Influence of Precipitation and Temperature on Tree-Ring Width of Brutia Pine (Pinus brutia Ten.) in Tartous-Syria

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Abstract

Tree rings width are strongly influenced by environmental factors especially climatic ones, Dendroclimatology concerns with studying the response of tree rings to climatic conditions. In order to study the relationship between tree rings width of brutia pine and both of precipitation and temperature in three sites in Tartous, 10 dominant trees were selected in each site. Using increment drill two perpendicular samples from each tree at breast height were taken. The samples were treated, and well cross dated, then the rings width were measured to the nearest 0.01 mm. The tree rings time series were standardized to avoid the influence of age and forest management. Response functions method was used to test the relationship between climate and tree ring-width. Results showed that, at low site Amreet, tree-ring width was more influenced by precipitation than temperature, especially in growing season and prior to it. At high site Kadmous, precipitation has significant effect between the end of spring and the beginning of summer (May and June), However, there was an obvious positive influence of April temperature (mean, max and min) on tree-ring width. At Tallah, tree-ring width did not significantly response to monthly precipitation, and showed negative influence by the mean and maximum temperature for July.

Keywords: *Dendroclimatology -Tree rings -Temperature -Precipitation – Brutia pine.*

I. INTRODUCTION

Brutia pine (*Pinus brutia* Ten.) grows naturally in the Mediterranean region covering extensive areas in Turkey, Greece, Cyprus, Lebanon and Syria [1]. It is widespread and abundant in the Eastern Mediterranean Basin, and actually spreading from plantations [2]. It is one of the most important forest trees in Syria, Especially in Tartous province, where the Mediterranean climate is dominated, by hot and dry summers, and mild humid winters [3].

Brutia pine is a typical Mediterranean tree and characterized also as a fast growing specie, and it is extremely drought-tolerant, and can grow in areas with mean annual rainfall as low as 400mm [4], and it is one of the main species used in reforestation and restoration programs, that is Brutia pine, however, were one of the most degraded trees during the war years in Syria [5].

In the cross section of conifer trees, we can clearly recognize the tree rings, which appear like circles around the same center, brutia pine tree rings (as all conifers) are generally composed of large, thin-walled cells of light early wood, followed by narrow, thick walled cells of dense latewood [6].

Tree ring width, cell profile, cell diameter and cell wall thickness are the main anatomical characteristics of tree rings described by the climatic signal [7].

Tree rings don't all look the same, the mean width of the tree ring is a function of many variables, including the tree species, tree age, soil nutrient availability, and a whole host of climatic factors [8]. Precipitation and air temperature are the two most commonly correlated with tree growth, other environmental factors such as soil moisture, light, wind, and relative humidity can also affect the growth, but they are associated with the fluctuations in precipitation and air temperature [9]. The climate-related environmental signal in tree ring is assumed to be always present in tree-ring series to a greater or lesser extent, depending on the limiting effects of climatic variables such as temperature and water availability ([10], [11]).

Dendroclimatology is a valuable tool for studying the climate-tree rings relationship, and increases our knowledge of climate variability beyond the period covered by instrumental data [10], and it is defined as the study of the relationship between tree-ring growth and climate variability, and the use of that relationship to reveal patterns of climate variation in the past [12].

Dendroclimatological studies in the Eastern Mediterranean was begun in the mid-20th century, the first dendroclimatological attempt in the was by

Gassner and Christiansen-Weniger In the year 1942, who demonstrated that tree growth in parts of northeastern Turkey is significantly influenced by precipitation [12]. There have been many subsequent studies like ([13], [14], [15], [16], [17], [18], [19], [20].

Few of those studies were about brutia pine, such as in southwestern Turkey, re. [18] used tree-ring data from living and dead trees to reconstruct spring (May-June) precipitation several centuries back in time, their reconstructions show clear evidence of multiyear to decadal variations in spring precipitation, within those variations, the longest period of spring drought was 4 years (1476–1479). Re. [19] reconstructed May to August precipitation on a much larger scale in the northeastern Mediterranean region, using many genera and species of conifers, including brutia pine. Re. [21] presented evidence of a recent drying in the eastern Mediterranean, based on weather and brutia pine tree-rings data for Samos island, they identified precipitation as the key driver for tree growth in eastern Mediterranean. Re. [22] developed a September-August precipitation and drought reconstruction for AD 1830–2006 from brutia pine tree rings for Cyprus, this study making use of trees from low and medium elevations, provides the first long-term assessment of annual precipitation and drought for Cyprus, and emphasizes the importance of elevation for the seasonality of the climate signal embedded in tree rings, and will aid in future plans for drought mitigation. The results of re. [23] indicate variability in the climate response of trees growing along altitudinal transects, with precipitation the primary factor but increased sensitivity to temperature at the higher altitudes, especially in area with thin soil.

In Syria there are rare dendroclimatological studies, the first study was by re. [13] on *Quercus cerrisssp. Pseudocerris* in north Latakia, then in (1989), re [24] used dendroclimatological tools to study the relationship between tree rings of *Abies cilicica* and climatic variables in Shouh Mountain in Syria, they found that a cool autumn of the previous year, as well as a cold winter, a warm spring and a relatively rainy summer, are favorable conditions to form wide tree rings, and adverse climatic factors form narrow tree rings.

This study aims to analyze the relationships between tree rings-width of brutia pine (*Pinus brutia* Ten.) and both of monthly precipitation and air temperature in three sites located in Tartous province: 1- Kadmous is a planted forest. 2-Tallah is natural forest growing almost at similar elevation of Kadmous. 3- Amreet is also a planted forest located almost at sea level.

II. MATERIAL AND METHODS

A.Study area

The study area includes three forests of brutia pine in Tartous province (Kadmous ,Tallah and Amreet), in the west of Syria in the Eastern Mediterranean region (Table 1).

Brutia pine was planted in Kadmous in1958, and in Amreet in 1974 , while Tallah is a natural forest.

Table 1.Study sites information.

Site	Location	Site code	Species	Lat.(N)	Long.(E)	Elev.(m)
Kadmous	Tartous	KD	*P. brutia*	35° 6.511'	36° 8.871'	885
Tallah	=	TL	=	35° 3.517'	36° 10.951'	788
Amreet	=	AM	=	34° 50.601'	35° 54.496'	25

Figure1. Location of study area

B. Climate data:

The meteorological data of Kadmous station was used in both of KD and TL sites, whereas data of Tartous station was used in AM site (Table 2). Meteorological data used include each of monthly mean, maximum, and minimum temperature, and sum of monthly precipitation as well (Figure 2).

Table 2.Information on Meteorological stations of study sites.

Met. station	Lat.(N)	Long.(E)	Elev.(m)	Mean Annual Precip. (mm)	Mean Annual Temp. (C⁰)
Kadmous	35° 6.152'N	36° 9.697'E	938	1300	14.5
Tartous	34° 52.253'	35° 53.245'	13	827	19.8

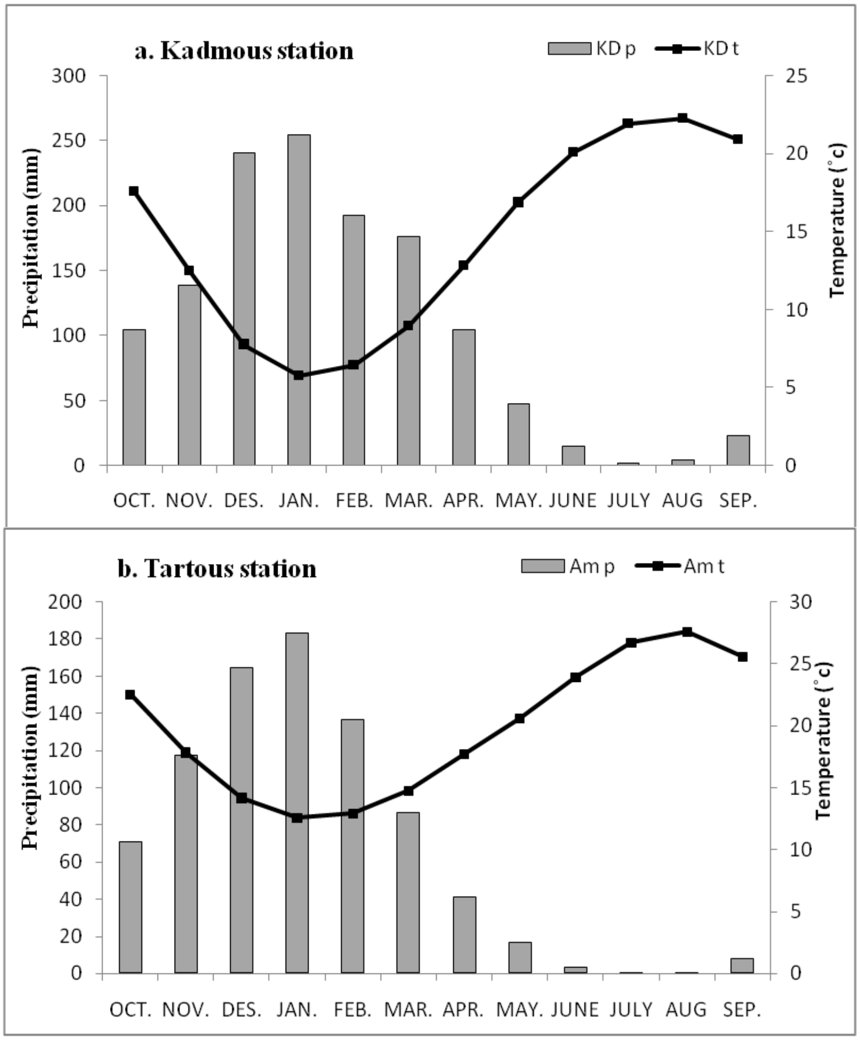

Figure 2. Climatic diagrams: a. Kadmous Meteorological station for the period 1966–2013
b. Tartous Meteorological stations for the period 1981–2013

Biological year was used in this study, the 12-month period that starts Oct. 1 and continues through Sept. 30 the following year. This period is the most widely used in the researches of Dendroclimatology in the Mediterranean region such as ([25], [26], [27], [22], [28], [29]).

C. Tree-ring data or Chronology development:

Ten dominant trees of brutia pine (the biggest and tallest trees) were selected in each site. Using an increment borer (Figure 3), two perpendicular (EW, NT) cores per tree at 1.3 m height were collected (Speer, 2010). The samples were treated and well sanded using finer grit paper [30]. The core samples were cross-dated according to standard dendrochronological techniques ([31], [32]). cross-dating is much easier for dominant or co-dominant trees [33], that the correct dating of tree rings is a crucial methodological step in all dendroecological and dendroclimatic studies [34]. The ring widths were measured to the nearest 0.01 mm, and tree-ring chronologies were developed for total ring width (early wood + late wood).

Using 3Pbase program [35], tree rings chronologies were standardized, to remove age-related tendencies from the growth curve, and avoid the effects of stand dynamics ([10], [36]). After standardization, the elementary series were respectively averaged for each tree, and master chronologies were constructed for each site by averaging tree series; finally, a mean indexed chronology was computed per site ([37], [38]).

Figure 3.Taking the samples using increment borer

D. Statistical analysis:

Relationship between climate and tree ring-width have been tested by 'response functions', which is a form of principal component regression designed to account for collinearity of monthly climate predictors ([39], [40]). Response function analysis was developed and used for the first time by re. [39]. Using 3Pbase program [35], response functions were conducted using a bootstrap method. Bootstrapped response functions were calculated, for each site, using the tree rings index values as a dependent variable and the 46 monthly climatic parameters as predictor variables, temperature (mean, max, min) of the 12 month period from October of the prior year to September of the current year, and precipitation for the same months except July and August, because in this two months the precipitation is absent for most years.

The significance of each bootstrapped regression coefficient is provided by the ratio between the mean value of bootstrap regression coefficients (MR) and its standard deviation (S). When the ratio ranges from 1.65–1.95, 1.96–2.57, 2.58–3.29, and >3.29, the significance of the corresponding regression coefficients respectively reach 90%, 95%, 99%, and 99.9%.

IV. RESULTS AND DISCUSSION

A. Cross-Dating and Chronologies

Figure 4. (A, B, C) shows the time span of our chronologies was 1981-2013 for AM, 1966–2013 for KD, and 1900–2013 for TL, with an average ring width of, 4.64 mm, 3.82 mm and 2.1 mm, respectively. They ranged between a minimum of 2.26 mm and a maximum of 9.09 mm for the 33 years in AM, 1.85 mm and 7.24 mm in KD for the 48 years, and 1.33 mm and 7.07 mm in TL for the 114 years. Tree ring-widths showed a decreasing age trend for all sites. According to the available meteorological data in TL, our study covered just the period1960-2013.

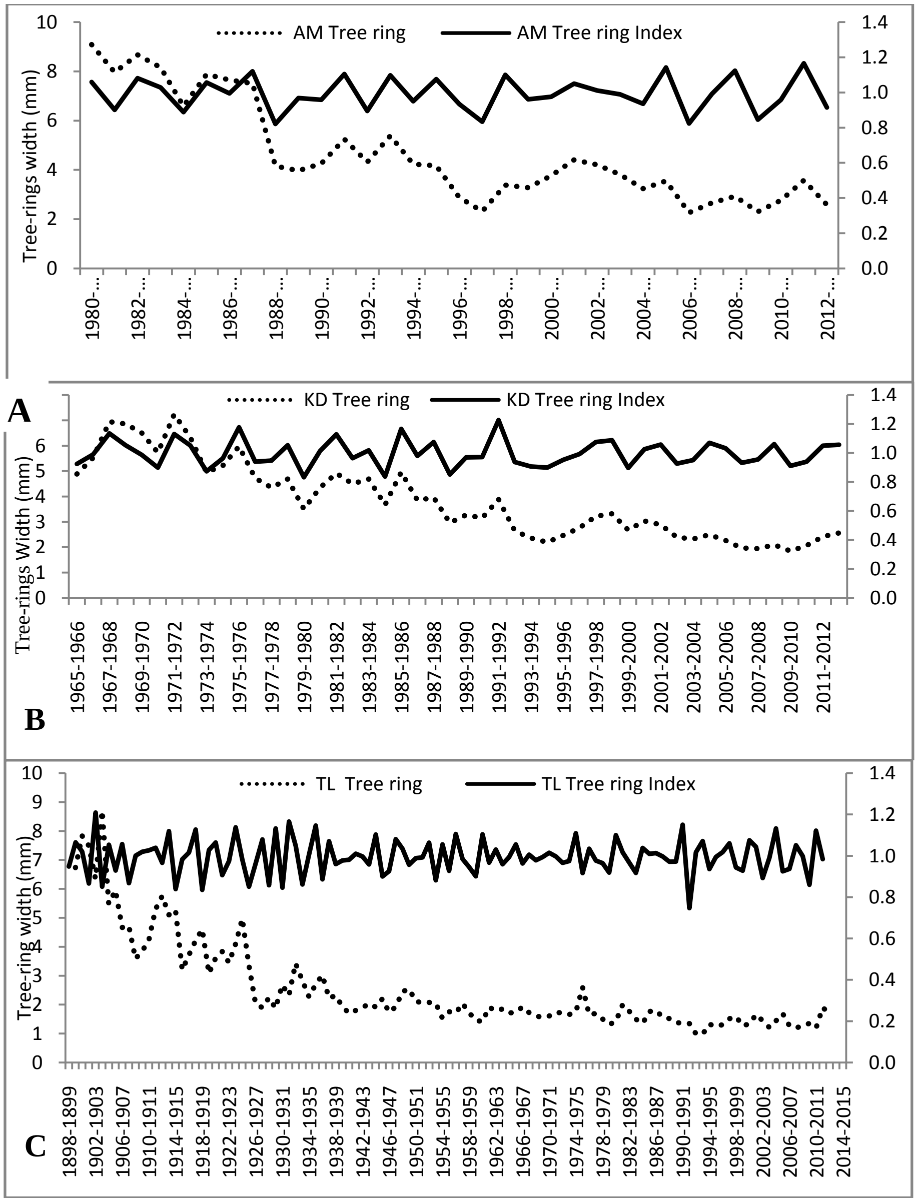

Figure4. Annual radial growth curves of *Pinus brutia* in study sites (dashed line ….) with the index curves which are derived from the annual growth (solid line—)

Samples did not show any missing ring, nor false one with an exception of AM in which two false rings were detected (1986- 1987, 1993-1994). False rings formation is considered as common source of error in tree ring research, they mostly are caused by drought during the growing season ([10], [41]).

The monthly precipitation and temperature of both years 1986-1987 and 1993-1994 were illustrated in Figure (5). In year 1986-1987, it is obvious that, after two months of drought some amount of rainfall had been occurred in August followed by dry period lasted till October, this in turn corresponded with temperatures below average lasted from March till October, consequently false tree ring could has been formatted.

The year 1993-1994 was characterized by a long period of drought lasted four months (from June till September), followed by a good amount of precipitation in October with temperature above average, these conditions encouraged little growth in late wood.

Additionally, the amount of precipitation in May for the same year was less than 50% of the average during period of study. This result is similar to study results conducted on *Pinus nigra* in Vienna, Which shows that, the false rings formation was recorded during years with less than half of May mean precipitation [42].

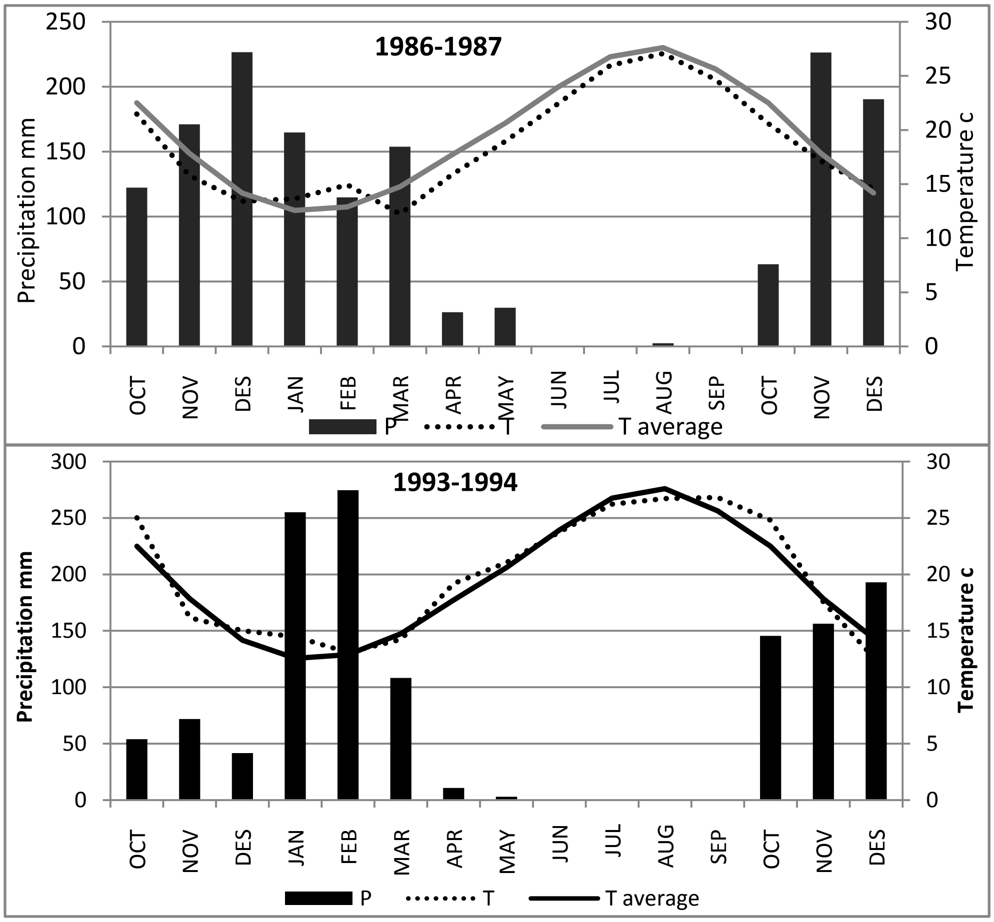

Figure5. Climatic diagrams: Site AM, Monthly temperature and precipitation during the years:1987 and 1994

B. Response Function

Results of bootstrap method applied to monthly precipitation reveals that, in AM the relationship was significant at confidence interval 95% for January and March, and also for June at confidence interval 90% (Figure 6), while it was significant at confidence interval 95% for June and at 90% for May in KD.

In TL there was not significance relationship between index and monthly precipitation (Figure 6).

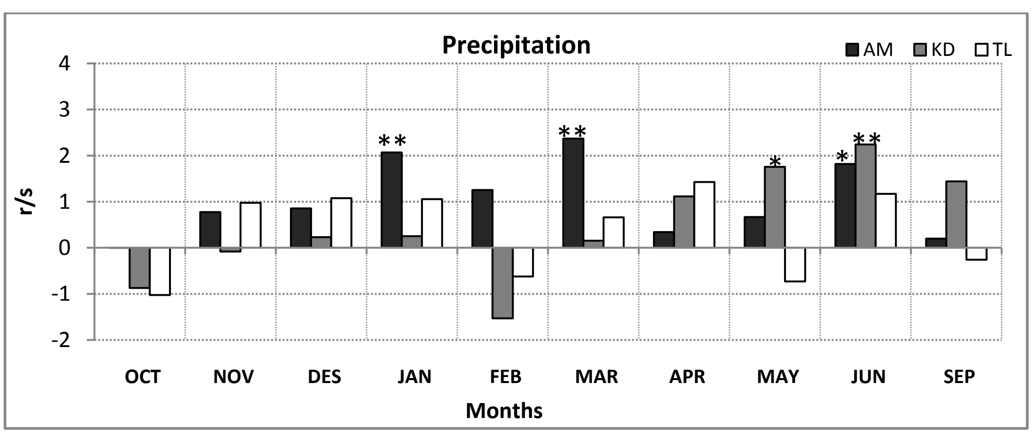

Figure6. Response function analysis for tree ring chronologies of *Pinus brutia* in the study sites (AM, KD, TL) to monthly precipitation from October (prior year) till September (current year) .

Bootstrap method applied for monthly mean temperature (Figure.7), shows, not significant relationship between tree ring index and monthly mean temperature in AM.

In KD It was positively significant at confidence interval 99% for April, and negatively significant at confidence interval 90% for each of June and July. Whereas, this relationship was negatively significant at confidence interval 90% just for July in TL.

In case of maximum temperature the results were different, it was negatively significant at confidence interval 90% for May in AM, and negatively significant at confidence interval 90% and 95% for March and July respectively in TL, but It was positively significant at confidence interval 95% for April in KD.

Monthly minimum temperature recorded positive significant value just in KD for April at confidence interval 95% .

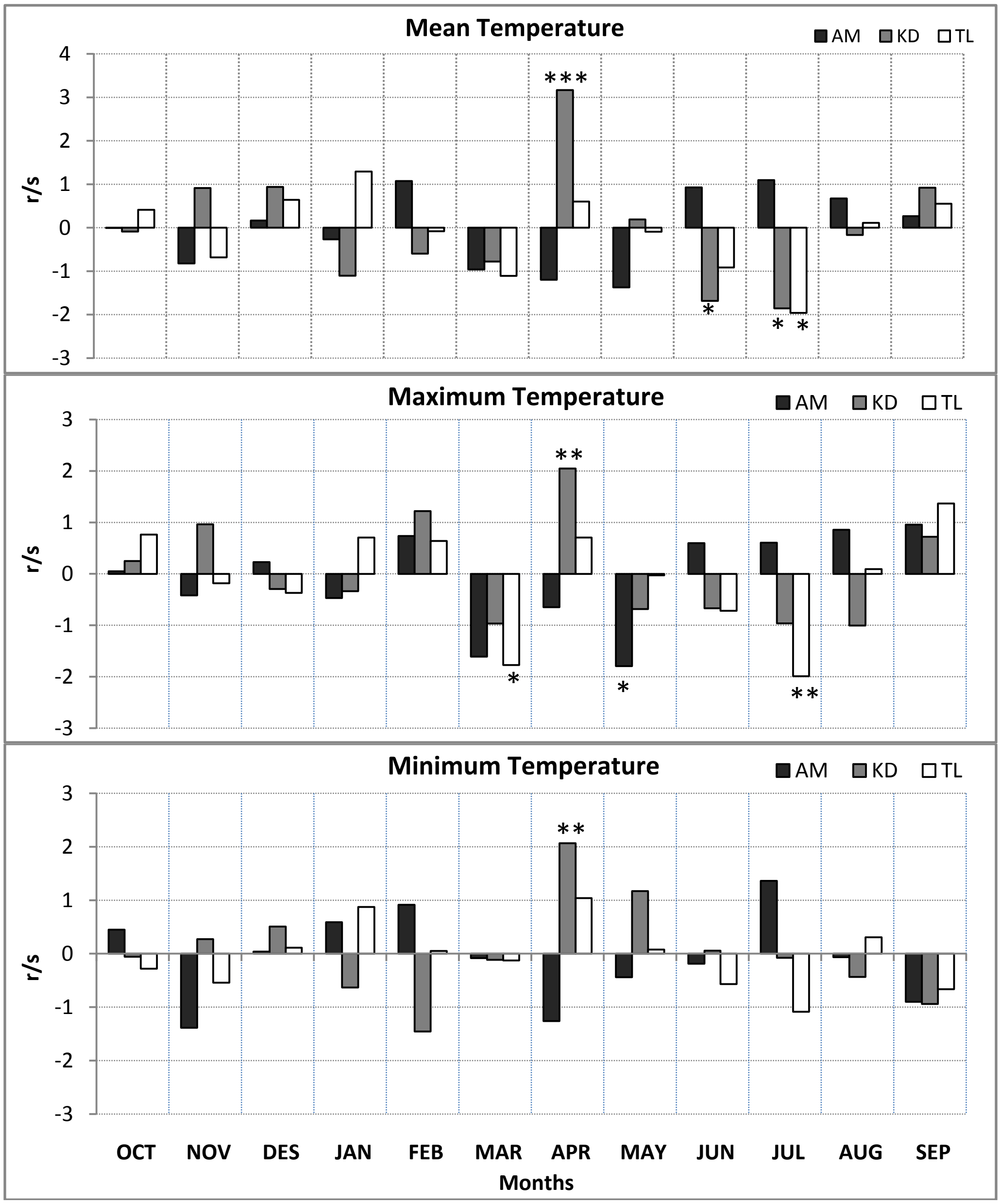

Figure7. Response function analysis of tree ring chronologies of *Pinus brutia* in the studying sites (AM, KD, TL) to monthly temperature (mean, max, min) from October (prior year) to September (current year) .

As compared to other studies, in Jordon a relatively high correlation was shown between October–April precipitation and a *Pinus halepensis* chronology, and between October–May precipitation and *Quercus aegilops* chronology, [43].

In Turkey, re. [16] reported important influence from both temperature and precipitation on *Pinus pinea* tree-ring chronology, a positive influence of precipitation was found for all months except March and June, while the significant influence of temperature was positive in March and April. Results of re. [44] revealed a pervasive positive association of tree growth with May, June, and sometimes July precipitation, positive correlations with winter and spring (December through April) temperatures, and negative relationships with May through July temperature.

Re. [44] found a common significant response to May–June precipitation in eastern Mediterranean, like re. [18], [20]. In Italy, positive moisture balance in the late spring-summer period of the year of growth was considered as the climatic driver of *Pinus pinea* radial growth [45].

The negative effect of maximum temperatures often result in increased transpiration at the plant, resulting in reduced cambium activity and thus a decrease in the tree rings width [46]. The positive effect of temperatures in April may be due to the fact that the moisture at the beginning of the growth season is still relatively abundant, that the high temperature helps to increase growth.

Results of our study are similar to results of re. [22] that emphasized the importance of altitude for the seasonality of the climate signal embedded in tree rings of *Pinus brutia*, also re. [23] indicated variability in the climate response of trees growing along altitudinal transects, with precipitation is the primary factor, but increased sensitivity to temperature at the higher altitudes.

V. CONCLUSIONS

- Tree-ring width at low site (AM ca.26 m above sea level) was more influenced by precipitation than temperature, especially in growing season and prior to it.
- At high site (KD ca. 885 m above sea level) where growing season is relatively late, precipitation has significantly affected Tree-ring width at spring end and summer beginning (May and June).
- At KD also, there was an obvious positive influence of April temperature (mean, max and min) on Tree-ring width.
- At TL site (with elevation of ca. 788 m above sea level) Tree-ring width were not significantly affected by monthly precipitation, It is likely that trees grow naturally and reached stabled growth period (all sampled trees aged more than 80years), where growth is slow and stable and less sensitive to environmental change, especially since this site is often characterized by heavy rain more than trees need.
- At TL also, Tree-ring width showed sensitivity to the mean and maximum temperature for July, which had a negative influence.

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