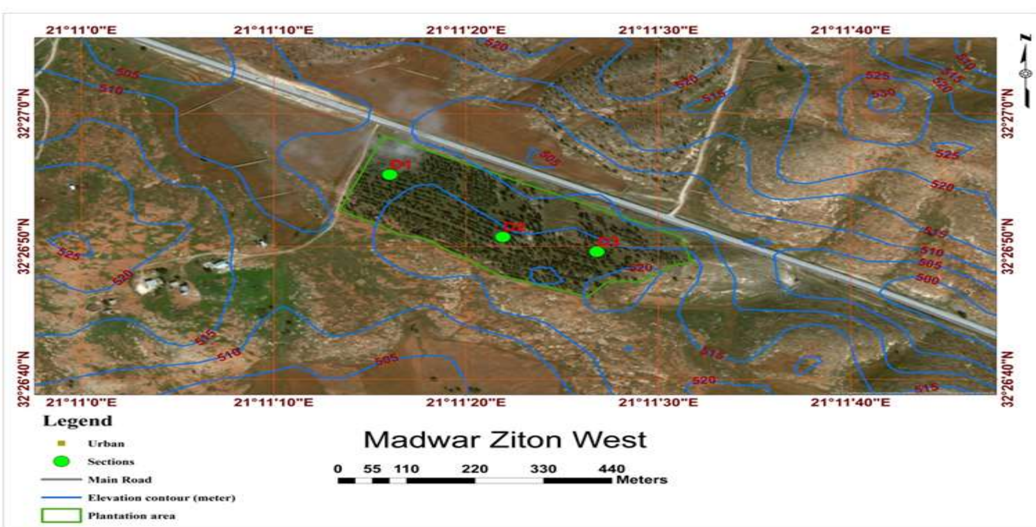

Fig. 5: Map of Western Madwar Zaiton plantation indicated From remote sensing image.

Biometrical investigation

For each plantation mentioned above, one plot of an area of 2500m^2 was selected in random fashion to encompass all forms of trees and to be representative for each plot selected, *Pinus halepensis* trees were studied, which regarded the dominant species on one hand and for its environmental and economic value, on the other hand. The sample was chosen at a complete random arrangement according to Gemez and Gomez (1984).

The stocking and growth parameters of *Pinus halepensis* trees selected had been assessed in each plantation and samples were obtained for analysis of the growth in relation to recorded climatic elements, notably, temperature and rainfall average.

The following are field investigation mensuration for each plot.

1-Tree height (m)

The tree height was measured using Haga altimeter and Suunto clinometers for trees exceeds15m in height, according to Turner (1995). The mean annual increase in tree height (m/year) was computed by dividing the tree height over its age.

2-Diameter at breast height (DBH) (cm)

The stem diameter (dbh) of the *Pinus halepensis* tree was determined using diameter tape at breast height for big diameter trees and with tree caliper for the small one. Two perpendicular readings were measured then arithmetic mean was calculated according to West (2009).The mean annual increase in tree stem diameter (cm/year) of the tree was computed by dividing the stem diameter of the tree over its age.

3- Diameter of the tree crown

To determine the diameter of the crown, in two directions (perpendicular to each other), images have been taken up using guide scale, then the images were analyzed by calibration to determine the width of the crown. The values recorded were for the widest part of the crown. The mean annual increase in crown diameter (m/year) of the tree was computed by dividing the crown diameter of the tree over its age.

4- Determination of tree age

In this connection, an increment borer tool was used at 1.0 m height of the trunk. The obtained pellets were extracted carefully, then number of annual increment rings(early and late wood together)were counted. Discontinuous and false rings were discarded and only true rings were tested. In addition, the obtained pellets were kept for further tests, notably thickness of late and early wood in laboratory.

5- Bark thickness determination

A bark thickness gauge device was used to determine the thickness of the trees bark without felling the tree on one hand and to calculate the bark thickness constant " K_b " of the bark, on the other hand.

However "K_b " was calculated using the following equation:

$$K_b = \frac{\sum dib}{\sum dob}$$

Where dib is the diameter inside bark, and dob is the diameter outside bark, both at breast height (135cm).

The K_b can be used also for prediction of diameter inside bark, Just using dob, i.e.,

Dib = dob $*K_b$ .Ten trees (replications) were tested to fit this purpose.

6- Basal area (BA)

The basal area, i.e., the total area of the stem (trunk) section at breast height of stand in a given area.

It is regarded as an indicator of plantation stocking. BA was calculated according to (Van Laar and Acka, 1997), using the following equation:

Dobh)^2 * 3.14∑(BA=

Where, dobh is the diameter of the stem outside bark at breast height.

7- Log volume (m^3)

Based on the available data pertaining stem diameter, so that basal area, and tree height the following equations were used to determine the log volume of the tree prevailing at each plantation site according to(Cochran ,1977 and Freese,1967) and (Steel and Torrie,1980). as follows:

Hemre

$$V = -0.633 + 0.0770 * H - 0.0816 * BA$$

Marawah

$$V = -0.938 + 0.171 * H - 0.127 * BA$$

Madwar Ziton East and West

$$V = -0.154 + 0.0524 * H - 0.126 * BA$$

Kashaf

$$V = -0.194 + 0.0402 * H - 0.0532 * BA$$

Where:

V is thevolumeof tree

H is theheight of tree

BA is the basal area

The mean annual increase in volume of the log/ tree was computed by dividing the volume of the log over its age. The total log volume/ ha of the stand was calculated by multiplying the average of log volume of the tree in the number of the trees/ ha. The mean annual increase in volume of the log/ ha was computed using the following equation:

*Vtr = MAI * TR*

Where, Vtr is the mean annual increase of log volume / tree and TR, is the total number of the trees/ ha

Physical and chemical properties of plantation soil

1- Organic horizon (OH)

In all sites, the organic horizon(OH) was studied, in term of literation (litter properties) to pinpoint the annual amount of fallen litter. To fit such purpose, a woody box of 50*50 cm (as a frame) were placed over the soil in each site, then the encompassed litter was collected carefully without soil particles, oven dried then weighed.

Such amount of litter collected, is represented an area of 50*50 = 2500 cm^2, was then calipered to find out the mean annual literation (MAL) per hectare using the following equation:

$$MAL = \frac{10000 * W_b / 0.2500}{T_2 - T_1} \quad Or \quad MAL = \frac{4 * 10^4 W_b}{T_2 - T_1}$$

Where; MAL is the mean annual literatification per hectar

W_b is the average of dry weight of litter extracted from the 50*50 cm-box

T_1 is the time or date of seedlings planting, and

T_2 is the time or date of sampling in plantation;

Thus, on the other word,

$T_2 - T_1$ is the age of plantation trees at the time of sampling, to nearest year.

2- Horizon A

Soil samples were taken at depth of 30 cm(3 samples for each site) for lab testing.

The chemical and physical tests were determined in Faculty of Natural Resources and Environmental Sciences Lab – University of Omar AL-Mokhtar, Libya. The tests of soil properties applied can be described as follows:

a – Moisture content (MC) (%).

Certain weight of soil samples were oven dried at 105°C for 24 hours to a constant weight, then the MC (%) was calculated using the following equation:

$$MC\% = \frac{W_f - W_{0.d}}{W_{0.d}} * 100$$

Where, W_f is the fresh weight of soil sample

$W_{0.d}$ is the oven dry weight of the same soil sample

b- Organic matter content (OMC %)

Organic matter content was determined according to the methoddescribed by Black,(1965)

C- pH values

pHValues of were determined using Haker Instrument, Electronic pH meter according to the method described by Black,(1965).

d- Electric conductivity (EC).

The water extract of the soil samples were tested for EC using electric conductivity set.

The value of EC was expressed as Millimhos/ cm according toBlack,(1965).

Meteorological Studies.

In this work, data reported by Climate Data Sourcas @Climatic Research Unit, University of East Anglia: CRU TS 3.21 which has been published in #/http: / www.globalclimatemonitor.org were employed for analysis of the ecophysiological aspects:

Statistical analysis of data

Data were analyzed using the statistical program (SPSS, 2007). The following statistical model was used.

$$Yij = u + Ti + eij$$

Where Y_{ij} : the observed trait

u = overall mean

T_i : the effect of treatment (i)

e_{ij} : experimental error

Data also were analyzed using simple linear regression system, using SPSS Inc. (2007) statistical package, version 16, SPSS, USA, as follows:

$$\hat{Y} = a + bx$$

Where $\hat{Y}$ is dependent variable

a: intercept

b: coefficient of regression

x: independent variable

Simple and multiple regressions were performed according to (Steel and Torrie,1980). Statistical analysis was done by, ANOVA, F-test, and L.S.D procedures available within the SAS software package**.**

Linear regression analysis was used to determine the relationship between the different Simple phenotypic correlations were calculated among all traits using SPSS version 24 package. The linear regression function between and each of the studied traits was predicted according to Kleinbaum and Kupper, (1978) using the following equation:

$Y_i = a + b_iX_i$

Where Yi observed value for any character

a= constant which fixes the position of regression line

b = regression coefficient

X_i= independent variable

RESUITS

Upon the investigation and biometrical measurements of *Pinus halepensis* trees growing in the 5 plantations, namely Hemre, Marawah, Madwar ziton East, Madwar Ziton West and Kashaf,period from Septameber, 2016 to Sep., 2017.as well as the statistical analysis of data obtained, the results can be listed as follows:

1. Growth Parameters

1.1. Tree height (TH) (m)

The statistical analysis of the variance has revealed significant differences among the locations inspected, in terms of TH of *Pinus halepensis*. However, *P. halepensis* trees growing at Hemre has displayed the highest TH (14.61m) vs 6.38m for Madwar Ziton West plantation. On the other hand, no significant differences among all plantations inspected, in terms of mean annual increment of tree height, which nonetheless averaged 0.26 m/ year.

1.2. Stem diameter (SD) (cm)

The average of SD of *Pinus halepensis* trees was the highest for Hemre and Marawah plantation, with nonsignificant differences between each other (21.70 and 21.55 cm, respectively), whilst Madwar ZitonWest plantation displayed the lowest SD.

Upon the statistical analysis, the *P. halepensis* trees growing in Marawah and Hemre have displayed the highest 20 year basal age (27.66 and 23.06 cm, respectively), with no significant differences between each other. On the other hand, the *P.halepensis* trees of Kashaf have displayed the lowest value (11.06 cm). The scenario of diameter increment of the stem is set out in Table (1) and Fig (7), illustrating that the trees of Marawah exhibited the highest diameter in its life span, yet with non significant differences with those of Hemre.

Observing data depicted the mean annual increment in stem diameter presented in **(**Table,1**)**, it is noticeable that *P. halepensis* trees growing at Marawah plantations have the highest rate (0.66 cm/year), with non significant differences with those located at Madwar Ziton West one. Furthermore, except for the trees growing at Marawah plantation as, non significant differences were detected among all rest sites, in terms of the annual increment in stem diameter.

1.3. Crown diameter (CD) (m)

As it has been detected in the case of tree height and stem diameter, the highest value was found in the *P. halepensis* trees growing at Hemre site (5.23m), whilst the lowest CD value was found in those of Madwar Ziton West (3.13m)

As for the mean annual increase in crown diameter, the highest value was detected in *P. halepensis* trees of Marawah and Madwar Ziton West (0.13 m/ years , for both plantations), yet the lowest value was for trees planted in Madwar Ziton East and Kashaf (0.08 m / year for both) (Table 1).

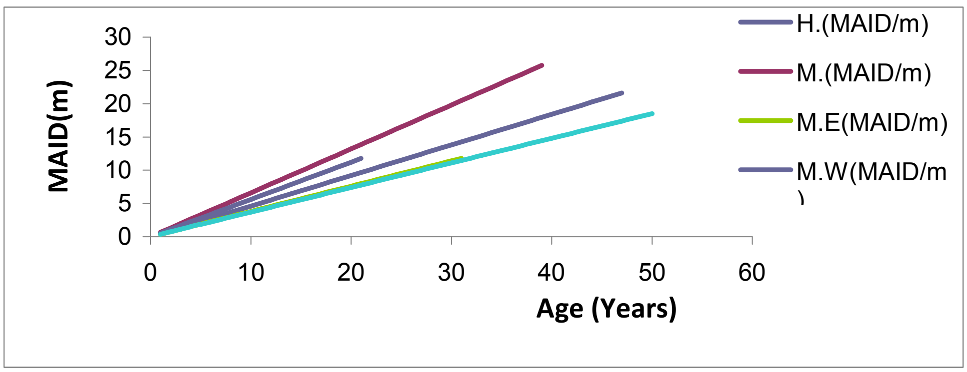

Fig 7: Mean annual increase in diameter (MAID)(cm/year)

Table 1: Tree height (m), mean annual increase in tree height(MAIH)(m/year), Diameter outside bark at breast height (dobh) (cm), mean annual increase in diameter (MAID)(cm/year), Stems diameters(SD) (cm/20 years), crown diameter(CD)(m) and mean annual increase in crown diameter (MAICD)(m/year) of the five plantations investigated.

Locations	Tree height (m)	MAIH (m/year)	dobh (cm)	MAID (cm /year)	SD (cm/20yeas)	C D (m)	MAICD (cm /year)
				Mean ± SE			
Hemre	14.61[a] ± 0.12	0.30 ±0.00	21.70[a] ± 0.22	0.46[b] ±0.03	23.06[ab] ± 3.12	5.23[a] ± 0.05	0.10[b] ±0.00
Marawah	9.64[b] ± 0.23	0.28 ±0.04	21.55[a] ± 0.42	0.66[a] ±0.10	27.66[a] ± 0.33	4.87[b] ± 0.09	0.13[a] ±0.01
Madwar Ziton East	8.52[c] ± 0.19	0.23 ±0.00	14.44[b] ± 0.33	0.38[b] ±0.00	19.60[bc] ± 3.55	3.27[cd] ± 0.07	0.08[bc] ±0.00
Madwar Ziton West	6.38[d] ± 0.23	0.27 ±0.01	12.80[c] ± 0.40	0.56a[b] ±0.03	12.80[cd] ± 0.94	3.13[d] ± 0.09	0.13[a] ±0.00
Kashaf	8.59[c] ± 0.17	0.21 ±0.25	14.90[b] ± 0.31	0.37[b] ±0.03	11.06[d] ± 0.52	3.46[c] ± 0.07	0.08[c] ±0.00
Overall	10.25 ± 0.08	0.26 ±0.01	18.59 ± 0.15	0.49 ±0.03	18.84 ± 1.85	4.13 ± 0.03	0.11 ±0.00

Within each column, the values of the same superscript letters are not significantly different at the level of probability of 0 .01.

2. Stocking and basal area (BA) of the plantations

Non significant differences among all plantations in number of the trees / ha were obtained. However, the number of trees/ ha was 536, 289, 358, 244 and 309 for Hemre, Marawah, Madwar Ziton East, Madwar Ziton Weast and Kashaf, respectively, with an overall average of 347.45 trees / ha (Table, 2).

Both plantations of Hemre and Marawah have displayed the highest BA (m^2/ha) of the *P. halepensis* they implied, since it was21.20 and 19.25 m^2/ha, respectivelywith non significant differences between each other, while for Madwar Ziton East, Madwar Ziton West and Kashaf they were statistically close (6.37, 3.37 and 6.17 m^2 / ha , respectively) (Table 2).

3. Specific gravity (SG) of wood

Determining the specific gravity (SG) of the wood as an average of sap and late- wood, there is no significant differences in SG among the trees of the all plantations studied, with a mean of 0.45 (Table, 2).

4. Bark thickness (BT) coefficient

Observing data set out in (Table, 2), it is evident that there were non significant differences in BT coefficint among the *P. halepensis* trees growing at the five plantations understudy, with an overall mean of 0.93.

5. Litterification rate (LR) (Ton / ha / year)

Non significant differences among all plantations studied in LR. However, the mean annual litteration ranged between 4.92 to 15.10 ton litter / ha / year, for Marawah and Kashaf plantation, respectively, with an average, for all plantations of 10.51 ton/ ha / year (Table, 2).

6. Log Volume (m^3) and its increment rate (m^3 /year).

6.1. Log volume of single tree (m^3/tree)

Marawah displayed the highest log volume (1.02m^3/tree), followed by that obtained in Hemre (0.50m^3/tree), with non significant differences with those of Madwar Ziton East, Madwar Ziton Weast and Kashaf, which displayed the lowest log volume (0.29, 0.19, and 0.18 m^3/tree, respectively) (Table, 3).

6.2. Mean annual increase in log volume of single tree(m^3/tree/year)

There are significant differences among trees growing in the five plantations studied, where the highest mean annual increase in log volume (MAILV) was detected in Marawah (0.020 m^3/tree/year), whilst the lowest value was found in Kashaf plantation (0.004 m^3/tree/year), with non significant difference with those in Madwar Ziton East and Madwar Ziton West (0.007 and 0.008m^3/tree/year, respectively) (Table, 3).

6.3. Wood yield (m^3/ha)

Determining the total commercial log volume of the five locations studied, significant differencesamong such locations were found. However, both of Hemre and Marawah plantations displayed the highest wood yield (256.22 and 307.47 m^3/ha, respectively) with no significant differences between each other.

On the other hand, the Madwar Ziton East , Madwar Ziton West and Kashaf displayed non significant differences among each other, in terms of log volume (103.12,43.93 and 48.08 m^3/ha, respectively) (Table, 3).

Table 2: Basal area (BA) (m^2/ha), specific gravity (SG) of the wood, bark thickness coefficient (BTC), Number of tree/ha and litterification rate (ton/ha/year) of the five plantations investigated.

Locations	BA (m^2/ha)	Number of tree/ha	BTC	S.G	litterification rate (ton/ha/year)
	Mean ± SE				
Hemre	21.20^{a} ± 1.13	536 ±94.12	0.91 ± 0.00	0.44 ± 0.02	5.28 ± 1.55
Marawah	19.25^{a} ± 2.37	289 ±4.29	0.93 ± 0.00	0.46 ± 0.00	4.92 ± 2.20
Madwar Ziton East	6.37^{b} ± 0.40	358 ±37.54	0.92 ± 0.00	0.46 ± 0.01	15.10 ± 1.66
Madwar Ziton West	3.37^{b} ± 0.11	244 ±27.22	0.93 ± 0.00	0.45 ± 0.02	12.85 ± 4.41
Kashaf	6.17^{b} ± 0.22	309.6 ±94.04	0.91 ± 0.00	0.46 ± 0.01	14.40 ± 3.26
Overall	11.27 ± 2.01	347.45 ±40.38	0.93 ± 0.00	0.45 ± 0.009	10.51 ± 1.57

Within each column, the values of the same superscript letters are not significantly different at the level of probability of 0 .01.

Table 3: Wood volume per tree (m^3/tree), mean annual increase in volume (MAIV) (m^3/tree/ha), wood yield (m3/ha) and mean annual increase in wood volume per ha (m^3/ha/year).

Locations	logvolume (m^3/tree)	MAILV (m^3/tree/year)	Wood yield (m^3/ ha)	MAIV (m^3/ ha/year)
	Mean ± SE			
Hemre	0.50[b] ± 0.03	0.01[b] ± 0.004	256.22[a] ±39.27	5.33[b] ±0.81
Marawah	1.02[a] ± 0.12	0.02[a] ±0.002	307.47[a] ±66.84	8.54[a] ±1.85
Madwar Ziton East	0.29[c] ±0.006	0.007[bc] ± 0.00	103.12[b] ±10.42	2.78[bc] ±0.27
Madwar Ziton West	0.19[c] ± 0.01	0.008[bc] ± 0.00	43.93[b] ±2.14	1.91[c] ±0.09
Kashaf	0.18[c] ± 0.04	0.004[c] ± 0.00	48.08[b] ±11.13	1.11[c] ±0.25
Overall	0.44 ± 0.02	0.012 ± 0.001	151.76 ±15.59	3.93 ± 0.37

Within each column, the values of the same superscript letters are not significantly different at the level of probability of 0 .01.

6.4. Meanannual yield of wood (m^3/ha/year)

The highest value was found in Marawah Plantation (8.54m^3/ha/year), followed by Hemre (5.33m^3/ha/year), with non significant differences with that obtained in Madwar Ziton East plantation (2.78m^3/ha/year) (Table, 3).

7. Analysis of trunk increment and its relation with climatic conditions.

7. 1. Edaphic factors

As illustrated in Tables (4, 5), Hemre plantation encompassed *P.halepensis* trees displayed the best edaphic conditions, in terms of moisture (4.92%), organic matter (5.96 %), ash (25.84 %), nitrogen (411.16ppm),phosphorus (169.8ppm) and magnesium content (20.16ppm).

As for potassium and sodium content, soil of Marawah planation displayed the highest level, since it was 0.15 and 1.04 meq/ l, respectively (Table, 5).

It is worthy pointing here that there were non significant differences among all plantation soils, in terms of pH (Averaged 8.10)and EC at 25°C (averaged 328.46 millmohs/cm).

7.2. Climatic Conditions

Based on the meteorological data obtained at Al-Gabal Al-Akhdar region, the mean temperature is ranged between 17.73°C for Madwar Ziton East to 18.93 °C for Kashaf plantation atmosphere, with mean temperature of 18.47 °C (Table,6).

As a rule of thumb, there is an increase in temperature with the time, so it is expected that the temperature will be surged to be more than 18.5 °C in 2020. However, the increase rate of the temperature is about 0.019°C / year (Fig, 8).

However, the increase rate in temperature is set out in Table (6)and illustrated inFig (8) for each plantation site. In addition, there were increases in temperature recorded in 1960 up till now

As for the precipitation (rainfall) rate, there were significant differences among the plantations inspected. However, the highest rainfall rate was detected in Hemre (444. 62 mm/year),whilst the rest plantations received rainfall rate ranged between 372.98 to 404.28 mm/ year, with no significant differences among each other (Table, 6). However, the average of rainfall at Al-Gabal Al-Akhdar plantation is 394.54 mm / year. Monitoring the rainfall level since 1960 up till now(and that expected in 2020) , it is noticeable a slight decrease in rainfall rate with the time However, rainfall rate is illustrated inTable (6) and Fig (9).

7.3. Annual increment rings (mm)

It has been found that the mean annual increment rings was affected by the location, where

P. halepensis trees growing in Hemre , Madwar Ziton East and Marawah displayed the thickest mean annual increment rings (3.56, 3.63, 4.03mm, respectively) with non significant differences among each other .On the other hand, the thinnest mean –annual increment rings was found in the stem of *P. halepensis* trees standing in Madwar Ziton West and Kashaf plantation, i. e, 2.39 and 2.53mm, respectively, with non significant differences between each other (Table, 7).

As for early / late wood ratio (E / L ratio), the highest value was found to be in Kashaf plantation (4.62).On the other hand, non significant differences were attained among the rest locations. It can be concluded in general, that the early wood thickness is 2.73 fold that obtained in latewood as a mean for all locations (Table,7).

Table 4: Physical properties of soil of the five plantations studied.

Location	Moisture (%)	Organic matter (%)	Ash (%)	pH	EC at 25 C° (Millimhos/cm)
	Mean± SE				
Hemre	4.92 [a] ±0.11	5.96 [a] ±0.08	25.84 [a] ±0.69	8.06 ±0.03	344.3 ±26.11
Marawah	2.42 [c] ±0.23	1.47 [b] ±0.27	10.45 [c] ±0.49	8.03 ±0.03	318 ±24.99
Madwar Ziton East	1.65 [d] ±0.09	2.83 [b] ±0.51	14.87 [bc] ±1.07	8.13 ±0.03	388.3 ±28.91
Madwar Ziton West	2.07 [cd] ±0.15	1.87 [b] ±0.07	12.87 [bc] ±0.92	8.16 ±0.08	278.3 ±11.01
Kashaf	3.79 [b] ±0.31	2.84 [b] ±0.74	17.27 [b] ±3.31	8.10 ±0.05	313.3 ±27.03
Overall	2.97 ±0.33	2.99 ±0.42	16.26 ±1.54	8.10 ±0.02	328.46 ±13.45
Sig.	***	****	***	NS	NS

***$p \leq .001$ ****$p \leq .0001$ NS = Not Significant

Within each column, the values of the same superscript letters are not significantly different at the level of probability of 0 .01.

Table 5: Chemical properties of soil of the five plantations studied.

Location	N (ppm)	P (ppm)	K (meq/L)	Ca (ppm)	Mg (ppm)	Na (meq/L)
	Mean ± SE					
Hemre	411.16 [a] ±25.38	169.8 [a] ±12.27	0.09 [b] ±0.00	36.08 [b] ±1.25	20.16 [a] ±0.15	0.63 [b] ±0.05
Marawah	180.10 [b] ±17.59	83.5 [b] ±6.26	0.15 [a] ±0.01	32.69 [b] ±0.28	12.99b [c] ± 0.80	1.04 [a] ±0.09
Madwar Ziton East	164.93 [b] ±10.54	86.8 [b] ±5.34	0.11 [b] ±0.00	82.29 [a] ±19.96	18.03 [a] ±0.59	0.75 [b] ± 0.05
Madwar Ziton West	161.49 [b] ±14.07	56.3 [c] ±2.80	0.11 [b] ±0.00	36.37 [b] ±2.22	11.08 [c] ±0.51	0.75 [b] ± 0.05
Kashaf	211.21 [b] ±32.27	54.5 [c] ±6.52	0.10 [b] ±0.01	35.65 [b] ±0.34	14.22 [b] ± 1.40	0.69 [b] ± 0.09
Overall	225.78 ±26.48	90.2 ±11.5	0.11 ±0.00	44.61 ±6.06	15.29 ±0.94	0.77 ± 0.04
Sig.	****	****	**	**	****	**

**** $p \leq .0001$ **$p \leq .01$

Within each column, the values of the same superscript letters are not significantly different at the level of probability of 0.01

Table 6: Mean values of rainfall (mm/year) and mean annual temperature (°C) of the five plantations and average temperature of Al-Gabal Al-Akhdar region.

Locations	Rain(mm/year)	Temp.(°C/year)
	Mean ± SE	
Hemre	444.62^{a} ±10.78	17.73^{d} ±0.05
Marawah	372.98 ^{b} ±14.10	18.51b^{c} ±0.08
Madwar Ziton East	376.62 ^{b} ±13.81	18.48^{c} ±0.07
Madwar Ziton West	373.22 ^{b} ±18.81	18.72^{b} ±0.09
Kashaf	404.28 ^{b} ±11.30	18.93^{a} ±0.05
Overall	394.34 ±6.12	18.47 ±0.04

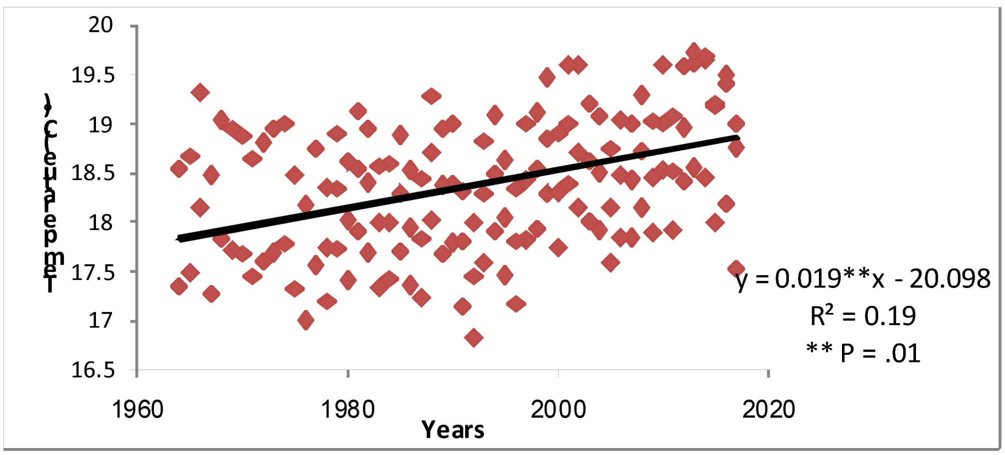

Fig 8: Temperature trend of the region understudy from 1960 to that expected in 2020

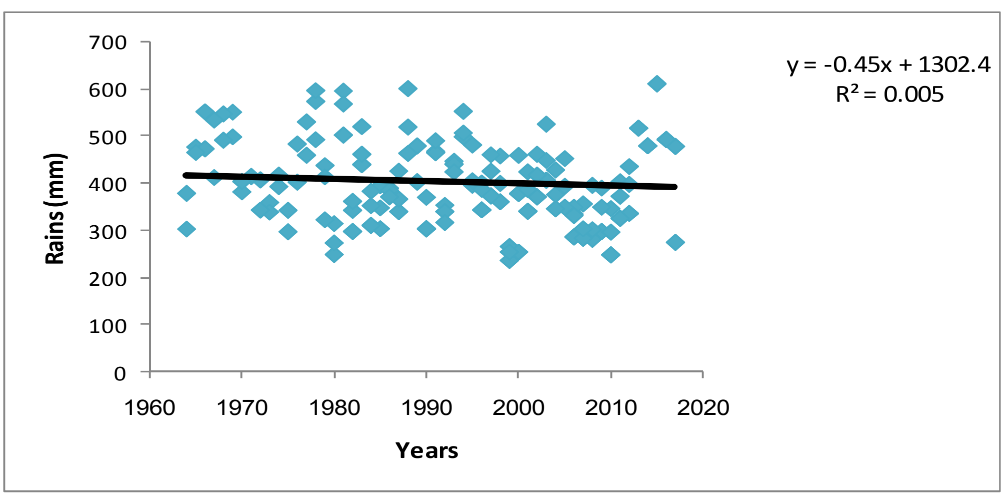

Fig 9: Rainfall rate of understudy region from 1960 to that expected in 2020.

Table 7: Thickness of the early wood, late wood, annual increment ring (early-and late- wood) (mm) andearlywood/late wood (E/L ratio).

Locations	Thickness of early wood (mm)	Thickness of late wood (mm)	Thickness of L and E wood (mm)	(E / L ratio)
	Mean ± SE			
Hemre	2.33[a] ± 0.18	1.23[b] ± 0.08	3.56[a] ± 0.26	2.31 [b] ± 0.35
Marawah	2.39[a] ± 0.17	1.71[a] ± 0.16	4.03[a] ± 0.30	1.95 [b] ± 0.23
Madwar Ziton East	2.43[a] ± 0.27	1.32[b] ± 0.14	3.63[a] ± 0.33	2.11 [b] ± 0.21
Madwar Ziton West	1.61[b] ± 0.24	0.84[c] ± 0.14	2.39[b] ± 0.34	2.66 [b] ± 0.46
Kashaf	1.93[ab] ± 0.07	0.65[c] ± 0.06	2.53[b] ± 0.12	4.62 [a] ± 0.24
Overall	2.14 ± 0.08	1.15 ± 0.05	3.23 ± 0.12	2.73 ± 0.23

Within each column, the values of the same superscript letters are not significantlydifferent at the level of probability of 0 .01.

The thickest early wood was found in the stem of *P. halepensis* trees of Hemre, Marawah, Madwar Ziton East and Kashaf (2.33, 2.39, 2.43 and 1.93 mm, respectively), with non significant differences among each other, whilst the thinnest early wood ring (as a mean annual) was detected in those growing at Madwar Ziton West (1.61 mm).

However, the widest latewood thickness of *P. halepensis* stem was found in Marawah plantation (1.71 mm), whilst the thinnest late wood ring was found in the stem of *P. halepensis* growing at Madwar Ziton West and Kashaf (0.84 and 0.65 mm, respectively) (Table, 7).

7.4.Dendroclimatological studies (relationship between environmental factors and increment rings).

Upon the precise analysis of growth ring (early-and/or late-wood thickness) in relation to the synchronous climatic conditions (Temperature and rainfall rate), i.e., dendroclimatological analysis, it has been revealed that the rainfall rate, except for Kashaf plantation, neither significantly impacts on the width of E.W, L.W nor annual ring developed in the stem of the trees in all plantations analyzed. The dendroclimatological analysis has also indicated, however, that the width of E.W, L.W and annual ring was inversely proportional with the simultaneous temperature in all sites investigated. Data presented in (Table, 8) depicted the simple regression equations and thosepresented in(Table, 9) depicted pearson the multiple regression coefficient to be used for prediction of the impact of the climatic factors in anticipation.

DISCUSSION

Categorizing the results pertaining the growth and yield parameters of the 5 plantations under study, three facts can be recognized as follows:

First, that there are no significant differences among the plantations in terms of mean annual increment in tree height, number of trees/ha and specific gravity of stem wood.

Second , there are significant differences among all plantations in all the rest parameters (would be mentioned below).

For Hemre plantation, the highest value of tree height and crown diameter was obtained, whilst for Marawah plantation, mean annual increment in stem diameter, mean annual increase in crown diameter, wood volume per tree and late wood thickness was obtained. In Kashaf plantation, only the highest early-/ late-wood ratio was obtained.

Third fact, that both Hemre and Marawahplantation have displayed the highest values of basal area, wood (log volume/ha), thickness of early wood and annual ring thickness with non significant differences between both above mentioned plantations.

Regardless their ages, all *P. halepensis* trees growing in all plantations studied showed non significant differences in height growth rate, i.e., not affected by the site they established. On the contrary, the mean annual increase in stem of the tree is a site dependent, where the Marawah plantation displayed the highest rate, so that the highest log volume not only per tree, yet per hectare as well.

Table 8: Relationship between late wood, early wood and annual ring thickness of *Pinus halepensis* and temperature as well as rainfall rate, in terms of simple regression.

Locations	*Factors*	*E . wood*	*L . wood*	*E and L .wood*
Hemre	*Temperature*	$Y = 9.838 - 0.475x^*$	$Y = 7.241 - 0.367x^*$	$Y = 17.080 - 0.843x^*$
		$SE = 0.207$ $R^2 = 0.200$	$SE = 0.181$ $R^2 = 0.163$	$SE = 0.378$ $R^2 = 0.190$
	Rain	$Y = 1.789 - 0.001x$	$Y = 0.766 - 0.0003x$	$Y = 2.556 - 0.001x$
		$SE = 0.001$ $R^2 = 0.050$	$SE = 0.0009$ $R^2 = 0.005$	$SE = 0.002$ $R^2 = 0.025$
Marawah	*Temperature*	$Y = 21.290 - 1.036x^*$	$Y = 11.100 - 0.534x^*$	$Y = 34.295 - 1.670x^*$
		$SE = 0.340$ $R^2 = 0.306$	$SE = 0.263$ $R^2 = 0.170$	$SE = 0.573$ $R^2 = 0.287$
	Rain	$Y = 1.995 - 0.0003x$	$Y = 1.047 - 0.0002x$	$Y = 3.042 - 0.000x$
		$SE = 0.002$ $R^2 = 0.001$	$SE = 0.001$ $R^2 = 0.001$	$SE = 0.003$ $R^2 = 0.000$
Madwar Ziton East	*Temperature*	$Y = 12.939 - 0.614x^*$	$Y = 7.161 - 0.344x^*$	$Y = 17.529 - 0.824x^*$
		$SE = 0.149$ $R^2 = 0.445$	$SE = 0.116$ $R^2 = 0.295$	$SE = 0.250$ $R^2 = 0.351$
	Rain	$Y = 1.575 - 0.0004x$	$Y = 0.777 - 0.0001x$	$Y = 2.349 - 0.0005x$
		$SE = 0.001$ $R^2 = 0.010$	$SE = .0007$ $R^2 = 0.003$	$SE = .0.001$ $R^2 = 0.005$
Madwar Ziton West	*Temperature*	$Y = 26.367 - 1.322x^*$	$Y = 13.250 - 0.662x^*$	$Y = 34.423 - 1.711x^*$
		$SE = 0.453$ $R^2 = 0.288$	$SE = 0.274$ $R^2 = 0.217$	$SE = 0.653$ $R^2 = 0.246$
	Rain	$Y = 2.071 - 0.001x$	$Y = 1.267 - 0.001x$	$Y = 3.178 - 0.002x$
		$SE = 0.002$ $R^2 = 0.008$	$SE = 0.001$ $R^2 = 0.023$	$SE = 0.003$ $R^2 = 0.013$
Kashaf	*Temperature*	$Y = 5.028 - 0.174x$	$Y = 3.208 - 0.141x$	$Y = 3.950 - 0.094x$
		$SE = 0.274$ $R^2 = 0.018$	$SE = 0.117$ $R^2 = 0.064$	$SE = 0.352$ $R^2 = 0.003$
	Rain	$Y = 0.684 + 0.002x^*$	$Y = 0.091 - 0.001x^*$	$Y = 0.775 + 0.003x^*$
		$SE = 0.001$ $R^2 = 0.221$	$SE = 0.000$ $R^2 = 0.185$	$SE = 0.001$ $R^2 = 0.255$

Table 9: Relationship between late wood,early wood and annual ring thickness of *Pinus halepensis* and temperature as well as rainfall rate, in term of multiple regression.

Locations	*Factors*	*E . wood*	*L . wood*	*E and L .wood*
Hemre	*Rain &Temp.*	*Y = 10.61 - 0.001X1 - 0.487X2**	*Y = 7.492 - 0.0004X1 - 0.371X2**	*Y = 18.105 - 0.0017X1 - 0.859X2**
		SE = b1= 0.001	*SE = b1= 0.0009*	*SE = b1= 0.001*
		SE = b2= 0.204	*SE = b2= 0.185*	*SE = b2= 0.381*
		R^2 − 0.259	R^2 − 0.172	R^2 − 0.222
Marawah	*Rain & Temp.*	*Y = 24.735 + 0.002X1 - 1.273X2***	*Y = 15.774 + 0.002X1 - 0.824X2***	*Y = 40.509 + 0.004X1 - 2.097X2***
		SE – b1– 0.001	*SE – b1– 0.001*	*SE – b1– 0.003*
		SE = b2= 0.373	*SE = b2= 0.276*	*SE = b2= 0.626*
		R^2 = 0.368	R^2 = 0.308	R^2 = 0.359
Madwar ziton East	*Rain & Temp.*	*Y = 15.400 + 0.001X1 - 0.779X2***	*Y = 8.606 + 0.0009X1 - 0.441X2***	*Y = 23.46 + 0.002X1 - 1.18X2***
		SE = b1= 0.000	*SE = b1= 0.000*	*SE = b1= 0.001*
		SE = b2= 0.162	*SE = b2= 0.131*	*SE = b2= 0.27*
		R^2 = 0.536	R^2 = 0.361	R^2 = 0.495
Madwar ziton West	*Rain & Temp.*	*Y = 30.69 + 0.003X1 - 1.61X2***	*Y = 14.41 + 0.0008X1 - 0.74X2**	*Y = 39.02 + 0.003X1 - 2.02X2**
		SE = b1= 0.002	*SE = b1= 0.001*	*SE = b1= 0.004*
		SE = b2= 0.521	*SE = b2= 0.323*	*SE = b2= 0.761*
		R^2 = 0.330	R^2 = 0.226	R^2 = 0.270
Kashaf	*Rain & Temp.*	*Y = 5.55 + 0.002X1* - 0.25X2*	*Y = 3.42 + 0.001X1* - 0.17X2*	*Y = 8.98 + 0.003X1** - 0.432X2*
		SE = b1= 0.001	*SE = b1= 0.0004*	*SE = b1= 0.001*
		SE = b2= 0.246	*SE = b2= 0.106*	*SE = b2= 0.307*
		R^2 = 0.261	R^2 = 0.282	R^2 = 0.322

The values of the tree height obtained, however, are regarded in the trend of those reported by others(Fisher *et al*.,1986;Kitikidou*et al*.,2016; Elaieb *et al*.,2017 andAlsanousi and Ali, 2018).

Also, the diameter obtained, as an average of all plantation, came in the trend reported by Fisher *et al*.,(1986); Elaieb *et al*.,(2017) and the same for crown dimension Ayari *et al*., (2012).

Furthermore, the basal area (BA) was affected by the site, where in both Marawah and Hemre plantation was the highest relative to that of the other plantation sites. This fact is evident, since in both sites, the annual thickness of stem diameter is actually depended on increment ring width (IRW).

The average of IRW of the stem of the trees growing in Marawah and Hemreplantation was the highest (with non significant differences), but for late wood, Marawah´s *P. halepensis* trees displayed thicknesssignificantly higher than those of Hemre plantation. Thus, it can be concluded that the thickness of latewood-increment ring is a limiting factor for enhancing the whole increment ring.

Highlighting the earlywood/ latewood ratio, it is noticeable that only the trees growing in Kashafplantation displayed the highest value relative to those of the other plantations. Tracing the encompassed environmental conditions, the highest temperature trend was recorded in Kashaf plantation. This interprets how the high temperature induced less latewood thickness as it compared with the trees in the other plantations.

It is worthy pointing here, that the highest increment ring thickness was found in Hemre, Marawah and Madwar Alzaytun East(MAE)(with non significant differences among each other), so it is expected that the log volume produced would be the highest as well, yet only both the former have displayed the highest, whereas MAE is an exception. This to great extent is attributed to the tree height, since the trees of Marawah and Hemre plantation have displayed tree height ignificantlyhigher s than that of MAE plantation ones.

The trees of Kashaf site displayed the lowest shoot height, stem diameter, so it can be ascribed to existence of other vegetation, that probably compete for nutrients and water, and owing to antagonisms between root system and shoot elongation of the tree (Cuesta *et al*., 2010), which leads eventually to decrease of tree height and its stem diameter. On the other hand, Elliott and Vose,(1994) have revealed the significant decrease in the efficiency of photosynthesis of *P. strobus*, particularly from July to September and in *P. merkusii*, (Buckley *et al*.,2007) ascribedthe reduction of the growth to low light rather than decrease in temperature. Highly-density stand of *P. pinaster* may undergo prolonged shortage of water under low precipitation (Mazza *et al*., 2014).

Litter fall rate (LFR) in plantation floor (10.51 ton/ ha / year as an overall average) was statistically the same for all plantations investigated. This means that the fermentation and mineralization rate of the litter is also the same, despite stand age. Litter fall is also can be capitalized on as a mulch on growth improving of seedlings and ectomyccorization(Aucina *et al.,* 2014) for tree seedlings besides provision of aesthetic environmental, economic values to urban landscape (Chalker-Scott, 2007). Fortunately, *P.halepensis* litter and root exudates have no impact on the growth of the other vegetation (Maestre *et al*., 2004).The mean annual litterification in this study would be a base for equilibrium point analysis as described by King,(1995),carbon balance(Wutzler and Reichstein, 2007), microbial activity modeling (Gulis and Suberkropp, 2003). Also, to understand the mineralization rate and its dynamic (Portillo-Estrada *et al.*, 2016 and Krishna and Mohan, 2017).

Our results indicated that the specific gravity of stem wood was the same for allstudied sites, regardless diversity of its growth rate. Relationship between growth rate and specific gravity is not the same for all tree species. Zhang (1995) in his study on such relationship as well as with mechanical properties found that some soft wood species were affected by growth rate and the others were not, in terms of specific gravity and /or mechanical analysis.

Also, there was no significant relationship between the specific gravity of latewood and the number of increment ring in wood as it gathered by Yao,(1970) in loblolly pine, particularly at breast height of the trunk, and for the whole increment ring, Foti *et al*., (2018) revealed no relationship between ring width and its density in the graft of Aleppo pine(aged 21-23 years old). Long term drought issignificantly prevail on tree ring density in *P. pinaster* (Kurz-Besson*et al*., 2016).

The bark thickness coefficient (BTC)as an overall mean was 0.93. However, to great extant, BTC is genetic-governed trait.Bark thickness, in advance would be helpful in determination of its volume even in branches (Gordon, 1983)and S-curve model (Kitikidou *et al.*, 2014).

The dendroclimatological studies here revealed that the thickness of early-, late-wood and annual increment ring as an indicator of synchronous environmental condition were chiefly affected by temperature, whilst for impact of rainfall, only trees of Kashaf plantation displayed positive response to the rate of rainfall, i.e., the higher the rainfall rate, the wider the early-, the late- and the growth ring thickness was obtained.

The impact of temperature on thickness of growth rings was analyzed by many investigators, notably, Scott,(1972), who found that the thickness of annual rings is correlated with temperature only in certain sites, yet besides the rainfall rate in the other ones.

The impact of temperature on the growth of pine generally is significant in many studies and according to the model presented by Salminen and Jalkanen (2005), the increase of temperature by 1.0°C in July has brought about an increase in height by 1.8 cm in the next year in *P. sylvestris.* Bajwa *et al.* (2015) found a positive, yet insignificant correlation between temperature with ring width and Hordo *et al.* (2009) considered the temperature is the most important single agent in terms of growth activity for *P. sylvestris*, when they were tracing increment ring width extreme temperature, yet Gonzales-Benecke *et al.*,(2017), in addition to temperature impact,stated that an elevated CO_2 contributed significantly in increase in the growth of *P. taeda.*

Many studies have revealed the significant impacts of rainfall on annual ring thickness or increment rate of the stem diameter. The analysis of the increment annual rings in addition to crown growth dynamic of *P. halepensis* by Girard *et al.* (2012) during 16 years has revealed the decline in growth during drought years, which affected photosynthetic biomass for several following years. There is also significant relationship (r = 0.42) between thickness of annual increment ring and rainfall rate during Juli for *P. patula* in Ethiopia (Tombe, 2016). Either with higher or less rainfall, the increment ring is affected in the following years, whilst with dry spring the impact takes place in the same year on ring thickness (Robbins, 1921). In their study, Olivar *et al.*(2014) found that the radial growth of Aleppo pineis controlled by soil water availability and the rainfall during previous autumn has positive impact on growth of *P. cembra* (Vittoz *et al.,* 2008) and in *P. taeda* (Moore *et al.,* 2006) and width of ring is correlated. The response of increment rings of *P. sylvestris* and *P. strobus* to summer rainfall in warm dry area is recognized clearly, but the former species only positively responded to the high temperature in February/ and March temperature (Macova, 2008). Precipitation influenced radial growth of stem and wood density (Oliver *et al.*, 2015).as wellas the rainfall in the growing season in *P. sylvestris* (Bogino *et al*., 2009). In additions, Sensula and Wilczynski,(2017) suggested that the surface temperature impacts on water-use efficiency in *P. sylvestris* and surged CO_2 emission is involved. The thickness of annual ring of *P. wallichiana* wassignificantly correlated with precipitation rate(Bajwa *et al*., 2015)and of *P. sylvestris*(Pritzkow *et al*., 2014)and particularly during June to July (Cedro , 2001), but not in all sites she inspected , notably so humid stands . Not in all times,here the positive impacts of precipitation and temperature on the growth of *P. halepensis, P. pinaster , P. sylvestris* even *Fagus sylvatica,* yet it is likely in the future, the rainfall impact on the growth (Sabate *et al*., 2002).

Generally, it can be concluded that the all plantations are sensitive to temperature and suffering no shortage of water, except for Kashaf site, because of competition of the other vegetation with *P. halepensis* trees foravailable water. Therefore, it is emphasized to apply cleaning and liberation cutting at least for the Kashaf site as will as site amelioration as measures of silvicultural practices.

CONCLUSIONS AND RECOMMENDATIONS

- *Pinus halepensis* is a promising tree species as it would be candidated for plantations in Al-Gabal AL-Akhdar region wherein environmentally and economically fit.
- Responses *of P. halepensis* to environmental conditions in the five regions studied were not the same, wherein Marawah and Hemre sites were the best, in terms of growth and yield parameters.
- Dendroclimatological studies have manifested the indirect proportional response of the tree to temperature in the all sites, whilst to rainfall rate, only for Kashaf site, yet directly proportional.
- Irrespective the site wherein the tree established, specific gravity of wood was inherent trait, prevailing Al-Gabal AL-Akhdar region.
- Bark thickness coefficient and litterfication would be helpful in further research.
- It is recommended to follow up the proper silvicultural practices upon the situation of each plantation.

REFERENCES

Aljos, F**. 1984**. Pines: Drawings and Descriptions of the genus *Pinus*. E.J. Brill / Dr. W. Backhuys, 220pp.

Alsanousi, A.A. and Ali, A.M**. 2018**. Age structure and current status of Aleppo pine*(Pinus halepensis*)trees on the western Sidi Alhumry pine plantation in Al-Jabal Al-Akhdar Region. Al-Mukhtar Journal of Sciences, **33(3):**185-191.

Al-Zaghat, M.F. **1978**.Forests and TheirTrees in Arabic Countries. Arabic Center for Dry and Arid Lands. Acsad, Syria .(Arabic Ref.)

Aucina, A.; Rudawska, M.; Leski, T.; Skridaila,A.; Pasakinskiene, I. and Riwpsas, E.**.2014**. Forest litter as the mulch improving growth and ectomycorrhizal diversity of bare-root Scots pine *(P. sylvestris)* seedlings. Biogeosciences and Forestry, **8:** 394-400.

Ayari, A.; Zubizarreta-Gerendiain,A.; Tome, M.; Tome, J. Garchi, S. and Henchi, B. **2012.** Stand, tree and crown variables affecting cone crop and seed yield of Aleppo pine forests in different bioclimatic regions of Tunisia. Forest Systems**, 21(1):** 128-140.

Azzawam, S. **(1984).**Al Jabal Al Akhdar: A Natural Geography Study. Garyounis University. Benghazi, Libya.

Bajwa, G.A.; Shahzad, M. K. and Satti, H. K.**2015.** Climate change and its impacts on growth of blue pine (*Pinus wallichiana*) in Murree forest division. PakistanScience, Technology and Development**, 34 (1):** 27-34.

Barbero, M.; R. Loisel; P. Quezel; D. M. R. Barbero and F. Romane. **1998.** Ecology and Biogeography of *Pinus*: *Pines* of the Mediterranean Basin. Cambridge University Press.

Black, C.A.; Evans, D,D.; White, J.L.; Ensminger, L.E. and Clark , f. **(1965).**

Methods of Soil Analysis.Am Soc. of Agron, Inc. Wisc., U. S. A.

Bogino, S.; Nieto, M.J.F and Bravo, F.**2009**. Climate effect on radial growth *Pinus sylvestris* at its southern and western distribution limits. Silva Fennica, **43(4):**609-623.

Britt, K.W. (ed). **1970**. Handbook of Pulp and Paper Technology (2nd ed.). Van Nostrand Reinhold Co. New York: 356- 363. In Passialis, C.N.;

Grigoriou, A.H. and Voulgaridis, E.V. **1995.** Utilization of Oleoresin and Bark Extractives from *Pinus halepensis*Mill .inWood Products.

Buckley, B.M.; Duangsathaporn, K.; Palakit, K.; Butler, S.; Syhapanya, V. and Xaybouangeun, N. **2007**. Analyses of growth rings of *Pinus merkus* Lao P.D.R. forest ecology and management, **253:**120-127.

Cedro, A**. 2001**. Dependence of radial growth of *Pinus sylvestris* L. from western Pomerania on the rainfall and temperature conditions. Journal on Methods and Applications of Absolute Chronology**, 20**: 69-74.

Chalker-Scott, L. **2007**.Impact of mulches on landscape plants and the environment-A review. J.Environ. Hort., **25(4):** 239-249.

Climate Data source: Climatic Research Unit, University of East Anglia: CRUTS 3.21 http:// www.globalclimatemonito.org/#

Cochran, G.W. **1977**. Sampling Techniques,third edition, John Wiley & Sons,Inc.

Cuesta, B.; Vega, J.; Villar-Salvador, P. and Rey-Benayas, J.M. **2010.** Root growth dynamics of Aleppo pine (*Pinus halepensis* Mill.) seedlings in relation to shoot elongation, plant size and tissue nitrogen concentration. Trees, **24**: 899-908.

Earle, J.**2019**.The Gymnosperm Database. Edited by Christopher J. Earle
pingora@protonmail.com.

Elaieb, M.T.; Shel, F.; Elouellani, S.; Janah, T.; Rahouti, M.; Thevenon, M. and Candelier, K. **2017**. Physical, mechanical and natural durability properties of wood from reforestation *Pinus halepensis* Mill in the Mediterranean Basin. Bois Et Forest Des Tropiques, **331(1**):19-31

Eldoumi, F.; Elsaedi, O. and Zunni, S.A**. (2002).** Study of Aljabal Alakhdar's plant cover. Final report in Arabic.University of Omar Al Mokhtar. El- Bieda . Libya.

Elliott, K.J.and Vose, J.M**. 1994.** Photosynthesis, water relations, and growth of planted*Pinus strobus* L. on burned sites in the southern palachians. Tree Physiology, **14** :439-454.

FAO.**2000**. Global Forest Resource Assessment. No.140.p :23.38.

FAO. **2018.** The State of the World's Forests **2018**. Forest Pathways to Stainable Development. Rome. Methods of Soil analysis. Am Soc. of Agron., Inc. Wisc., U. S. A.

Fisher, J.T.; Neumann, R.W. and Mexal, J.G. **1986**. Performance of *Pinus halepensis* / *brutia* group pines in southern New Mexico. Forest Ecology and Management**, 16:** 403-410.

Foti, D.; Passialis, C.; Voulgaridis, E.; Skaltsoyiannes, A. and Tsaktsira, M. **2018**. Wood density and tracheid length of Aleppo pine (*Pinus Halepensis* Mill.) grafts in relation to cambium age and growth rate.Journal of Forest Science, **64(3):** 101-107.

Freese, F. **1967**. Statistician Forest Laboratory. Maintained by the Forest Service at Madison, Wis., in cooperation with the University of Wisconsin.

Gernandt, D. S., G. G. López, S. O. García and A. Liston. **2005**. Phylogeny and classification of *Pinus* Taxon, **54 (1):** 29-42.

Gindel, J. **1944**. Aleppo pine as a medium for tree-ring analysis.Tree-Ring Bulletin , **11(1):**6-8.

Gindel, I. **1955**. Ecological behavior, growth, and yield of the Aleppo-pine *(Pinus halepensis)* Mill in Israel. Commonwealth Forestry Association, **34(4):** 369-383.

Girard, F.; Vennetier, M.; Guibal, F.; Corona**. 2012.** ***Pinus*** *halepensis* Mill. Crown development and fruiting declined with repeated drought in Mediterranean France. Eur. J. Forest Res, **131(4):** 919-931.

Gemez, K.A. and Gomez, A.A. **1984**. Statistical Procedures for Agricultural Research. An International Rice Research institute Book. 536pp.

Gordon, A. **1983**. Estimation bark thickness of *Pinus radiate*. New Zealand Journal of Forestry Science, **13(3**): 340-353.

Gonzalez-Benecke, C.A.; Teskey, R.O.; Dinon-Aldridge, H. and Martin, T.A.**2017.** *Pinus taeda* forest growth predictions in the 21st century vary with site mean annual temperature and site quality. Global Change Biology, **23**: 4689- 4705.

Gulis, V. and Suberkropp, K. **2003**. Leaf litter decomposition and microbial activity in nutrient-enriched and unaltered reaches of a headwater stream. Freshwater Biology, **48**: 123-134.

Haddad, A; D. Lachenal; A. Marechal; G. Janin and M. Labiod**. 2009.** Delignification of Aleppo pine wood (*Pinus halepensis* Mill) by soda anti- anthraquinone process: Pulp and paper characteristics. Cellulose Chem. Technol., **43 (7-8):** 287-294

Hordo, M.; Metslaid, S. and Kiviste, A. **2009.** Response of Scots Pine-- (*Pinus sylvestris* L.) radial growth to climate factors in Estonia. Baltic Forestry, **15(2):** 5-205.

Johnson, D. L. **1973**. Jabal Al-akhdar, Cyrenaica, An Historical Geography of Settlement and Livelihood.The University of Chicago, Deot.of Geography. Res. Pap. No. 148. Chicago. In: Zunni, S.A.; Bayoumi, A.M. **(2006).** ImportantLocal and Exotic Trees and Shrubs in Jabal el-Akhdar, Libya (In Arabic). Aldar Academy for Printing, Uthoring, Translation and Publishing. Tripoli, Libya.

Kitikidou, K.; Papageorgiou, A.; Milios, E. and Stampoulidis, A. **2014.** A bark thickness model for *Pinus halepensis* in Kassandra, Chalkidiki (northern Greece). Silva Balcanica, **15**(1).

Kitikidou, K.; Papageorgiou, A.; Milios, E. and Stampoulidis, A. **2016**. Preliminary individual tree growth model, site index model "mortality" model for Aleppo pine (*Pinus halepensis* Mill.) in Chalkidiki (northern Greece). Ciencia Florestal, Santa Maria**, 26(4):** 1247-1257.

King, D.A. **1995**. Equilibrium analysis of a decomposition and yield model applied to *Pinus radiata* plantations on sites of contrasting fertility. Ecological Modelling, **83:** 349-358.

Kleinbaum, D.G. and L.L.Kupper**. 1978**. Applied Regression Analysis and Other Multivariable Methods. Dexbury, Boston, U.S.A.

Krishna, M.P. and Mohan, M. **2017**. Litter decomposition in forest ecosystems: a review. Energ. Ecol. Environ., **2(4):** 236-249.

Kurz-Besson, C.B.; Lousada, J.L.; Gaspar, M.J.; Correia, I.E.; David,T.S.; Soares, P.M.; Cardoso, R.M.; Russo,A.; Varino, F.; Meriaux, C.; Trigo, R.M. and Gouveia, C.M. **2016.** Effects of recent minimum temperature and water deficit increases on *Pinus pinaster* radial growth and wood density in southern Portugal. Frontiers in Plant Science, (7).

Macova, M. **2008**. Dendroclimatological comparison of native *Pinus sylvestris* and invasive*Pinus strobus* in different habitats in the Czech Republic. Preslia, **80:** 277-289.

Maestre, F.T.; Cortina, J. and Bautista, S. **2004.** Mechanisms underlying the interaction between *Pinus halepensis* and the native late-successional shrub*Pinuslentiscus* in a semi-arid plantation. Ecography**, 27(6):**776-786.

Mazza, G.; Cutini, A. and Manetti, M.C. **2014.** Influence of tree density on climate-growth relationships in a *Pinus pinaster* Ait. forest in the northern mountains of Sardinia (Italy). Biogeosciences and Forestry, **8**: 456-463.

Moore, D. J. P; Aref, S.; Ho, R. M.; Pippen,J.S.; Hamilton, J.G. and Delucia, E.H. **2006**. Annual basal area increment and growth duration of *Pinus taeda* in response to eight years of free-air carbon dioxide enrichment. Global Cgange Biology,**12** : 1367-1377.

Olivar, J.; Bogino, S.; Rathgeber, C.; Bonnesoeur, V. and Bravo, F. **2014**. Thinning has a positive effect on growth dynamics and growth–climate relationships in Aleppo pine (*Pinus halepensis*) trees of different crown classes. Annals of Forest Science, **71**: 395-404.

Olivar, J. Rathgeber, C. and Bravo, F. **2015.** Climate change, tree-ring width and wood density of pines in Mediterranean environments. IAWA Journal **36(3):** 257-269.

Omar Al-Mukhtar University. **2005.** Reconnaissance study and evaluationof the natural Vegetationcover of Al-Jabal Al-Akhdar (GM).Final report. 946pp (In Arabic).

Robbins, W.J. **1921**. Precipitation and Growths of Oaks at Columbia, Missouri.Univ. Missouri Agri. Exp. Sta. Res. Bull. 44.

Passialis, C.N.; Grigoriou, A.H. and Voulgar E.V. **1995** Utilization of Oleoresin and bark extractives from *Pinus halepensis*Mill .in wood products. ForetMediterraneenne, **1:**19-27

Portillo-Estrada, M.; Pihlatie, M.; Korhonen, J.F.J.; Levula, J.; Frumau, A.K.F.; Ibrom, A.Lembrechts, J.J.; Morillas, L.; Horvath, L.; Jones, S.K. and Niinemets, U**. 2016**. Climatic controls on leaf litter decomposition across European forests and grasslands revealed by reciprocal litter transplantation experiments. Biogeosciences, **13:** 1621-1633.

Price, R. A., , A. Liston and S. H. Strauss. **1998**. Phylogeny and systematics of Pinus.P: 49–68 in: Richardson, D. M. (ed.), Ecology and Biogeography of Pinus. Cambridge Univ. Press, Cambridge. In: Gernandt, D. S., G. G. López, S. O. García and A. Liston. **2005**. Phylogeny and classification of *Pinus Taxon*, **54 (1):** 29-42.

Pritzkow, C.; Heinrich, I.; Grudd, H. and Helle, G. **2014**. Relationship between wood anatomy, tree-ring widths and wood density of *Pinus sylvestris* L. and climate at high latitudes in northern Sweden. Dendrochronologia, **32:** 295-302.

Sabate, S.; Gracia, C.A. and Sanchez, A. **2002.** Likely effects of climate change on growth of *Quercus ilex,Pinus halepensis, Pinus pinaster, Pinus sylvestris and Fagus sylvatica* forests in the Mediterranean region. Forest Ecology Management, **162:** 23-37.

Salminen, H. and Jalkanen, R. **2005**. Modelling the effect of temperature on height increment of Scots pine at high latitudes. Silva Fennica, **39(4):** 497-508.

SAS Institute, Inc**. (2007),** SAS Technical Report AS/STAT Software: Changes and Enhancements User's Guide, Vol.**2**, Version 9.1.3, Fourth Edition, Cary, NC: SAS Institute, Inc.

Scott, D. **1972**. Correlation between tree-ring width and climate in two areas in New Zealand. Journal of the Royal Society of New Zealand, **2(4):** 545-560.

Sensula, B. and wilczynski, S. **2017.** Climatic signals in tree-ring width and stable isotopes composition of *Pinus sylvestris* L. growth in industrialized areanearby kedzierzyn-kozle. Geochronometria**., 44**: 240-255.

Spanos, K., D. Gaitanis, and, I.Spanos. **2010**. Resin production in natural Aleppo pine stands in northern Evia, Greece. – Web Ecol. **10**: 38–43.

SPSS Inc. **2007.** Statistical Package for Social Science, version 16, SPSS, USA.

Steel, R.G. and Torrie. **1980**. Principles and procedures of statistics 2nd ed.McGraw Hill, NewYork, U.S.A.

Tisler, V.; Ayla, C. and Weissmann, G. **1983.** Untersuchung der Rindenextrakte von Pinus halepensis Mill. Holzforschungu. Holzverwertung, **35**: 113.116. In: Passialis, C.N.; Grigoriou, A.H. and Voulgaridis, E.V. **1995** Utilization of oleoresin and bark extractives from *Pinus halepensis* Mill.in wood products, ForetMediterraneenne, **1**: 19-27.

Tombe, T.B. **2016**. Climate-growth relationship of *Pinus patula* Schldl. Et cham. In Wondo Genet, South Central Ethiopia. Journal Climatology Weather Forecasting, **4(3):** 2332-2594.

Turner, J**. (1995).** Field methods manual. Research Division, State Forests of NewSouth Wales, Technical Paper No. 59, Australia

Van Laar, A. and Akca, A. **1997**. Forest mensuration"Pages(64:78)Copyright**(2007)**avai labla .at: www.springer.com

Vittoz, P.; Rulence, B.; Largey, T. and Frelechoux, F. **2008**. Effects of climate and land- Use change on the establishment and growth of cembran pine (*Pinus cembra* L.)over the altitudinal tree line ecotone the central Swiss Alps. Arctic Antarctic Alpine Research, **40:** 225-232.

Yao, J. **1970**. Influence of growth rate on specific gravity and other selectedproperties of loblolly pine. Wood Science and Technology, **4**: 163-175.

Yaniv, Z and N. Dudai. **2004**. Medicinal and Aromatic Plants of the Middle-East.

Weinstein, A. **1989**. Phenology of *Pinus halepensis* at two sites in Israel. Forest Ecology and Management, **26(4)**: 305-309.

West, P. **(2009).** Tree and forest measurment. Germany: Springer Dordrecht Heidelberg London New York.

William, D.; Jackson, A.B .and Harrison, S.G. **1967**. A handbook of Coniferae and Ginkgoaceae, 4th ed. New York: St. Martin's Press. xix, 729 p.

Woodson, G.E. **1986**. Fiberboard Manufacturing Practices in the United States. USDA Forest Serv. Agr. Handbook No. 640-88.In Passialis, C.N.; Grigoriou, A.H. and Voulgaridis, E.V. **1995** Utilization of Oleoresin and bark extractives from *Pinus halepensis*Mill .in wood Products, ForetMediterraneenne**, 1**:19-27

Wutzler, T. and Reichstein, M. **2007**. Soils apart from equilibrium-consequences forsoil carbon balance modeling. Biogeosciences, **4**: 125-136.

Zhang, S.Y.**1995**. Effect of growth rate on wood specific gravity and selectedmechanical properties in individual species from distinct wood categories. Wood Science and Technology, **29**: 451-465.

Zunni, S.A.; Saadi, P.T. and Bayoumi, M.P. **(1996).** The impact of environmental factors on natural pastures. Al Marj. Libya. Science Magazine (**3**).

Zunni, S.A.; Bayoumi, A.M. **(2006).** Important Local and Exotic Trees and Shrubs in Jabal el-Akhdar, Libya (In Arabic). Aldar Academy for Printing, Authoring, Translation and Publishing. Tripoli, Libya.

الملخص العربى

تقييم بعض الغابات الاصطناعية فى منطقة الجبل الاخضر– ليبيا

محمد عمران الفيتوري[1]، ابراهيم السيد خيرالله[2]، أحمد محمد البحة[2]، حسني عبدالعظيم أبو جازية[2]، أحمد عامر الستاوي[2]

[1]قسم الغابات، كلية الموارد الطبيعية وعلوم البيئة، جامعة عمر المختار، ليبيا

[2]قسم الغابات وتكنولوجيا الأخشاب، كلية الزراعة، جامعة الاسكندرية، مصر

تهدف نلك الدراسة الى التحقق من طبيعة وديناميكية النمو، المتساقطات، محصول الخشب والعوامل المناخية بالنسبة لأشجار الصنوبر الحلبي(*Pinus halepensis*) Aleppo pine التي تنمو في 5 مشجرات مختلفة تسمى الحمري، مراوة ، مدور الزيتون الشرقي، مدور الزيتون الغربي ومشجر الكشاف في منطقة الجبل الأخضر - ليبيا.

اتضح من واقع النتائج التي تم التحصل عليها، أن مشجر مراوة قد سجل أعلى قطر عند مستوى ارتفاع الصدر (DBH) (21.55 cm)، معدل الزيادة السنوية فى القطر عند مستوى الصدر(DBH) (0.66 cm/year)،المساحة القاعدية (BA)(19.25 m2 /ha)، حجم الكتلة الخشبية(1.02 m^3/tree)، الزيادة السنوية في الكتلة الخشبية(0.02 (m^3/tree/year، محصول الخشب(307.47 m^3/ha) ومعدل الزيادة السنوية فى حجم الخشب(8.54 m3/ha/year).

أبدى مشجر الحمري، على كل حال أعلى ارتفاع في الأشجار(14.61 m)، قطر التاج (5.23 m)، مع عدم وجود فروق معنوية عند مستوى ارتفاع الصدر (DBH)،(21.70 cm)، (BA) (21.20 m2 / ha) والكتلة الخشبية (256.22 m3/ha) مع نظيرها فى مشجر مراوة، في حين أظهر مشجر الكشافأقل قيم في النمو والمحصول الخشبى التي ذكرت سابقاً. معدل التساقط السنوي للمخلفات الشجريه على سطح المشجر كان 10.51 ton/ha/year ، كمتوسط لكل المشجرات التي تم دراستها، مع عدم وجود فروق معنوية بينهم . كما لا يوجد فروق معنوية بين كل المشجرات في الثقل النوعي (SG) للخشب (0.45 كمتوسط لكل المشجرات) معامل القلف كان أيضاً هو نفسه في كل المشجرات التي تم دراستها (0.93) .

بمراقبة معدل تساقط الأمطار منذ عام 1960 الى2017، لوحظ ان هناك انخفاض بسيط في معدل سقوط الأمطار مع الوقت بمتوسط عام (394.34 mm/year)، مع ارتفاع بسيط في درجات الحرارة وبمتوسط عام (18.47 °C) في منطقة الجبل الأخضر.دراسة علاقة العوامل المناخية بحلقة النمو التزامنيه أظهرت أن عرض الخشب المبكر والمتأخر في حلقة النمو يتناسب عكسياً مع الزيادة النسبية في درجات الحرارة في كل المواقع التي تم دراستها. باستثناء مشجر الكشاف، معدل سقوط الأمطار لم يكن له تأثير على عرض الخشب المبكر والمتأخر حتى في تطور سمك الحلقة السنوي في ساق الشجرة في كل المشجرات التي تم تحليلها.

ضمن التغيرات المناخية السلبية والتأثير السلبي على نمو الغابات ننصح بتطوير الممارسات الزراعية للمحافظة عليها قدر الأمكان.