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# Annual ring analysis of persian oak (*Quercus Brantii*) to determine periods of stress and tensions on Zagros Forests (case study: forests of Ilam County)

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**Abstract**

Goal of this study was to analyze relationships between the annual variability of Persian Oak (*Quercus Brantii)* tree-ring chronologies and the variability of the main climatic parameters in Zagros forests of Iran. In order to conduct this research, 17 annual ring diskettes of 17 Persian Oak tree collars, in CheghaSabz District of Ilam County, were collected and transferred to laboratory. The measurements of the cores were made with the LINTAB device and TSAP program. Growth status analysis and dendrochronology results indicated that since 2001, growth rate has declined and on the other hand, reduced rate of annual rainfall, temperature rise and increased dust, considering that the area is prone to such factors, have imposed stress in species of Persian Oak. General conclusion drawn is that dominant situation on the study regions, increases the sensitivity of the area towards start of stress and drying and considering changes in climate features and high rate of human activities, reduced growth and consequently start oak wilt and decay and the process is completed by the activity of secondary pests.

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## Introduction

In the recent decades the Mediterranean and semi-Mediterranean forests have been faced with climate changes (Nogués Bravo *et al.*, 2008; Parry *et al.*, 2008). Rainfall diminution, inappropriate annual rainfall distribution and ground water recharge decreases in forest ecosystems may compromise tree health and survival (Bréda *et al.*, 2006; Van Mantgem *et al.*, 2009). Warmer and drier conditions are partly responsible for reduced forest productivity (Kirilenko and Sedjo, 2007; Schröter *et al.*, 2005). Zagros forests, located in the western part of Iran. These forests characterized by a semi-Mediterranean climate, are one of the most important and sensitive ecosystems in Iran. These forests are about five million ha, occurring in the western part of country. The main tree species in these forests are Persian oak (*Quercus. Brantii* Lindl) and it have at least 5,500 years old antiquities (Purhashemi *et al.*, 2004). Persian oak has dominated in all parts of Zagros Mountains from north to south, especially on the southern side of mountain in Ilam province (Fatahi, 1994). During the last four years (2009- 2012) several reports of this Oak tree decline were received. Complaining about serious damage and death of many oak trees. The disease has been spread throughout forests of Zagros.

Growth failure and extinction of plant species in massive areas of woods in the world is reported (FAO, 1994). Some scientists consider growth failure and tree decline to be the outcome of climate change and effect of climate variables (Larsen and McDonald, 1995; Pittock, 1982), Obviously, the phenomenon of forest decline existed in different periods, however, considering the dominant situation at any given period its level has varied and effective factors have been different, for which it is coercive to identify the origin and share of each factor. Through identification of these factors and influence of each factor it would be possible to take important measures through pathology and proper and suitable operational policies to preserve and maintain remaining woodlands. Starkey *et at.*, 1999 Forest health studies on oak mortality and wilt in Ozark National Forests, it was stated that wilt is an indicator that occurs through predisposing, initiating and participatory factors and all together result in wilt and mortality of oaks epically, Scarlet Oak (*Quercus coccinea*). Width of growth rings is usually a proper indicator to determine the stress periods in the past, especially in areas known for their severe climate changes. Generally, in some areas, growth rings are mostly influenced by one climate factor (Vogel, 2002). Response of various tree species to climate variables such as temperature (Akkemik, 2014), rainfall (Schweingruber *et al.*, 1988) and dust (Ulbrich *et al.*, 2003) varies which changes the growth process in the rings.

Drobyshev *et al.*, 2006 in their study of oak mortality in southern Sweden, through analysis of annual rings of 44 trees which had recently died in comparison with live trees in the same habitat, claimed that the highest mortality rate has been in 2002, and 80% of dead oaks show decline growth rate and approximately 51% of dead trees, experienced declined growth 4 years prior to their death. Sonessoon *et al.*, 2010 in their studies on decline of oaks in south Sweden, claimed that improper climate change caused negative productivity of the crown in oak trees. These studies indicate the importance and role of climate change (harsh winters during sleeping period and drought during growth season) in start of deterioration process and crown productivity status and annual growth rings are discovered to be highly correlated. The objective of this study, besides identifying the period in which oak trees suffered stress, is to identify and define the influence of climate variables on the growth of this species during past 30 years.

## Materials and Methods

*Study Area*

Ilam province is located in 46° 45 to 48°11eastern longitude and 32° 57 to 34° 41 northern latitude, in the western side of the country. This study is in the forests of CheghaSabz of Ilam County where massive dryness prevails. Average annual rainfall is 570mm and average annual temperature is 27.5 degree centigrade. According to Amberje climate classification the Ilam province is classified in mountain temperate climate. 6417 square kilometer, equal to 32 percent of the province area is covered by persian oak forests.

*Study Methodology*

In order to identify the period when oak trees have suffered stress and tension in the study area, dried tree trunks were analyzed. Considering that in the study area (CheghaSabz), Department of Natural Resources of Ilam Province is in the process of cut and transformation of dried trees for health, rehabilitation and regeneration operations (Winter 2013), 17 trees, in various diagonals were selected from among cut trees randomly and diskettes with one centimeter thickness were cut from the tree collar to review the status of annual rings and growth in the laboratory of the Karaj University of Natural Resources and Watersheds.

After the disks were transferred to the laboratory, their surface was leveled by electric sander in order to enable us to distinguish growth rings. In order to measure the width of growth rings, upon leveling the surface of the samples and placing them under the loop, counting started from the bark (rhytidome) to the heartwood. The width of the rings were measured in two different directions with 0.01mm precision by binocular and measuring table (RINNTECH) LINTAB and time series analysis software of TSAP. Along with start of measurement at the end of the last ring which belonged to the growth of 2013, measuring table was moved according to the width of the ring towards the heartwood and upon reaching to the wood, the end of the last year ring and right click of the cursor, ring width was recorded. In order to study the growth of these trees, annual growth chart with average periodic growth since 1975 to 2013 was drawn and from all 17 samples in two perpendicular directions, separate averages were obtained.

**Results**

*Dendrochronology & Trunk Analysis Results*

Considering the results obtained from annual growth ring measurement, it was concluded that growth rate from 2001 to 2013 had descending trend and has been less than average annual growth rate (Fig 1). This result indicates that stress and tension have started towards the end of the decade starting from 2001 (almost 13 years ago).

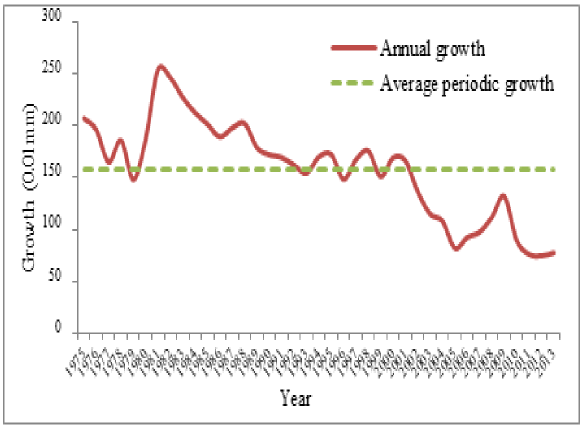


**Fig. 1.** Comparison of annual growth and average growth rate.

Comparison of annual growth and average growth rate of disk No. 1 (Fig 2), indicates that in 1981, 1987 and annual period from 1990 to 1991, annual growth has been more than average growth. From 1987 significant changes occurred in growth rate, which resulted in a growth rate less than average growth, however, the tree had been growing, but from 2001 for a decade the drop in growth aggravated and shows that the tree has suffered some environmental tensions.

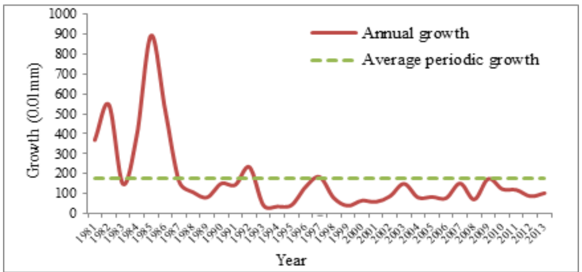


**Fig. 2.** Comparison of annual growth and average growth rate of disk No. 1.

Results of analysis on disk No. 10 (Fig 3), show that from 1981 to 1995, annual growth, despite minor changes, has been more than average growth rate, however normal growth volatility are observed. Growth rate from the decade starting from 2001 has suffered serious decline, and this trend continues till now.

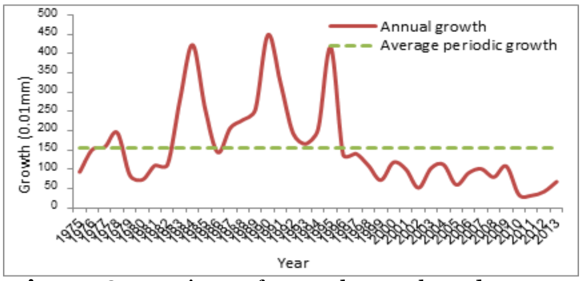


**Fig. 3.** Comparison of annual growth and average growth rate of disk No. 10Fig 3. Comparison of annual growth and average growth rate of disk No. 10.

Comparison results of annual growth and average growth period in disk No. 12 (Fig 4), indicate that annual growth rate since 90s and from a short while before that, has had a declining trend.

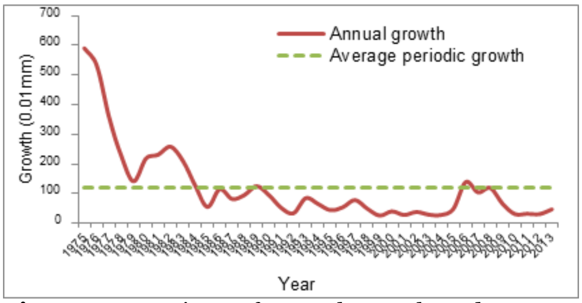


**Fig. 4.** Comparison of annual growth and average growth rate of disk No. 12.

*Analysis of Growth Rate and Climate Data*

Average rainfall in the statistical 30 years of study (1983 to 2013) is equal to 574.5mm, with a minimum rainfall in 2007 and 2008 equal to 297 mm (Fig 5). As Fig 5 indicates, since 2004 average annual rainfall dropped and from 2006 to 2013 it has been less than average rainfall during the study period. As discussed above, this phenomenon coincides with the period where annual diagonal growth of the tree falls under the average growth rate in the period of study (Fig 6). Study on the influence of average annual temperature on growth status of the trees indicates that during the statistical period of 30 years, the temperature has had a subtle increasing trend (Fig 7). As demonstrated in Fig 8, along with increase of temperature since 2004, annual growth rate has taken a descending trend. However, it should be stated that average annual temperature has not have significant impact on annual growth rate and trend and the maximum temperature during growth season is of crucial importance (Fig 8).

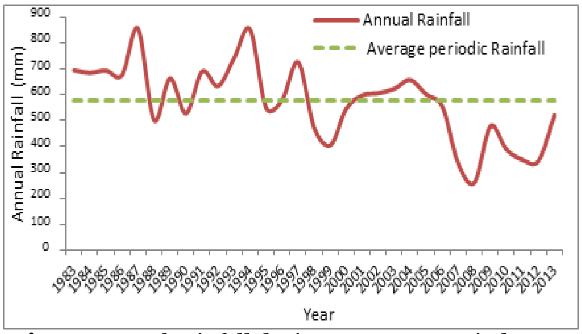


**Fig. 5.** Annual rainfall during a 30-year period.

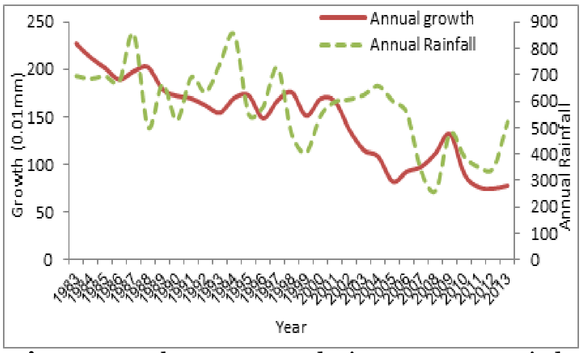


**Fig. 7.** Annual temperature during a 30-year period.

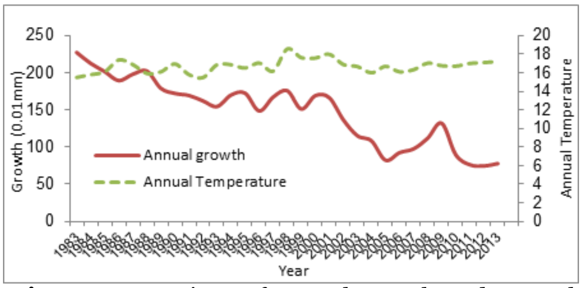


**Fig. 8.** Comparison of annual growth and Annual temperature.

Comparison of results on data concerning number of dusty days during the statistical study period with the data of annual growth rate show that from mid-decade starting from 2001, dust rate has had an ascending trend and aggravated during this period (Fig 9) and along with increase in dust rate the annual growth rate has declined (Fig 10).

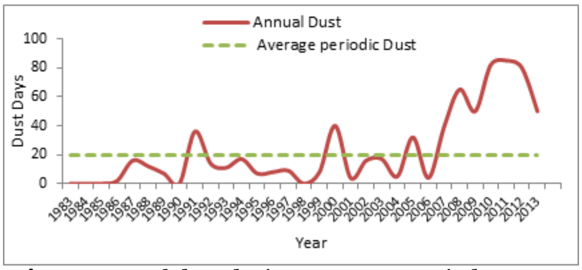


**Fig. 9.** Annual dust during a 30-year period.

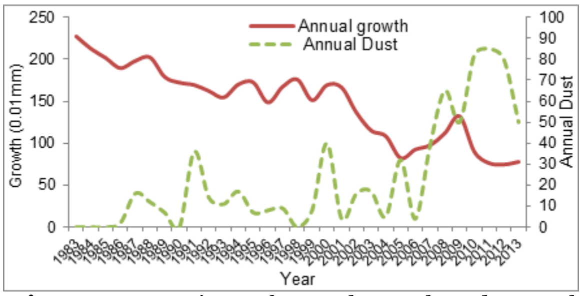


**Fig. 10.** Comparison of annual growth and Annual Dust.

### Discussion

Study of growth rate and annual rings in various trees indicate that since 2001, almost in majority of sample trees, annual growth rate has dropped and reached below annual growth during a 38-year period. However, annual growth rate changes has not always been negative and during some years annual growth has been less than average growth rate but upon dominance of favorable environmental conditions, again annual growth has increased. Of course, it is to be said that sinusoidal oscillation of growth during the beginning of the statistical period studied has been due to oak tree seeding cycle when most of the energy and production of the tree serves towards completion of production process and is less supportive of growth. However, during the last 13 years ending in 2013, annual growth rate has taken a descending trend and low growth has been a dominant feature in successive years, when trees have not been able to compensate the stresses and tensions and have wilted.

Dwyer *et al.*, 1995 in their study on wilt of Eastern Black Oak (*Quercus velutina*) and Scarlet Oak (*Quercus Coccinia*) based on dendrochronology in Ozark Missouri, also concluded that wilting trees which have suffered severe drought in a period of ten years have had less diagonal growth compared to healthy trees. Drobyshev *et al.*, 2006 in their study on death of oak trees in south Sweden also found similar results. Through analysis of annual rings of 44 trees which had recently died, they announced that approximately half of tried oak trees have experienced decline in annual growth and half of dead trees, 4 years before death, have had low growth rate.

Considering the results obtained through comparison of growth and climate data it was discovered that climate changes in the area including low annual rainfall, increase of annual temperature and increased dust during the past decade are factors starting stress in oak trees in the area. Since 2004, annual rainfall has had a descending trend and annual growth has dropped under average growth rate which indicates the impact of rainfall on the commencement of stress on trees. Regarding the impact of average annual temperature on growth rate of oak trees in the areas, similar results are obtained, whereas the impact of this climate variable on reduced growth rate of the trees and eventually their wilt has been less significant and a reason for this might be ecologic balance or tolerance rate of Persian Oak against the parameter of temperature.

On the impact of dust on tree growth rate in the areas it is possible to say that during the statistical period of study, number of dust days has increased and aggravated during the past decade and along with this increase, tree annual growth rate has declined. Obviously before and during dust, tree leaf holes are clocked and hinder photosynthesis which has a crucial role in drying oak trees and it is to say that oak trees have dried after incident of dust during the past decade. Sonesson *et al.*, 2010 also, in their study on the wilt of oak trees in south Sweden, claimed that unfavorable climate change has played an important role in start of wilt phenomenon in trees.

It is to conclude that various factors in different ratios have influenced wilt of oak trees in the study area and Zagros oak trees. Climate factors provoke a situation leading to drying of trees and are known as the starting factors of damage and along with them presence of secondary pests and fungal diseases' pandemic are complementary factors of the damage resulting in drying and wilt process of Persian oak trees in Zagros forests. Denman *et al.*, 2010 and also BabayiKafaki *et al.*, 2011 in their research on wilt of oak trees obtained similar results and claimed that wilt of oak is due to various factors which might be live agents such as insects, fungus or non-living factors such as drought and weak soil.

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