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Impact of Environment Conditions on Grapevine (*Vitis vinifera* L.): To Optimal Production and Sustainability, Achieving Food Security and Increasing the Palestinian Economy

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Abstract

Grapevine (*Vitis vinifera* L.) is one of important economic fruit crops found in Hebron of Palestine. Climate is one of the key controlling factors in grape and wine production. **Materials & Method:** We analyzed grape production in Hebron region, and studied the correlation analyses between productions and climatic, bioclimatic factors. The bioclimate, climatic factors were obtained according to Rivas-Martinez to classification of the earth. However, the independent variables were examined: the bioclimate factors as compensated thermicity index, annual ombrothermic index, water deficit and simple continentality index; and following climate factors: mean monthly temperature, precipitation and soil water reserve. The data used were from one meteorological station of the Palestinian Meteorological Department for the years 1993 to 2009 (16 years), and to the same years of grape production (rain-fed) from the Palestinian Central Bureau of Statistics (PCBS). **Result & Discussion:** When we applied a Principal Component Analysis (PCA), and observed that the Hebron type plots are located at the left of axis 1 during 1999-2004 negatively affected by the bioclimate factors as compensated thermicity index, with a large proportion of the variance explained by axes 1 (76.66%), but precipitation was positive influenced on grape yield for the years (2004-2009), with a proportion of the variance explained by axes 2 (23.34%); Hebron type plots are located at the right of axis1during 1993-1999 positive affected by the bioclimate factor as a simple continentality index and annual ombrothermic index, and climate factors as water deficit, soil water reserve and mean monthly temperature, with a large proportion of the variance explained by axes 1 & 2 (100%). **Conclusions:** Grapes are sensitive climate and the surrounding environment factors, and in order to get a high production and high-quality grapes, mean monthly temperature must be between 15˚C - 20˚C, and 20˚C - 30˚C (27˚C) in the last two months of the maturation process, the value of simple continentality index is 15 - 18, compensated thermicity index is 220 - 350, and annual ombrothermic index is more than 3.

Keywords

Palestine, Hebron, Grapes, Food Security, Economy, Climate

1. Introduction

A grape (*Vitis vinifera* L.; Vitaceae) is a fruit, botanically a berry, of the deciduous woody vines of the flowering plant genus Vitis. The cultivation of the domesticated grape began 6000 - 8000 years ago in the Near East [1]. The earliest archeological evidence for a dominant position of wine-making in human culture dates from 8000 years ago in Georgia [2] [3], Ancient Egyptian, and the West Asia region as Syria, and Palestine where it has existed since the Canaanite era; furthermore ancient Egypt was supplied with Palestinian wine as early as Chalcolithic, the Early and Late Bronze Ages [4], and Egyptians from the 15th century BCE described the wine of Canaan as being "more abundant than water" [4]. However, most *Vitis* species are found in the temperate regions of the Northern Hemisphere in Asia, North America and with a few in the tropics regions in the world, also grapevines are influenced to their surrounding environment with a seasonal variation in production of 30% - 32.5% [5]. Climate is one of the key controlling factors in grape yields [6], affecting the suitability of certain grape varieties to a particular region as well as the type and quality of the wine produced. A few years ago, many researchers in Mediterranean region have studied the relationship between plant production (fruit trees), physiology, plant biology [7]-[26], biodiversity, phytosociological, plant communities and climate-bioclimate factors [8] [9] [10], and biologically, most *Vitis* species have 38 chromosomes (n = 19) [27], while *Vitis rotundifolia* has 40 (n = 20).

According to the Food and Agriculture Organization (FAO), 75,866 km^2 of the world are dedicated to grapes, of which 71% of world grape production is used for wine, 27% as fresh fruit, and 2% as dried fruit. Over the past few years, China, the United States, Turkey, South Africa, Argentina and some European countries such as Spain, Italy and France have been among the world's top grape producers (**Figure 1**) [28].

In Palestine, grapes are the second crop after olives in terms of production and economic importance, and constitute 36.4% of total agricultural land cultivated in

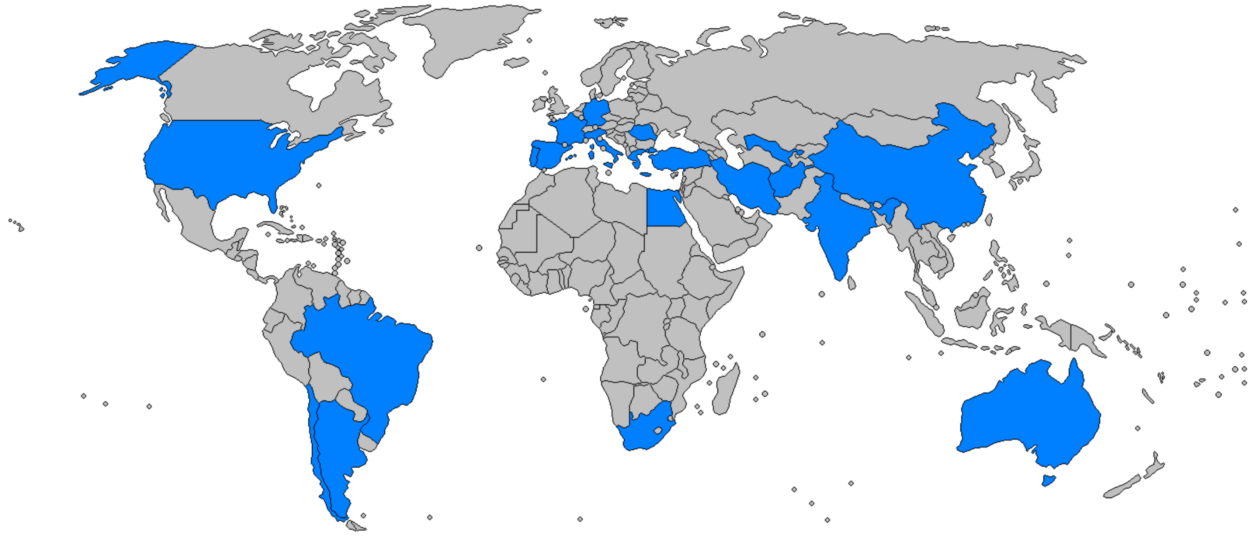

Figure 1. Top 20 grape producing countries (blue color) in 2012 by FAO in the world [28].

the West Bank [29]. The annual total production of grapes is estimated at 50,065 tons in the West Bank, representing 9% of total production of all targeted crops. Hebron region is the highest producer of grapes, constituting 58% of total production, followed by Bethlehem province (27%), and Jenin province (6%) [30].

Analyses of the present work are to: i) analyze the physical factors of Hebron bioclimate; ii) study the relationship between the climate, bioclimate factors and grapes yield to maintain and achieve food security in Hebron of Palestine.

2. Materials & Methods

2.1. Study Area

Hebron is located between longitudes 35˚05'42" east and latitude 31˚32' north in the southern West Bank, 30 km south of Jerusalem, it lies 930 meters above sea level, area of 74.102 km^2 (28.611 sq. mi (Square Miles), it is the largest city in the West Bank, and the second largest in the Palestinian state after Gaza strip. Historically, Hebron (older Hebron) was originally a Canaanite royal city [31], archaeological excavations reveal traces of strong fortifications dated to the Early Bronze Age, covering some 24 - 30 dunams centered around Tel Rumeida, and the city flourished in the 17^{th}-18^{th} centuries BCE before being destroyed by fire, and was resettled in the late Middle Bronze Age [32] [33].

2.2. Data Collection and Analysis

In this work, we analyzed grape production in Hebron Territories, and studied the correlation analyses between production and climatic, bioclimatic factors. The independent variables were examined the following climate, bioclimate factors, climate factors: Mean monthly temperature (T), precipitation (P) and soil water reserve (R); and bioclimatic factors as compensated thermicity index (It/Itc), annual ombrothermic index (Io), simple continentality index (Ic) and water deficit (Df). However, the data used were from one meteorological station of the Palestinian Meteorological Department for the years 1993 to 2009 (16 years), and to the same years of grape production (rain-fed) from the Palestinian Central Bureau of Statistics (PCBS) (**Figure 2**) and (**Table 1**). The study was dependent on the correlation analyses between grape production in one station (Hebron) over sixteen years, and the bioclimate, climatic factors were obtained according to Rivas-Martinez to classification of the earth (http://www.globalbioclimatics.org) [34]-[39]. In addition, we applied the Shapiro-Wilk and Jarque-Bera normality tests [40] [41] [42] [43], the p-value was obtained for the eight variables. Furthermore, we applied an ANOVA linear regression analysis to each of the eight

Figure 2. Location of the meteorological Hebron station.

Table 1. Represents of independents variables (bioclimate factors as annual ombrothermic index, simple continentality index, deficit water, and compensated thermicity index, and climate factors as a mean monthly temperature, precipitation, and soil water reserve); dependents variable is consist of grape production.

Years	T	P	Df	R	It/Itc	Ic	Io	Grape P.
1993-1999	16.7	601	650	430	299	18	3	688
1999-2004	16.5	595	640	417	350	17	3.1	804
2004-2009	16.4	598	610	410	311	17	3.4	847

Productivity: kg/dunum, dunums: 1000 m^2, and P: Production.

variables (independent and dependent variables), the three bioclimatic variables and the four remaining physical variables (climate factors), and the dependent variable as grape production, to obtain principal component analysis and correlation variables were subsequently applied to determine the effect of independent variables on grape production, and using XLSTAT software, statistical analyses were done in these study.

3. Result and Discussion

3.1. Effect of Climate & Bioclimate Factors on Grapes Production

Principal Component Analysis (PCA)

In the general, by using the bioclimatic classification of earth to Salvador Rivas-Martinez to analyses of the climate factors and bioclimatic parameters or variables, and we obtained p-value from the variables studied tended to be below 0.05, the odds are conventionally accepted to value, after application of the Shapiro-Wilk normality test [40] [41] [42] [43]. PCA is mostly used as a tool in exploratory data analysis, covers standard deviation, covariance, eigenvectors and eigenvalues, and others.

Eigenvectors and eigenvalue

Eigenvalues and eigenvectors play a prominent role in the study of ordinary differential equations and in many applications in the physical sciences. Furthermore, calculate of the Eigenvectors and eigenvalue given by: Let M be an $n \times n$ matrix. A is there is a nontrivial solution x of $Ax = \lambda x$. Where, V is an eigenvector of M if $M \times v = \lambda v$, λ is called the eigenvalue associated with v.

For any eigenvectors v of M and scalar a, $M \times av = \lambda av$. Thus you can always choose eigenvectors of length 1:

$$\sqrt{v_1^2 + \cdots + v_n^2} = 1 \quad (1)$$

If M has any eigenvectors, it has n of them, and they are orthogonal to one another, thus eigenvectors can be used as a new basis for an n-dimensional vector space. And $AX = \lambda X$, for some scalar λ. The scalar λ is called an eigenvalue of A, and x is called the eigenvector of A corresponding to the eigenvalue λ.

However, PCA was used to help identify the variables different, using factor extraction with an eigenvalue > 1 after varimax rotation. The results of principal component analysis, including the factor loadings with a varimax rotation as well as the eigenvalues, are tabulated in (**Table 2**), two of the eigenvalues were found to be >1, and the total variance for the two factors is about 76.659%.

Moreover, factor 1 was dominated by climate, bio-climate factor as precipitation (0.031), mean monthly temperature (0.031), water deficit (0.022), soil water reserve (0.037), annual ombrothermic index (0.066) and simple continentality index (0.058) excepted compensated thermicity index (−0.014), with accounts (0.002) of eigenvalue and (76.659%) to the total variance or variability. Factor 2 is a positive dominated by water deficit (0.016), soil water reserve (0.006), but negatively to the rest of factors as compensated thermicity index (−0.057), annual omrothermic index (−0.011) and simple continentality index (−0.009), with accounts (23.341%) of the total variance, as tabulated in Table 2 & Figure 3.

In the other side, when we applied a Principal Component Analysis (PCA), observed that the Hebron type plots are located at the left of axis 1 during (1999-2004) affected negatively by the bioclimate factors as compensated thermicity index, which negatively affected the grape harvest for this occurred in the y-axis negative, with a large proportion of the variance explained by axes 1 (76.66%), but precipitation was a positive effect on grape yield for this occurred

Table 2. Factors of eigenvectors and eigenvalue of the principal component analysis and variables data (dependent and independent variables).

Variables	F1	F2
T	0.031	−0.011
P	0.031	−0.004
Df	0.022	0.016
R	0.037	0.006
It/Itc	−0.014	−0.057
Ic	0.058	−0.009
Io	0.066	−0.011
Grapes production	−0.058	0.010
Eigenvalue	0.002	0.000
Variable (%)	76.659	23.341
Cumulative%	76.659	100

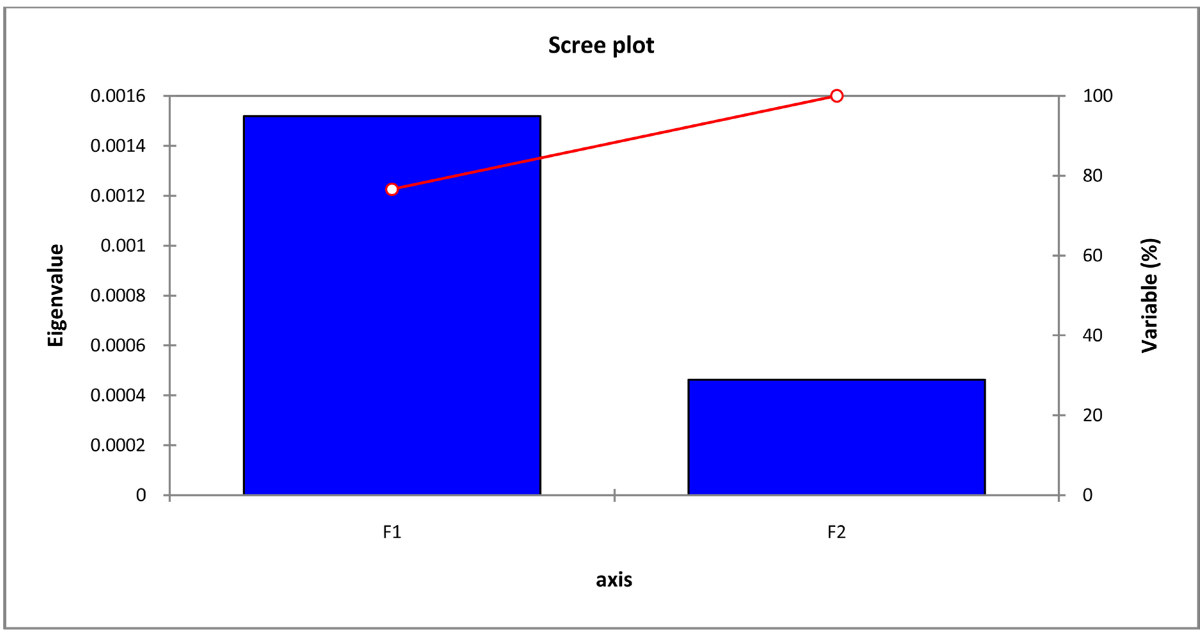

Figure 3. Graphic representing the eigenvalue of the principal component analysis and data variables.

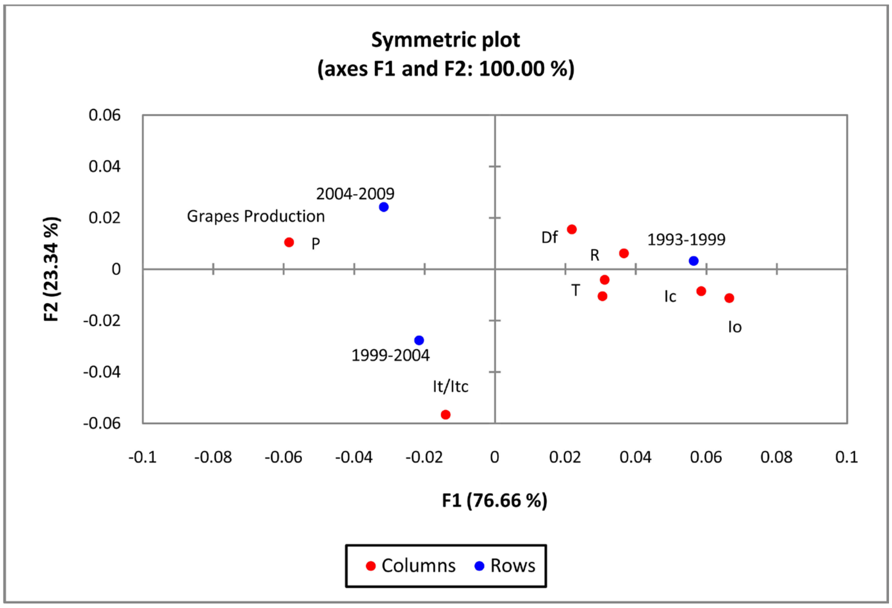

Figure 4. Graphic of principal component analysis using both eigenvectors and biplot axes of a new data points variables.

in the y-axis positive during the year (2004-2009), with a proportion of the variance explained by axes 2 (23.34) Hebron type plots are located at the right of axis1during (1993-1999), which has a positive effect on the grapes yield by bioclimate factors as a water deficit, simple continentality index and annual ombrothermic index, and climate factors as a soil reserve water and mean monthly temperature, also these factors have a positive effect on the grape because it lies in the positive X-axis, with a large proportion of the variance explained by axes 1 & 2 (100%) (**Figure 4**). In this analysis we also observed that the bioclimate, climate factors have a positive effect on the production of grapes except compensated thermicity index, that's means grape are environmental adapted in meso-mediterranean with the value of compensated thermicity index is 210/350, annual ombrothermic index < 3, simple thermicity index is 15 - 18, mean monthly temperature is 15˚C - 20˚C, and with precipitation is 450 - 950 mm., for this, grapevine is one of the plants fruit trees affected by climatic, bioclimatic [7] [10] and biological factors [5].

3.2. Impact of Temperature on Grapes

However, in our study, it is clear that the optimum mean monthly temperature ranging from 15˚C - 20˚C to produce grapes with a high quality, and that optimum mean monthly temperature during the last two months to the maturity of the crop ranges between 20˚C - 30˚C (27˚C), and a high levels are positively correlated to commercial quality, and the temperature between (10˚C - 12˚C) is the starting point of growth and activity of the grape buds. Warmer climates (21˚C - 24˚C), are lead to a high grape sugar and low acidity which makes a very sweet product but lacks to colour and subtlety in some of Europeans countries (southern Spain), Asia countries, southern California and Cyprus, therefore grapes need sustained warmth to ensure a high sugar content in the fruit for convert it into alcohol, also the grape does not ripen properly, leading to too much acidity especially when the climate is cold and the temperature less than 15˚C in the final month of grape maturity.

Furthermore, in the spring when the mean daily temperature reaches 10˚C, rapid growth of shoots takes its places, about seven to eight weeks later, and when mean daily temperature has risen to about 20˚C, flower clusters bloom, whereas when the temperature is low −18˚C grape can be tolerated for short periods whilst in spring - 4˚C will kill young leaves, and - 2˚C will damage emerging flower clusters [44].

Moreover, research has shown that grapevines exposed to temperature consistently around 30˚C had significantly lower concentrations of anthocyanin's compared to grapevines exposed to temperatures consistently around 20˚C [45]. Temperatures around or exceeding 35˚C are found to stall anthocyanin production as well as degrade the anthocyanins that are produced [46]. Furthermore, anthocyanins were found to be positively correlated to temperatures between 16˚C - 22˚C from change of colour of the berries to harvest [47].

In the end, the fruit of the vine, quantity and quality of the resultant wine is influenced by macro-climate to micro-climatic conditions of the vineyard and also the climate change and the weathers events occurring in each growing season. In the fact, we emphasize that the difference in temperature and climate change in recent years, will negatively affect the grapes and plant production, which leads to food shortages and thus a disruption in food security of Palestine in the future, unless there is a strategy to keep the food security plan. Therefore, there should be careful study of climate factors, water sources, soil type, control of pests, plant diseases, and plant varieties, especially fruit trees, in an integrated manner to determine where plants can be grown according to the ability of plants to adapt to increase production and high quality, hereby achieving food security, increase the national output and Palestinian economy.

4. Conclusion

Climate is one of the role controlling factors in grape and grapevine production in Hebron and all over the world. Grapes are sensitive climate and the surrounding environment factors, and in order to get a high production, high-quality grapes and achieve food security, grapes were adapted in places where the mean monthly temperature is between 15˚C - 20˚C, with 20˚C - 30˚C (27˚C) during the last two months of the maturation process, the value of simple continentality index is between 15 - 18, compensated thermicity index is 220/350, annual ombrothermic index is more than 3, and rainfall is between 500 - 900 mm; therefore, grapes are adapted to the Meso-Mediterranean environmental areas in the world. Furthermore, Hebron grapes are the finest grapes in the world, because it has all the best international standards, and the climates of Hebron and Bethlehem are one of the best climatic conditions for the production of high quality grapes in the world, due to the appropriate temperature, soil type and other climatic, bioclimate factors. However, Hebron has a unique biodiversity and climate in the world as: i) mountainous highlands, which are affected by the climate of the Mediterranean basin; ii) the eastern region, which is affected by the climate of the Dead Sea and the Jordan Valley; iii) the western region, which is affected by the climate of the Palestinian coast and the Mediterranean coast; and iv) the southern region, which is affected by the climate of the African Sahara, as Sinai and the Red Sea.

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