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# THE EFFECT OF CLIMATIC CONDITIONS ON HAZELNUT *(CORYLUS AVELLANA)* YIELD IN GIRESUN (TURKEY)

## Giresun'da İklim Koşulları'nın Fındık (Corylus Avellana) Verimliliği Üzerine Etkisi

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***ABSTRACT***

*In this study the relationship between hazelnut yield and climatic conditions were analyzed. Black Sea Region, Turkey, is one of the most favorable habitat for hazelnut cultivation in the world. Having the highest economic value among various hazelnut cultivars cultivated in this region, Tombul hazelnut finds the optimum conditions- principal of these conditions is the climate one- in Giresun. Therefore, with the assumption that it can be accepted as the most suitable sample for this study, Giresun was selected. The time period between 1993 - 2007 which included reliable data on climate and production was analyzed. Among many factors effective on yield, climatic conditions have a principal role. With this purpose, the special climatic requirements of hazelnut during its each phenological period were examined and their effects on yield were analyzed. This analysis was made in two ways. The first one is the special climatic requirements analysis and the second one is the correlation and simple linear regression analysis. In the former the effect of daily, monthly and annual meteorological data in accordance with hazelnut's special climatic requirements on yield was analyzed year by year. In the latter, the correlation between climatic variables and yield was analyzed and then simple linear regression was performed. According to both analyses, the most considerable climatic variable affecting the yield was determined as temperature.*

***Keywords:*** *hazelnut, climate, correlation and simple linear regression analysis, Giresun (Turkey).*

***ÖZET***

*Bu çalışmada fındık verimliliği ile iklim koşulları arasındaki ilişki incelenmiştir. Fındık yetiştiriciliğinde Dünya'da en uygun alanlardan birisi Karadeniz Bölgesi'dir. Bölgede yetiştirilen fındık çeşitleri içerisinde ekonomik değeri en yüksek olan fındık Tombul fındık olup, en uygun koşulları, özellikle iklim koşullarını Giresun'da bulmaktadır. Bu sebeple çalışma alanı olarak Giresun ili seçilmiştir. 1993 – 2007 dönemine ait güvenilir iklim ve fındık üretimi verileri analiz edilmiştir. Fındık verimliliği üzerinde etkili olan birçok faktör arasında, en önemli faktörlerden birisi iklim koşullarıdır. Bu amaçla, fındığın fenolojik dönemlerinde özel iklim istekleri incelenmiş ve bunların verimlilik üzerine etkileri analiz edilmiştir. Bu analiz iki türlü yapılmıştır. Birincisi özel iklim istekleri analizi, ikincisi korelasyon ve basit lineer regresyon analizidir. Öncelikle, fındığın özel iklim isteklerine bağlı olarak günlük, aylık ve yıllık meteorolojik verilerin verimlilik üzerine etkisi yıldan yıla analiz edilmiştir. Sonrasında, iklim değişkenleri ve verimlilik arasındaki korelasyon analiz edilmiş ve basit lineer regresyon denklemi uygulanmıştır. Her iki analizin sonucuna göre; fındık verimliliğini etkileyen en önemli faktör olarak sıcaklık olarak tespit edilmiştir.*

***Anahtar Kelimeler:*** *Fındık, iklim, korelasyon ve basit lineer regresyon analizi, Giresun.*

## 1. INTRODUCTION

Hazelnut is a type of fruit found in temperate climates and cultivated in regions with humid temperate climate. According to harvests, Turkey, Italy, Spain and USA lead the ranking (FAO, Fiskobirlik 2008) (Figure 1). It finds a favorable habitat in coastal parts of Black Sea of Turkey, Adriatic coasts of Italy, Catalonia region of Spain and Oregon of USA. On the other hand, although it is possible to cultivate it in regions with half-humid climate, it needs irrigation due to lack of precipitation. Having favorable characteristics in terms of climatic conditions, Black Sea coastline is natural habitat of hazelnut and its climax plant is hazelnut. It can be cultivated economically in agricultural lands up to a height of 750 m along this coastline. These agricultural lands are divided into three zones on the basis of height above sea-level: 1.) "coastal zone", (0 - 250 m), 2.) "middle zone", (251 - 500 m) 3.), "high zone" (501 - 750 m). The first one of these zones has the most favorable conditions for cultivation. The more the height is, the less the yields are. Changing climatic conditions above 750 m limit the cultivation of hazelnut. Along this coastline, cultivation of hazelnut is carried out in plantations as monoculture and total production in the region has a 75 % share in world's production of hazelnut (FAO, Fiskobirlik 2008) (Figure 1).

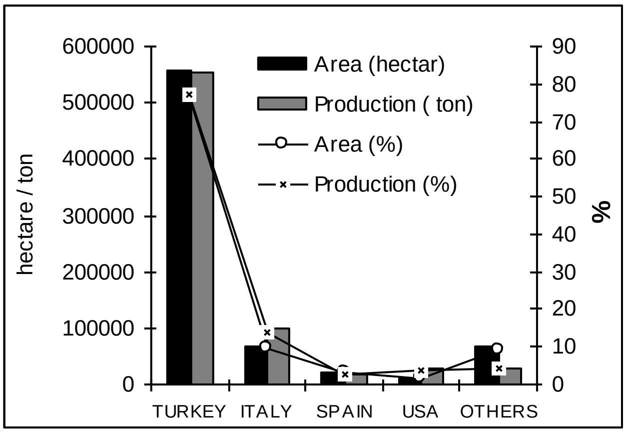


***Figure 1.*** *Area (hectar) and production (ton) of hazelnut in the world (1993 – 2007)*

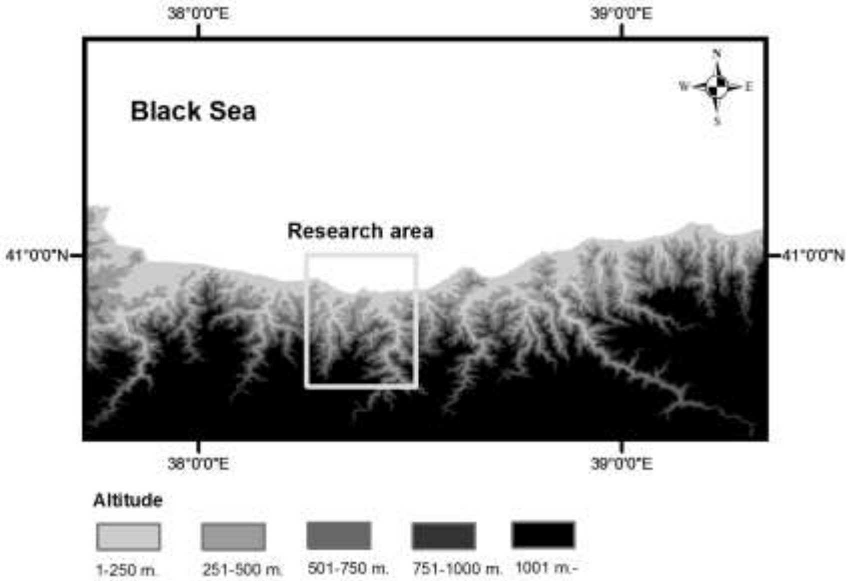


***Figure 2.*** *Location and altitude map of Giresun*

In this amount of production, Tombul hazelnut cultivar, which grows in Giresun, is the major commercial hazelnut cultivar in Turkey and subject to foreign trade in world markets (Köksal 2002). Therefore, the region Giresun was determined as field of study. This region is situated in the Black Sea, in northeastern of Turkey (Figure 2).

Climate is a natural factor which has a great control over the formation of geographical environment and human life. Agricultural activities are one of the most significant areas within the framework of adaptation of several human activities to climatic change (IPCC 2007). Climatic conditions have an impact particularly on cultivation and yield of crops (Szenteleki et al., 2012, Gaál et al. 2011, Adams et al. 2001, Mall et al. 2006, Kaymaz & Ikiel 2004, Ustaoglu, 2010). Thus, the relationship between agricultural activities and climatic conditions has been the subject of many studies. These studies were performed for different crops and regions. The result concluded from studies both for annual crops (Dilley 1997, Alexandrov and Hoogenboom 2000, 2001, Sun et al. 2007, Ramos et al. 2008 Tebaldi and Lobell 2008) and perennial crops (Challinor et al. 2003, Lobell et al. 2006, Lobell and Kimberley 2007, Peiris et al. 2008) is that climatic conditions have a great effect on crop yield from one year to another. Also in hazelnut growing, production is related to environmental and particularly climatic conditions with also type, technical and cultural factors (Beyhan and Odabaş 1996a). Therefore, an analysis will be done into yield of hazelnut, which is both economically valuable and important source of income of many farming families (68.303) (TMARA, 2007), on the basis of climatic conditions. Here, the objective of this study is to analyze the effect of climatic conditions on hazelnut yield in Giresun, where hazelnut finds the optimum climatic conditions for cultivation, and to develop a perspective on the state of hazelnut farming up to present and its state in the future within a possible climatic change on the basis of production and yield.

## 2. DATA

### 2.1. Hazelnut Data

The data on production of hazelnut (ton) and area (number of tree bearing fruit, number of tree not bearing fruit) was taken as raw data from 15 - year period from 1993, when it started to be recorded reliably, to 2007 (TSI, 2008). It was converted into a usable form through MATLAB 7.0 program. The yield data which used for relationship between climate and yield was computed by dividing total yearly production by the number of tree bearing fruit Eq. (2) (Figure 3).

$$\text{Yield (kg/ number of tree bearing fruit)} = \frac{\text{production (ton)} * 1000}{\text{number of tree bearing fruit}} \quad (2)$$

The data on production of hazelnut started to be recorded by both private and public sector in earlier years, but no real data could be obtained since the hazelnut is a commercial crop and because of the fact that as the production decreases, the price increases or vice versa.

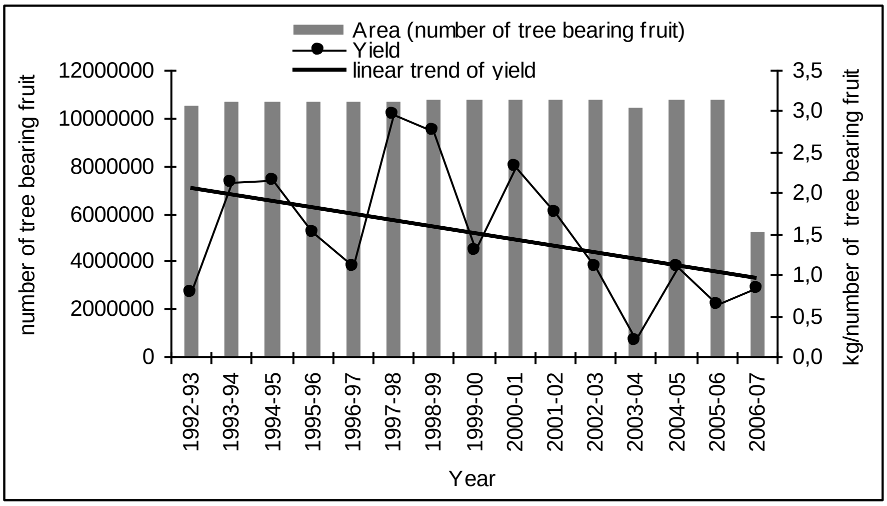


***Figure 3.*** *Area (number of tree bearing fruit) and yield (kg / number of tree bearing fruit) in Giresun (1993 – 2007)*

### 2.2. Climatic Data

Daily meteorological data regarding the Giresun was obtained as raw data during the same period with the production data, 1993 - 2007

(TSMS 2008). A database on mean, minimum, maximum and minimum ground temperatures, precipitation and relative humidity was developed on the basis of climatic requirements of hazelnut and made a homogeneity analysis on it. Correlation coefficient between climate data of Giresun, the research area, and that of Ordu and Trabzon provinces which have the same geographical characteristics was examined. Following this examination, it was accepted that the climatic data had an adequate homogeneity between 70 % - 90 % correlation. Finally, the data was arranged as daily, monthly, periodically and yearly according to phenological periods of hazelnut via MATLAB 7.0 program. Therefore, through the use of the vegetation year instead of calendar year, the data regarding the period from may of the previous year, when cultivation period of hazelnut starts, to august of next year, the harvest period (e.g. may, 1992 - july, 1993) was converted into an analyzable form.

### 2.3. Special Climatic Requirements of Hazelnut

Hazelnut is a quite selective plant considering its climatic requirements. Unlike other types of fruits in temperate climate, it flowers during winter months. This is the most significant factor limiting the cultivation of hazelnut in many regions (Beyhan and Odabaş 1996a). It can be naturally cultivated under humid temperate climatic conditions (Mehlenbacher 1991). Regions with annual mean temperature of 13 - 16 °C have the most favorable conditions for cultivation. However, such regions must not have a minimum temperature in winter months below -8, - 10 °C and the highest temperature in summer months above 36 - 37 °C. Yet, in order to ensure pollination, such regions should have maximum temperatures exceeding 21 °C for at least three days and, on average, two weeks at the beginning of june (Beyhan and Odabaş 1996a, Tous 2001). Also, total annual precipitation should be over 750 mm. and it should have a regular distribution over months. Moreover, relative humidity should not go down below 60 % during the months june and july (Köksal 2002).

The cultivation period of hazelnut starts in may and ends in july of next year. When hazelnut is approaching to harvest, the first fruits of the next year develop on the same branches. Called as formation of flower bud, loss of leaves, dormancy, flowering / pollination and fertilization / maturity as divided under five periods, the cultivation period lasts throughout the year. During the months may, june, july and august called formation of flower bud period when the first flower buds develop, newly-developed flower buds exist on the same branches with the fruits of last year. During the months november, december called as dormancy period for hazelnuts; following the loss of leaves period during september, october; female flower cluster called as set of female flowers are extremely vulnerable to low temperatures. Unlike other fruit trees, hazelnut flowers in winter corresponding to the months january, february, march and april. During this period called as flowering / pollination, it is necessary that minimum temperature and minimum ground temperature should not drop below 0 °C too frequently (Beyhan and Odabaş 1996a).

The hazelnut enters the fertilization / maturity period at the end of may and at the beginning of june. During this period, the embryo which is ovarian tissue develops and fertilization occurs. Towards the middle of july the hazelnut completes development of kernel and it bears fruit (Beyhan and Marangoz 2007). As of the mid of august, hazelnuts start to be harvested in Giresun.

Some previous researches on hazelnuts stated that this plant losses a yield caused by climatic conditions as well as several technical, cultural, genetic and physiological factors (Özbek 1978, Beyhan and Odabaş 1996a). The leading factors of yield loss are female cluster drop in spring months and cluster drop in summer months. According to its intensity and frequency, the frost occurs in dormancy period of hazelnuts during spring month cause to fall of flowers, i.e. future fruits, of hazelnuts. This frost-induced situation is called female cluster drop and cause yield loss (Beyhan 2000). In summer months june and july, known to be the fertilization / maturity period for hazelnuts, absolute maximum temperatures, irregular or inadequate precipitation and humidity deficit cause water stress, the situation in which the water balance of hazelnut is break down. Therefore, hazelnut clusters which are ready to harvest are burned and fall out due to drought. This drought - induced condition is called cluster drop and causes yield loss. In addition to this, if temperature is not seen adequate during the pollination period, the pollination doesn’t occur and blank nut appear. Analyzing the relationships between the blank nut and climatic conditions arithmetically, Silva et al. (1996) stated, according to the results of their eight-year study, that photosynthesis increases when temperature values, light exposure and relative humidity conditions in may and june are high and therefore the blank nut decreases (Beyhan and Marangoz 1999). Also, it is determined that hazelnut production has a periodicity. Therefore, it is understood that it yields plenty of fruits one year and fewer fruits another year. It is thought that this situation is determined by particularly climatic conditions as well as other factors (Beyhan & Odabaş 1996b).

## 3. METHOD

Crops have different responses to climatic changes. Since annual crops are not too selective about their climatic requirements, their responses to climatic changes, i.e. increases or decreases in its yield, are not much pronounced. However, perennial crops are rather selective about their climatic requirements; they are more sensitive to climatic changes. As known, while annual crops can be cultivated in many parts of the world, perennial crops can be cultivated in more limited parts. Most of crops modeling developed for evaluation of climatic effects has been focused on annual crops so far (Lobell and Kimberley 2007).The reason for this is that fruit trees form new shoots each year and they are more sensitive to climatic variability. Therefore, prediction models and projections developed for fruit trees are rather limited. These models also don't capture the extremes which are important factors for growing. For this purpose, the effect of climatic conditions on yield was analyzed on the basis of a new concept called "special climatic requirements". The concept "special climatic requirements" refers to optimum climatic conditions required for a plant to be cultivated in a region during its cultivation period and minimum and maximum limit values of climatic conditions a plant can tolerate. This study was examined the climatic conditions, mean (Tmean), maximum (Tmax), minimum (Tmin) and minimum ground temperatures (Tminground), monthly and annual total precipitation (Ptotal), monthly and annual mean relative humidity (RHmean) effective on hazelnut yield, a perennial crop, and changes in its yield from one year to another on the basis of special climatic requirements. This analysis was performed in two ways. The first one is the analysis of special climatic requirements and the second one is correlation and simple linear regression analysis.

For the analysis into special climatic requirements, firstly, the phenological periods and cultivation conditions of hazelnut were determined. The special climatic requirements (temperature, precipitation and relative humidity) required for hazelnut were determined according to the detailed literature review for each phenological period and annual average. The suitability of climatic conditions prevailing in the region was queried for special climatic requirements of hazelnut on daily, monthly, periodically and yearly basis. Therefore daily extremes weren't mask which can have important effect on yield.

Secondly, the correlation between climatic conditions and hazelnut yield was examined for indicating positive or negative, strong or weak effect on yield and then simple linear regression was performed according to correlation results. The effect of climatic conditions on hazelnut yield was found out through regression. Before performing correlation and regression, the trend in data on hazelnut yield was determined (Figure 2). To achieve that Eq. (1) was applied and the yield data was detrended so as to obtain a more reliable relationship between climate and yield (Alexandrov and Hoogenboom 2001) (Figure 4 ) Eq. (1)

detrended yield data = (yield data - trend of yield data) (1)

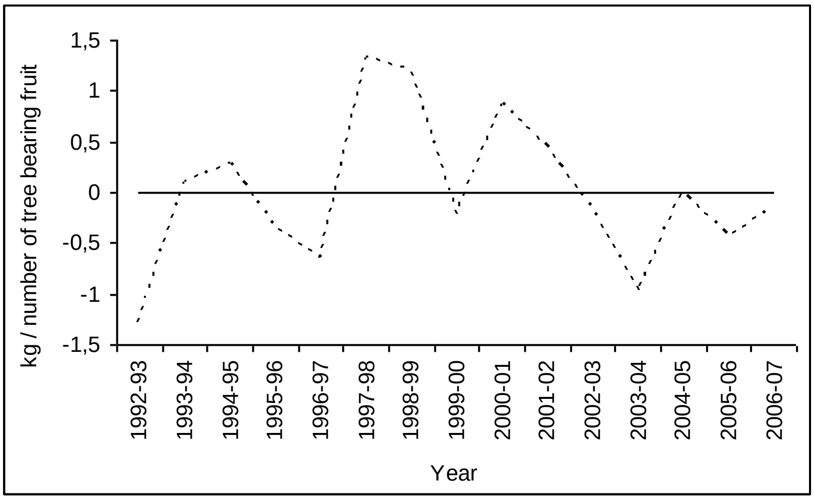


***Figure 4.*** *Detrended yields of hazelnut (kg / number of tree bearing fruit) in Giresun (1993 -2007)*

Because the fluctuations in yield trend from one year to another are affected also by the use of fertilizer as well as factors like management practices or garden care (TMARA, 2007). As a matter of fact, it is thought that the main reason for abrupt increases in yield during the periods 1997 - 1998 and 1998 - 1999 is use of extreme fertilizer. According to fertilizer - hazelnut parity recorded during the years 1980 - 2005, these years determined as the most use of extreme fertilizer year. After the detrended process of yield data, the correlation between special climatic requirements of hazelnut during cultivation period and hazelnut yield in that year was examined, at the statistically meaning level of $p<0.01$ and $p<0.05$ with using parametric Pearson correlation coefficient and non parametric Spearman rank correlation (Sneyers, 1990). Correlation was carried out in order to determine whether the effect of climatic conditions on hazelnut yield is positive or negative. Simple linear regression was performed on variables, whose correlation coefficient proves above + - 50 %. The most significant climatic condition affecting hazelnut yield was determined according to the result obtained from simple linear regression at the statistically meaning level of $p < 0.01$ and $p < 0.05$.

## 4. RESULTS AND DISCUSSION

In order to analyze the effect of climatic conditions prevailing in Giresun on cultivation of hazelnut, firstly, an evaluation of climatic conditions and their long year averages in the region was made according to special climatic requirements of hazelnut. Upon this evaluation, Tmean was found 14.7 °C (Table 1).

***Table 1.*** *Annual mean (Tmean), minimum (Tmin), maximum (Tmax) and minimum ground temperatures (Tminground) (°C), annual precipitation (Prep) (mm.), annual mean humidity (RHmean) (%) between, 1993 - 2007 in Giresun.*

| | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tmean | °C | 7,6 | 6,9 | 8,4 | 11,5 | 15,6 | 20,2 | 23,3 | 23,9 | 20,5 | 16,8 | 12,2 | 9,3 | 14,7 |
| Tmin | °C | 5,3 | 4,3 | 5,6 | 8,7 | 13,2 | 17,4 | 20,6 | 21,3 | 18,0 | 14,4 | 9,7 | 6,9 | 12,1 |
| Tmax | °C | 10,4 | 10,1 | 11,7 | 14,9 | 18,6 | 23,1 | 26,1 | 26,9 | 23,6 | 19,8 | 15,3 | 12,4 | 17,8 |
| Tminground | °C | 4,2 | 3,2 | 4,7 | 8,0 | 12,1 | 16,4 | 19,8 | 20,6 | 17,2 | 13,6 | 9,0 | 6,0 | 11,2 |
| Ptotal | mm | 121,6 | 93,6 | 98,2 | 88,0 | 64,8 | 71,4 | 54,0 | 91,7 | 142,2 | 189,1 | 137,2 | 131,1 | 1282,8 |
| | % | 9,6 | 7,4 | 7,7 | 6,9 | 5,1 | 5,6 | 4,3 | 7,2 | 11,2 | 14,9 | 10,8 | 10,3 | 100 |
| RHmean | % | 68,0 | 67,8 | 70,9 | 75,0 | 78,0 | 75,1 | 76,1 | 75,4 | 74,5 | 74,1 | 68,7 | 67,2 | 72,6 |

The region is within limit values in terms of temperature conditions (13 - 16 °C). It is observed that Tmin and Tminground throughout the year are close to Tmean (Figure 5). It indicates that particularly the winter season is temperate and frosts are rare in the region. It is observed that Tmax are over 21 °C in june but don’t have very high values in july and august (< 36 - 37 °C) (Figure 6).

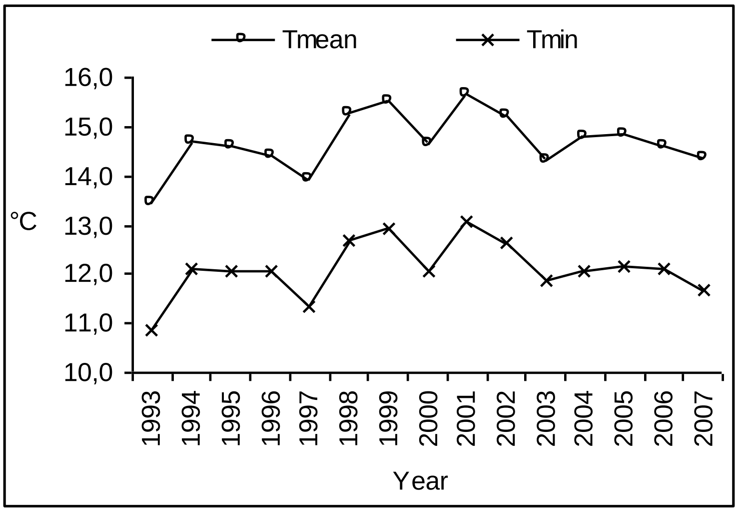


***Figure 5.*** *Annual mean (Tmean) and minimum (Tmin) temperature*

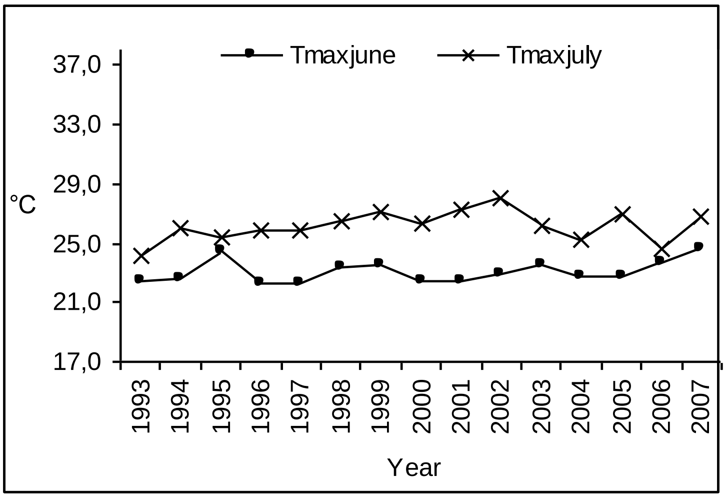


***Figure 6.*** *Annual june (Tmaxjune) and july (Tmaxjuly) maximum temperatures*

When analyzed in terms of precipitation and humidity conditions, it was determined that the region is quite above the limit values with Ptotal of 1282.8 mm. and RHmean of 72.6 % (Table 1, Figure 7 - 8) and the great majority of Ptotal, 93.4 %, consists of precipitation below 25 mm indicating regularity (Table 2).

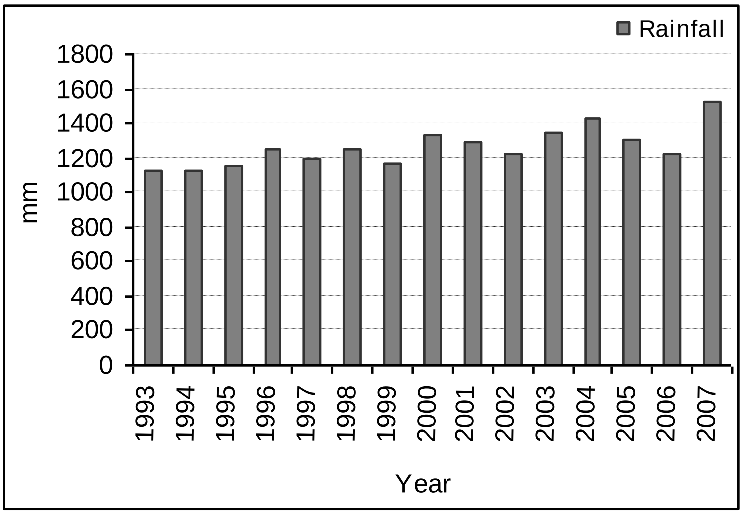


***Figure 7.*** *Annual total precipitation*

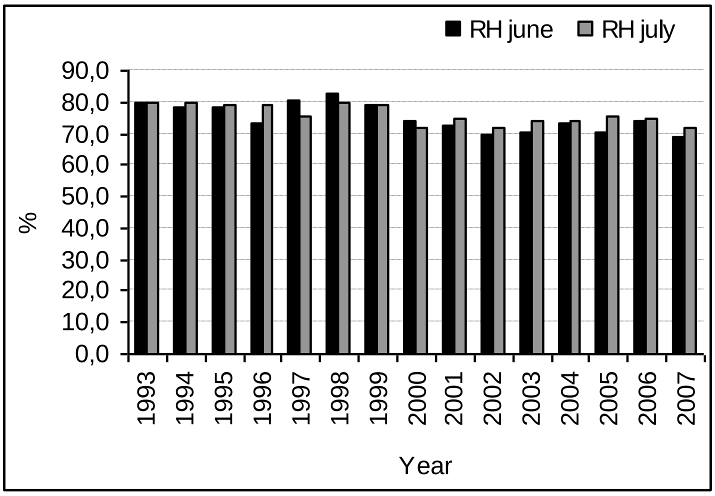


*Figure 8. Annual mean june (RHjune) and july (RHjuly) relative humidity*

***Table 2**. Classification of cumulative precipitation between 1993 - 2007 in Giresun.*

| | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 - 25 | Absolute | 508 | 501 | 563 | 556 | 517 | 420 | 366 | 357 | 430 | 453 | 440 | 484 | 5595 |
| mm | % | 93,9 | 97,3 | 98,1 | 97,0 | 98,1 | 94,8 | 94,6 | 89,9 | 90,9 | 85,2 | 86,3 | 93,1 | 93,4 |
| 25.1 - 50 | Absolute | 32 | 14 | 10 | 17 | 9 | 19 | 16 | 30 | 30 | 58 | 57 | 32 | 324 |
| mm | % | 5,9 | 2,7 | 1,7 | 3,0 | 1,7 | 4,3 | 4,1 | 7,6 | 6,3 | 10,9 | 11,2 | 6,2 | 5,4 |
| 50.1 - 75 | Absolute | 1 | 0 | 1 | 0 | 1 | 4 | 1 | 6 | 12 | 19 | 13 | 4 | 62 |
| mm | % | 0,2 | 0,0 | 0,2 | 0,0 | 0,2 | 0,9 | 0,3 | 1,5 | 2,5 | 3,6 | 2,5 | 0,8 | 1,0 |
| 75.1 - 100 | Absolute | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 1 | 1 | 0 | 0 | 8 |
| mm | % | 0 | 0 | 0 | 0 | 0 | 0 | 0,8 | 0,8 | 0,2 | 0,2 | 0,0 | 0,0 | 0,1 |
| > 100 | Absolute | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 3 |
| mm | % | 0 | 0 | 0 | 0 | 0 | 0 | 0,3 | 0,3 | 0,0 | 0,2 | 0,0 | 0,0 | 0,1 |
| Total number | | 541 | 515 | 574 | 573 | 527 | 443 | 387 | 397 | 473 | 532 | 510 | 520 | 5992 |
| of rainy days | | 9,0 | 8,6 | 9,6 | 9,6 | 8,8 | 7,4 | 6,5 | 6,6 | 7,9 | 8,9 | 8,5 | 8,7 | 100 |

Both special climatic requirements and correlation / simple linear regression were performed. Based on the results summarized in Figure 5 and Table 1 - 4, the following relationships appear most significant. The observed relationships were discussed below, based on literature reviews and discussions with crop experts. When the effect of extreme meteorological values related to special climatic requirements of hazelnut on yield from one year to another is assessed, the results are as follows Table 3:

***Table 3.*** *Special climate requirements of hazelnut and the state in the research area between 1993 - 2007 in Giresun.*

| Special Climate Requirements | Unit | Limit Values | Phenologic Perid | State in Research Area | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Mean | Maximum |
| Tmean | °C | 13 - 16°C | Annual | 13.4 * 1993 | 14,7 | 15,6 |
| Tmin | °C | > 0 °C | Flowering / Pollination | -2 * 2004 | 4.4 | 10.8 * 1998 |
| Tmax | °C | < 36 - 37 °C | Fertilization / Maturity | 32.5 * 2007 | 25.5 | 22.4 * 2001 |
| Tminground | °C | > 0 °C | Flowering / Pollination | -3.6 * 2004 | 11.2 | 24.4 * 1998 |
| Ptotal | mm | > 750 mm | Annual | 1128.6 * 1993 | 1282.8 | 1433.8 * 2004 |
| RHmean | % | > 60 - 70 % | Fertilization / Maturity | 69 * 2007 | 74.6 | 82.9 * 1998 |

•During march, april and may of 1993 – 1997 – 2000 – 2003 and 2004, the flowering / pollination period of hazelnut occurred frosts with the drop of absolute Tmin below 0 °C. This situation is thought to have led to female cluster drop and yield loss. Particularly the frost occurred in march ( - 2 °C) and april ( - 0.2 °C, - 0.8 °C) of 2004 caused 85 % decrease according to the average in yield (Figure 9).

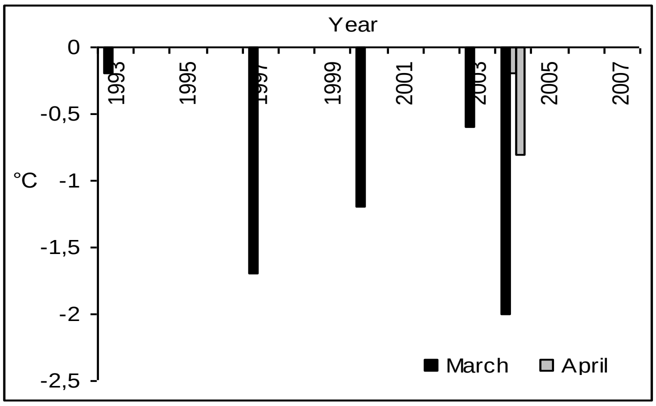


***Figure 9.*** *March and april absolute minimum temperatures (Absolute Tmin)*

•The fact that when daily absolute Tmax exceeded over 30 °C, monthly Ptotal was less than 25 mm. and monthly RHmean was below 70 % caused water stress and cluster drop during the fertilization / maturity period of hazelnut in june and july of 2002 and 2007. This reduced the hazelnut yield during these years (Figure 10). Particularly, in june Tmax (32.5 °C), june RHmean (69 %) and monthly Ptotal 24 mm. of 2007 caused drought and 45 % decrease according to the average in yield (Figure 10).

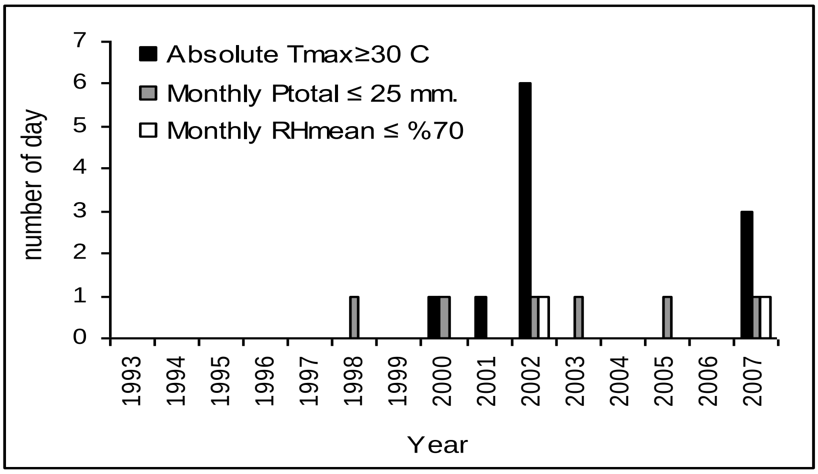


***Figure 10.*** *Number of days daily absolute maximum temperatures exceeded 30°C in june and july (Absolute Tmax > 30°C), monthly mean minimum rainfall was less than 25 mm. (Pmin < 25 mm.) and monthly mean relative humidity was below 70 % (RHmean < 70 %)*

- Although no extreme meteorological event is encountered, the year 1993 was to be the year with lowest Tmean and Ptotal, was also found to be a year with rather low yield.

- Although no extreme meteorological event is encountered, the year 1998 was to be the year with highest Tmin and RHmean, was also found to be the year with quite high yield.

- As a result of this assessment, it is thought that female cluster drop occurred in spring months might have resulted from absolute Tmin, i.e. frosts, and cluster drop occurred in summer months from drought. Then, it is understood that absolute Tmin and Tmax, inadequate precipitation and therefore humidity deficit among climatic conditions are effective throughout the cultivation period.

We also compared our findings with phenology records from TSMS Agro meteorological unit, existing reports from Hazelnut Research Institute and Fiskobirlik (Union of Agricultural Cooperatives for the Sale of Hazelnut). For example, frost damages in march and april of 2004 was recorded in TSMS Agro meteorological unit archives. Because of the hazelnut is commercial crop, every year in each phonological period, particularly flowering / pollination period, field survey is done by Fiskobirlik. They count female flower cluster for estimating the production. Every year each female flower cluster occur cluster in fertilization / maturity period. If there is no damage by climate, their estimate is generally correct. But if in a year there is frost damage in flowering / pollination period, it means there is female cluster drop and they compute again according to the percent of damage. And also other critical period, in fertilization / maturity, if there is water stress with high temperature it means all cluster is burned and then drop, and they computed again the possible production.

The following are results obtained from the relationship between climate and yield formed according to correlation coefficient and simple linear regression during phenological periods of hazelnut and annual average on the basis of its special climatic requirements (Table 4):

- The parametric Pearson correlation coefficient, non parametric Spearman rank correlation and simple linear regression relation between monthly meteorological values regarding Tmean, Tmin Tmax, Ptotal and RHmean, all of which are special climatic requirements of hazelnut and the amount of yield for each month corresponding to phenological periods of hazelnut and annual average were examined.

- According to correlation and regression performed in order to determine the relation between the climatic conditions and yield, the most significant positive correlation throughout the phenological periods of hazelnut was determined to be the flowering / pollination and fertilization / maturity period of hazelnut and annual average at the statistically meaning level of $p < 0.01$ and to be between 58 % and 85.8 % with temperature (Tmean, Tmin Tmax).

| 7 | | | V | VI | VII | VIII | P1 | IX | X | P2 | XI | XII | P3 | I | II | III | IV | P4 | V | VI | VII | P5 | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit | | Formation of Flower bud | | | | | Loss of Leaves | | | Dormancy | | | Flowering / Pollination | | | | | Fertilization / Maturity | | | | |
| Tmean | °C | R_P | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.682**** | *n.s* | *n.s* | **0.768**** | **0.748**** | **0.837**** |
| | | R_S | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.54*** | *n.s* | *n.s* | **0.73**** | **0.76**** | **0.75**** |
| | | R² | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.465**** | *n.s* | *n.s* | **0.590**** | **0.560**** | **0.700**** |
| Tmax | °C | R_P | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.590*** | *n.s* | *n.s* | **0.697**** | **0.572*** | **0.746**** |
| | | R_S | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.60 *** | *n.s* | **0.71**** |
| | | R² | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.348*** | *n.s* | *n.s* | **0.486**** | **0.328*** | **0.557**** |
| Tmin | °C | R_P | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.697**** | *n.s* | **0.592*** | **0.764**** | **0.853**** | **0.858**** |
| | | R_S | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.58**** | *n.s* | *n.s* | **0.78**** | **0.78**** | **0.80**** |
| | | R² | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | **0.486**** | *n.s* | **0.350*** | **0.583**** | **0.727**** | **0.736**** |
| Ptotal | mm | R_P | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* |
| | | R_S | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* |
| | | R² | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* |
| RHmean | % | R_P | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* |
| | | R_S | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* |
| | | R² | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* | *n.s* |

| | | | |
|---|---|---|---|
| *p<0.05 | I : January | VII : July | P1: Mean of First Period (Formation of Flower bud) |
| **p<0.01 *n.s: non significant* | II : February | VIII : August | P2: Mean of Second Period (Loss of Leaves) |
| R_P Pearson correlation coefficient | III : March | IX : September | P3: Mean of Third Period (Dormancy) |
| R_S Spearman correlation coefficient | IV April | X : October | P4: Mean of Fourth Period (Flowering / Pollination) |
| R² Linear Regression | V : May | XI : November | P5: Mean of Fifth Period (Fertilization / Maturity) |
| | VI :June | XII : December | |

***Table 4:*** *Relationship between climatic conditions and hazelnut yield according to correlation coefficient and simple linear regression in phenologic periods of hazelnut (*p < 0.05, ** p < 0.01, ns: non significant).*

According to simple linear regression performed in order to present this reason, the most significant relation was determined to be again the fertilization / maturity period of hazelnut and annual average at the statistically meaning level of $p < 0.01$ and between 46.5 % and 73.6 % with temperature parameters (Tmean, Tmin Tmax). According to the result obtained from this assessment, changes in temperature conditions during particularly fertilization/maturity period of hazelnut when they complete their development of kernel are quite effective on yield.

- Also over the whole year temperature conditions (annual Tmean, Tmax, Tmin) annual average, effective on the yield. At this time all temperature variables have similar results, because they are highly correlated in each other. Of course, temperature conditions are effective on yield also during other periods; however, the fertilization / maturity period was determined to be the most critical period according to assessment of long years. On the other hand, it is known that low minimum temperatures during winter and spring months have a negative impact on hazelnut flowers. Yet, since no regression could be performed with absolute meteorological values, the effect of extreme meteorological events isn't reflected on this relation.

- Correlation and regression could not find any effect caused by precipitation and humidity conditions on yield except for temperature parameters. That is because total precipitation (1282.8 mm) and humidity conditions (72.6 %) prevailing for long years are quite above precipitation and humidity limit values – minimum 750 mm and minimum 60 % respectively- specified for climatic requirements of hazelnut. If they were close to or below the limit values, then we might be able to explore a correlation or regression relationship. Therefore, any effect of fluctuations in precipitation and humidity could not be detected on yield.

## 5. CONCLUSIONS

This study has analyzed the effect of climatic conditions on yield. For this purpose, Giresun in Black Sea Region, Turkey, where cultivation of hazelnut is carried out naturally and economically was determined as field of study in order to analyze the effect of climatic conditions directly. According to the analysis of special climatic requirements, during march, april and may of 1993 – 1997 – 2000 – 2003 and 2004, the flowering / pollination period of hazelnut occurred frosts with the drop of absolute Tmin below 0 °C. This situation is thought to have led to female cluster drop and yield loss. Particularly the frost occurred in march ( - 2 °C) and april ( - 0.2 °C, - 0.8 °C) of 2004 caused 85 % decrease according to the average in yield. The fact that when daily absolute Tmax exceeded over 30 °C, monthly Ptotal was less than 25 mm. and monthly

RHmean was below 70 % caused water stress and cluster drop during the fertilization / maturity period of hazelnut in june and july of 2002 and 2007. This reduced the hazelnut yield during these years.

Particularly, in june Tmax (32.5 °C), june RHmean (69 %) and monthly Ptotal 24 mm. of 2007 caused drought and 45 % decrease according to the average in yield. According to correlation and regression, the most meaningful correlation between hazelnut yield and climatic conditions was determined to be the fertilization / maturity period and annual average at the statistically meaning level of $p < 0.01$ and to be between 58 % and 85.8 % with temperature parameters (Tmean, Tmin Tmax). No correlation was found in other periods. Secondly, in order to confirm the reason of this correlation, simple linear regression was performed. According to this analysis, it was determined to be between hazelnut yield and climatic conditions during the fertilization / maturity period and annual average at the statistically meaning level of $p < 0.01$ and between 46.5 % and 73.6 % with temperature parameters (Tmean, Tmin Tmax). According to the result obtained from these analyses, the fertilization and maturity period covering the months june and july when hazelnut fruits begin to develop and maturity is accepted as the period which is the most vulnerable to temperature. In correlation and regression, no effect brought about by precipitation and humidity conditions, other climatic parameters, was determined on yield except for temperature parameters. The reason for this is that precipitation (1282.8 mm) and humidity conditions (72.6 %) prevailing in the region from one year to another and for long years are quite above precipitation and humidity values – minimum 750 mm and minimum 60 - 70 % - determined for special climatic requirements of hazelnuts. If they were close to or below these limit values specified, then we would have correlation or regression relationship. Therefore, any change in precipitation and humidity can't make their effects felt on yield. We understood from both analyses that temperatures have an important control on yield and drive yield variability of hazelnut.

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