



Analysis of physical factors of climate and bioclimate and their effects on almonds production to increase the economy in Hebron area of Palestine

Jehad Mahmoud Hussein Ighbareyeh^{1,2} · Eusebio Cano Carmona² · Ana Cano Ortiz² · Asma Abdel-Rahim Ahmed Suliemeh¹ · Mohammed Mahmoud Hussein Ighbareyeh¹ · Abed Al-Qader Mohammed Daraweesh¹

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Abstract

For the 1993–2009 period, we analyzed the relationship between almond yield and three climatic variables (mean annual temperature, soil water reserve, and precipitation), and four bioclimatic variables (annual ombrothermic index, water deficit, simple continentality index, and compensated thermicity index), for one major Hebron crop (soft and hard almonds). Moreover, we obtained data almond production from the Palestinian Central Bureau of Statistics, while the climate data from the Palestinian meteorological station during the study period from 1993 to 2009, and analysis is it by using bioclimatic classification of the Earth of Salvador Rivas-Martinez to study the relationship between the almond yield and climate and bioclimate factors (variables). The climatic and bioclimate variables of greatest importance to almond were used to develop regressions analysis relating yield to climatic conditions. Hebron was positively affected by annual ombrothermic index, simple continentality index, precipitation, water soil reserve, and mean annual temperature, but negatively affected by water deficit, with a large proportion of the variance explained by axis F1 (72.48%), F2 (22.38%), and axes F1 and F2 (94.86%). However, in order to produce a high amount of almonds and quality, it can be grown in the regions of the mesomediterranean region, with the value of annual ombrothermic index more than 3, compensated thermicity index between 220/220 to 350/350, simple continentality index between 14 and 20, and in areas where the average annual temperature is between 15 and 20 °C.

Keywords Palestine · Hebron · Yield · Climate · Bioclimate · Almonds

Introduction

Almond (*Prunus dulcis* (Mill.) D.A. Webb) is a type of fruit trees, native to the Asia, the Indian regions (Yamuna River) and North Africa, almonds were domesticated in the Early Bronze Age (3000–2000 BC.) as Numeria (Jordan) (Ladizinsky 1999) and Hebron (Palestine), and the fruit found in Tutankhamun's tomb in Egypt (c.1325 BC), maybe

imported from the Levant as Palestine (almond Canaanite), Jordan, and Syria (Zohary and Hopf 2000). Climate of the Mediterranean basin is suitable for planting and producing almonds, it is a hot dry climate in summer and milder winter rain (Ighbareyeh et al. 2014b). In the past 5 years, several studies have been conducted on plant production and on impact of climate and bioclimate factors in the Mediterranean region as Palestine and Spain (Ighbareyeh et al. 2014a, b, c, d; Ighbareyeh et al. 2015a, b, c, d, e, f, g, h, i; Ighbareyeh et al. a, b, c, d; Ighbareyeh et al. 2017a, b; Ighbareyeh and Carmona 2017; Ighbareyeh and Cano Carmona 2018; Ighbareyeh and Carmona 2018; Leiva Gea et al. 2017; Cano Ortiz et al. 2014); all these studies have been shown to confirm that climate plays an important and active role in physiology, plant productivity, and other plant processes.

Global production of almonds amounted to 3.2 million tons in 2016, with the USA contributing 63% of the world's total production, followed by Spain, Iran, and Morocco combined

✉ Mohammed Mahmoud Hussein Ighbareyeh
jehadighbareyeh@hotmail.com

¹ Department of Plant Production and Protection, Faculty of Agriculture, Al-Quds Open University, Abu ktellah Street, Hebron, Palestine

² Department of Animal and Plant Biology and Ecology, Faculty of Experimental Sciences, University of Jaen, Jaen, Spain

by 14% of total production (FAOSTAT 2016). Furthermore, the production of soft almonds (rain fed) was about 169 kg/dunum, while hard almonds were 181 kg/dunum in Hebron Governorate, and the total production of Palestine was about 5257 metric tons in 2006–2007, in contrast with the year 2007–2008, that the production of soft almonds (rain fed) was about 280 kg/dunum, while hard almonds production were 350 kg/dunum, and the total production of Palestine was about 6233 metric tons (PCBS 2007). Therefore, almond production contributed about \$22,113 in the Gross Domestic Product of Palestine during 2007–2008. Since the Canaanite era, Palestine has been a paradise to this day, its rich food forests and fertile land, with unique biodiversity. Our almonds (Almond Canaanite) are the result of these thousands of food and agricultural traditions practiced by Palestinian farmers who are fully integrated into the ecosystem. Else, features almond Canaanite by the large size of 19 kernels per ounce, compared to all other almonds in the world (largest kernels of 23 oz), in addition to the sweet taste, good flavor, and high quality. However, there are two types of almonds in Palestine: sweet and bitter almonds. The areas of almond cultivation in the Hebron governorate include Dora, such as Al-Kom, Deir Samet, Beit Awwa, and Al-Muwarraq; Idna; Halhul; Surif; Beit Ummar; Seir villages and Hebron city as Farsh Al-Hawa, Beit Anoun, and other areas. The aim of this paper is to analyze of climate and bioclimate factors and their effect on almond production in Hebron Governorate in Palestine.

Methodology

Study area

Hebron is a Canaanite city located about 35 km south of the city of Al-Quds Al-Sharif, with a rises 400–1040 m above sea level, coordinates 31.5° N 35.1° E, and the governorate's land area of 997 km². Also, it is famous in the industry, agriculture, and a unique in biodiversity due to the availability of climate, soil, and other factors. The climate of Hebron is a part of Mediterranean basin, with high temperature, low humidity and cloudiness, no rainfall during the summer, the winter is mild, with a mean air temperature of about 4–7 °C during the coldest month (January), mean annual temperature was 15–17 °C, and precipitation was about of 300–600 mm (Ighbareyeh et al. 2014b).

The authors indicated a high values for the proportion of yield variance explained (adjusted $R^2 > 0.5$) for almond yield. In this study, we analyzed data on yield for one Hebron crop from 1993 to 2009 and their relationships with observed climate variations. In the other side, exploratory data analysis was used to identify the most relevant climate variables for the almond, and we were used done the XLASTAT software program.

Plant data sources

County level data on almond, yield (rain fed) and total value for 1993–2009 were obtained from the Palestinian Central Bureau of Statistics (PCBS) (<http://www.pcbs.gov.ps/>). We selected one crop (soft and hard almonds) for analysis, in contrast the same years for climate data from Palestinian meteorological stations.

Climate data sources and analysis

Monthly data on minimum and maximum temperatures (T_{\min} and T_{\max}) and precipitation (P or ppt) were obtained for one station from Palestinian Meteorology Department (<http://www.pmd.ps/englishIndexPage.do>) (Fig. 1): county average monthly climate data record for January 1, 1993–December 31, 2009 for the 16-year time period. Otherwise, statistical analysis included a bioclimatic and climate variables of Palestinian meteorology stations for the period previous by using bioclimatic classification of the Earth of Rivas Martínez (1996); Rivas-Martinez (2004, 2008); Rivas-Martínez (2005); (Rivas-Martinez et al. 1999; Rivas-Martínez et al. 2011, 2017), so climate variables were consisted of mean monthly temperature (T or T_m), precipitation (P or ppt), and soil water reserve (R); and bioclimatic factors or variables as compensated thermicity index (I_t/I_{tc}), annual ombrothermic index (I_o), simple continentality index (I_c), and water deficit (W_{df} or D_f). Annual ombrothermic index:

$$I_o = P_p/T_p \quad (1)$$

where P_p = positive precipitation and T_p = positive temperature (in this case, equivalent to annual precipitation and mean annual temperature divided by 12, as all the months have an average temperature above 0); bimonthly summer ombrothermic index, $I_{s2} = P_{\text{July} + \text{August}}/T_{\text{July} + \text{August}}$; trimonthly summer ombrothermic index, $I_{s3} = P_{\text{June} + \text{July} + \text{August}}/T_{\text{June} + \text{July} + \text{August}}$; and simple continentality index:

$$(I_c) = T_{\max} - T_{\min} \quad (2)$$

where T_{\max} = maximum temperature of the averages of the warmest month of the year, and T_{\min} = minimum temperature of the averages of the coldest month of the year; thermicity index, where applicable compensated thermicity index:

$$I_t/I_{tc} = (T + M + m) * 10 \quad (3)$$

where T = average temperature of the months; T = mean monthly temperature; M = average of the maximum temperature of the coldest month of the year, and m = average of the

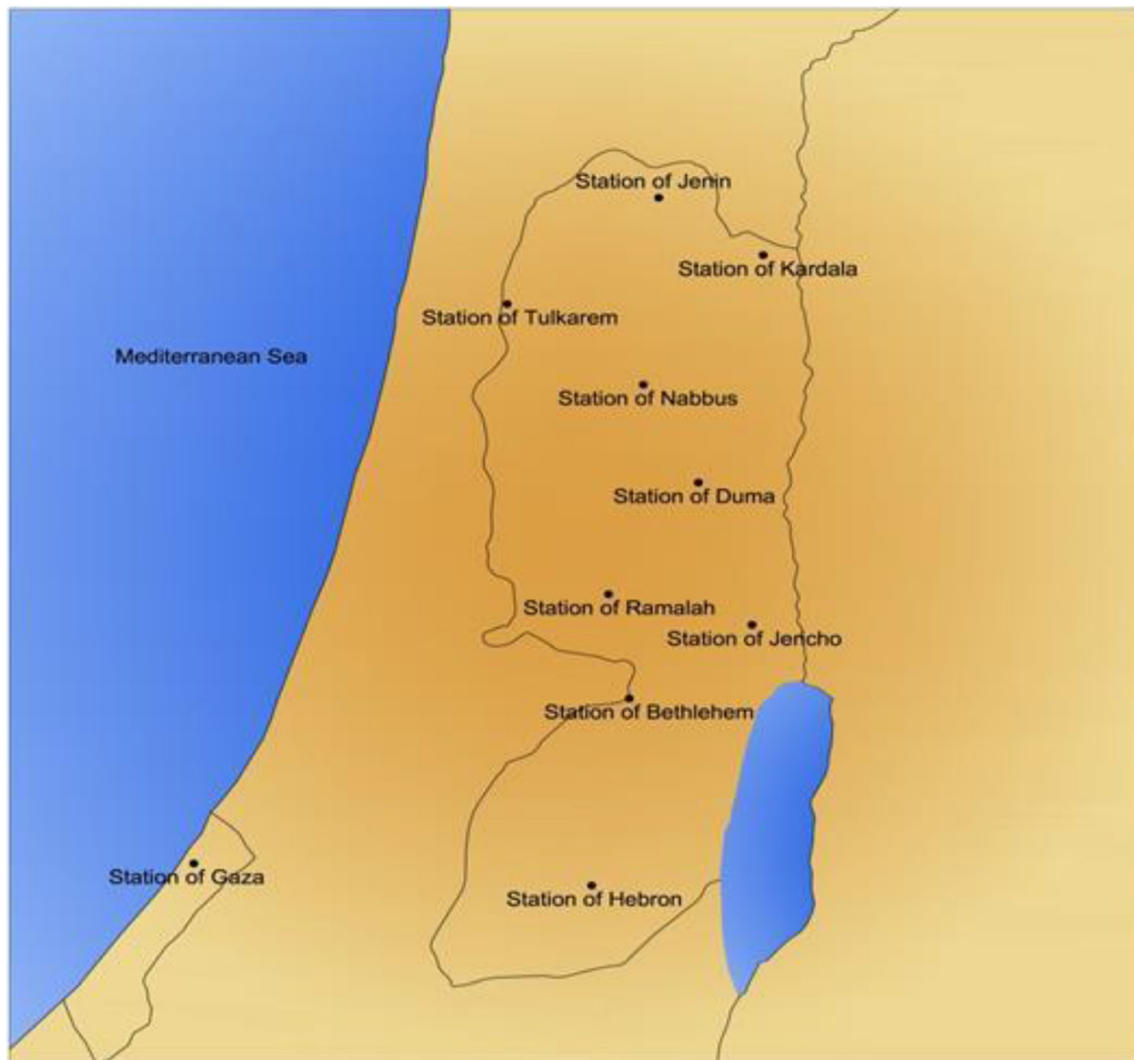


Fig. 1 Palestinian meteorological stations, including Hebron

minimum temperature of the coldest month of the year, and P = precipitation of the months indicated.

Exploratory data analysis

However, we used Jarque-Bera and Shapiro-Wilk normality tests for statistical analysis (Jarque and Bera 1980, 1987; Shapiro and Wilk 1965; Shapiro et al. 1968), the probability value was obtained for the all variables. We applied an analysis of variance (ANOVA) tests analysis to each of the nine independent and dependent variables (almond production: almond hard production, and almond soft production), four bi-climatic parameters, and the three remaining physical variables or climate factors (independent variables) to obtain the principal component analysis, factor loading, standardized coefficient, and coefficient of regression (R^2) to determine the impact of variables on plant yield Table 1.

Where, yield: kilogram/dunum; T or T_m : mean annual temperature; P or ppt: precipitation; R : soil water reserve; D_f or

W_d : deficit water; I_o : annual ombrothermic index; I_c : simple continentality index; and I_t/I_{tc} : compensated thermicity index; AHP: almond hard production and ASP: almond soft production.

Result and discussion

Principal component analysis

Principal component analysis is a mathematical process belonging to the data analysis division, which is to convert a number of interrelated variables into fewer non-interrelated variables. Variables resulting from the conversion process are called main compounds (components or axes). Principal component analysis was invented in by Pearson (1901) to generalize the principles of torque theory of inertia used in mechanics, later it was developed by Harold Hotelling (1933 and 1936), but eigenvalue decomposition in linear algebra,

Table 1 Almond production and meteorology data from 1993 to 2009

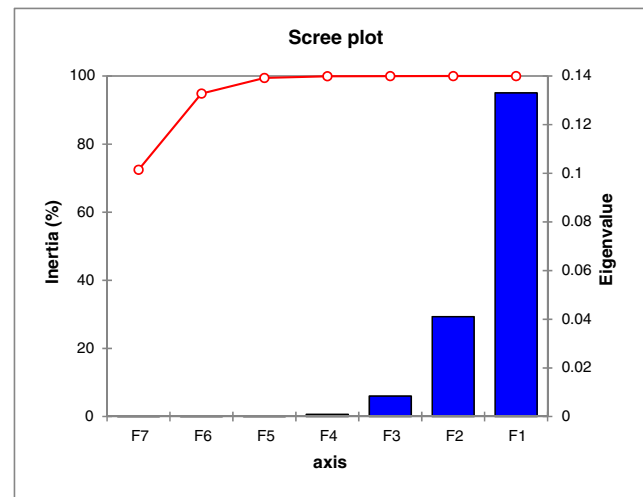
Years	<i>T</i>	<i>P</i>	<i>Df</i>	<i>R</i>	<i>Itc</i>	<i>Ic</i>	<i>Io</i>	A.H. P.	A. S. P.
1993–1998	15.5	596	570	420	390	16.8	3.1	59.3	202
1998–2004	16.6	585	583	471	297	16.1	3.3	204	168
2004–2009	17	596	500	250	311	15.5	3	134.5	255

factor analysis for explaining differences between principal component analysis and factor analysis (Jolliffe 2002) and empirical eigenfunction decomposition by Sirovich (1987).

Factor loading analysis

PCA was used to help identify the true eigenvector depending on multivariate analyses, and after varimax rotation could be used factor extraction with an eigenvalue > 1 . The results of PCA, including the factor loadings with a varimax rotation as well as the eigenvalues, are reported in (Table 2). Seven of the eigenvalues were found to be > 1 and the total variance for the two factors (F1 and F 2) are about (94. 86%) (Fig. 3); we applied the coefficient of correlation between all variables and factors, and constrained the correlation coefficient to a decrease in the range of ± 1 . The $+ 1$ value tells us that the points (x_i, y_i) determine a straight line with a positive slope. A value of $- 1$ tells us that the points (x_i, y_i) specify a straight line with a negative inclination, whereas when the value is 0 shows that there is no correlation of y on x or vice versa, and the probability value obtained from the studied variables tends to be less than 0.05, a value traditionally accepted.

Table 2 shows that the factor 1 was dominated by all climate and bioclimate factors as precipitation (0.16), simple continentality index (0.1227), and annual ombrothermic index (0.1696), except water deficit is a negatively (-0.1804) and accounts for 72.48% of the total variance and cumulative (Fig. 4). Factor 2 is a high correlated by mean monthly temperature (0.120177), compensated thermicity index (0.116436),

**Fig. 2** Graphic representing principal component analysis and factors loading

annual ombrothermic index (0.16977), and simple continentality index (0.1042). Factor 3 is a high correlated by mean annual temperature (0.116675), compensated thermicity index (0.165166), and water deficit (0.048992), but the reset of variables were negatively correlated (Fig. 2). Factor 4 is a positively dominated for all variables, except water deficit and soil water reserve were negatively correlated with the value (-0.04784), (-0.0145) respectively. Factor 5 is a positively correlated for all climate and bioclimate variables, except water deficit, mean annual temperature, and precipitation were negatively correlated with the value (-0.00594), (-0.00114), (-0.01078) respectively. Factor 6 is positively dominated by all variables, except precipitation (-0.00018), soil water reserve (-0.00109) compensated thermicity index (-0.00157). Factor 7 is a dominated by simple continentality index (0.019235), precipitation (0.000323), and water deficit (0.00023), and the factors 2 and 7 have been negatively influenced on the almond hard production, while the factors 4, 5, and 6 on the almond soft production as reported in Table 2.

Table 2 Representing principal component analysis and factor loading

Variables	F1	F2	F3	F4	F5	F6	F7
<i>T</i>	0.2278	0.12018	0.11668	0.02519	-0.0011	0.03386	-0.0079
<i>P</i>	0.16	0.09268	-0.0993	0.0291	-0.0108	-0.0002	0.00032
<i>Df</i>	-0.1804	0.03046	0.04899	-0.0478	-0.0059	0.00014	0.00023
<i>R</i>	0.1279	0.07966	-0.1172	-0.0145	0.01611	-0.0011	-0.001
<i>Itc</i>	0.2749	0.11644	0.16517	0.03706	0.00617	-0.0016	-0.0002
<i>Ic</i>	0.1696	0.1042	-0.0546	0.01074	0.03009	0.01963	0.01924
<i>Io</i>	0.1227	0.16978	-0.1823	0.0341	0.00946	0.04082	-0.0189
A. H. P.	0.20914	-0.3738	0.00591	0.00806	0.00066	0.425	-0.8
A. S. P.	1.3368	0.3057	0.02974	-0.0018	-0.0006	-0.8	0.362
Eigenvalue	0.13304	0.04108	0.00842	0.00091	0.797	0.18	3.12
Inertia (%)	72.4844	22.3794	4.58871	0.49596	0.04343	0.00642	0.0017
Cumulative %	72.4844	94.8638	99.4525	99.9485	99.9919	99.9983	100

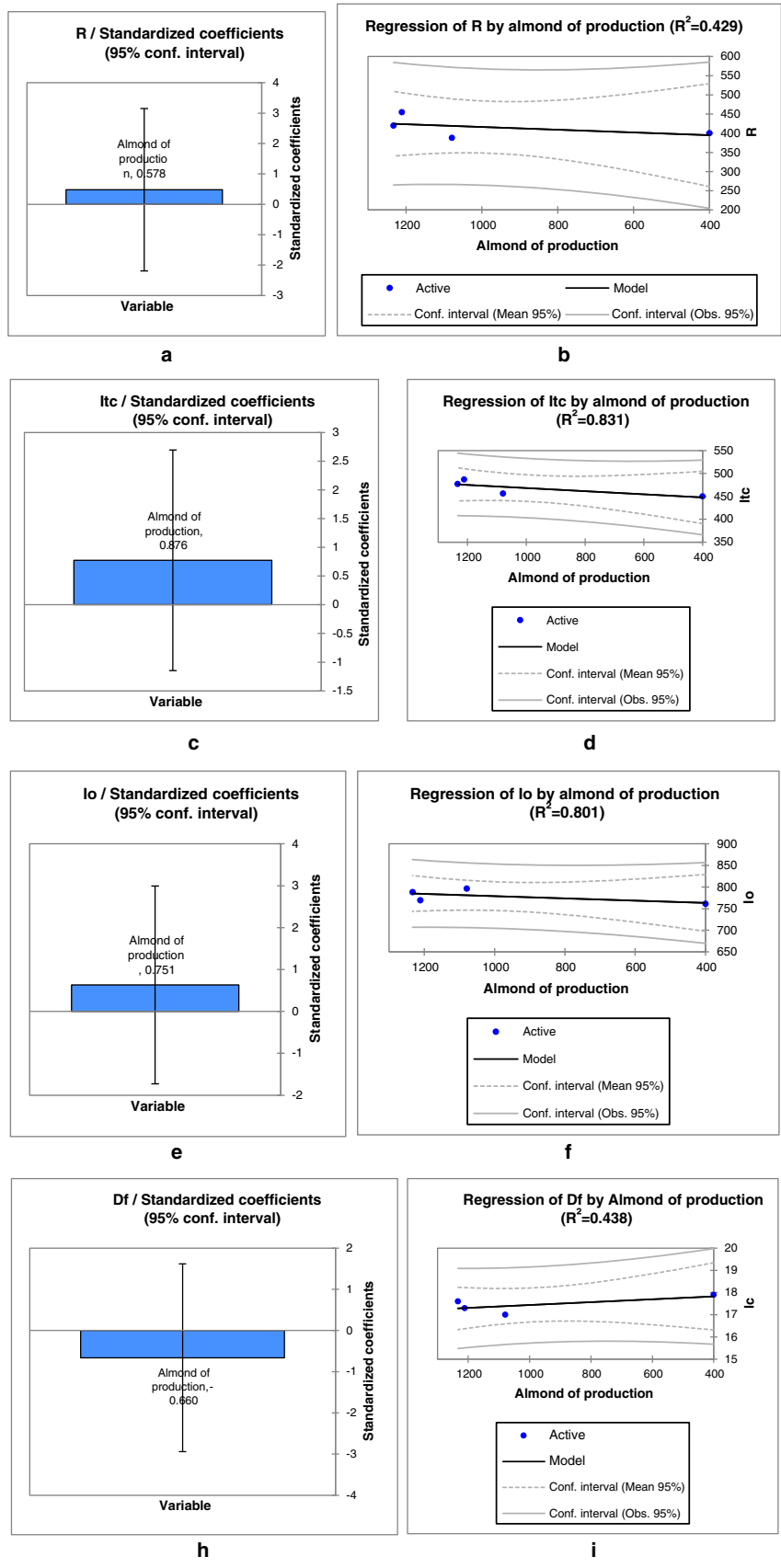


Fig. 3 Graphics representing of almonds regression linear and standardized coefficients (a, b, c, d, e, f, g, h, i)

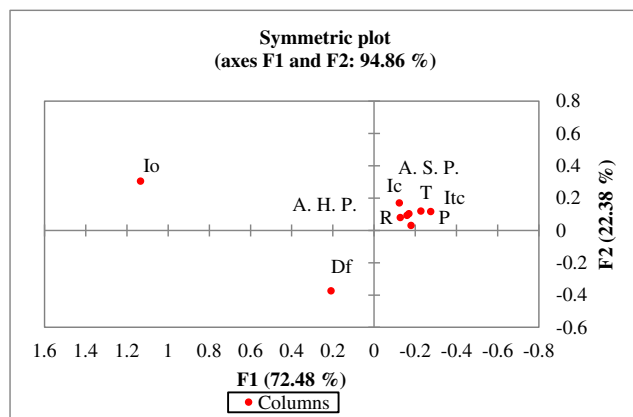


Fig. 4 Representing of canonical correlation analysis (CCA) and variables different as climate and bioclimate factors

Nevertheless, when we applied a principal component analysis (PCA), observed that Hebron affected by the most of bioclimate and climate factors, such as compensated thermicity index, simple continentality index, and annual ombrothermic index, soil water reserve, mean annual temperature because its lies in the positive x -axis, while water deficit was a negative effected on the plant yield for this occurred in the y -axis negative (Fig. 4).

The analysis of variance (ANOVA), with a 95% confidence interval has been applied to almond crop yield, with the seven independent variables factors (Tm or T , P , or ppt, R , Df or Wdf , Io , Ic , and It/Itc), clarify significant differences in almond production, which confirms the impact of this factors on the almond production, in the multiple regression analyses and standardized coefficient, the case of almond (hard and soft production) shows a better standardized coefficient with the values of ($R^2 = 0.876$, 0.751) respectively, being nearly to 1 (Fig. 3c, e), but had a lower correlation value (0.578), with annual ombrothermic index factor, this means that there are significant differences statistical that are acceptable in this analysis, as the histogram is positive (Fig. 3a, b, c, d, e), whereas there are no significant differences in the case of almond production with water deficit because the histogram is negative (Fig. 3h).

On the other hand, the high linear regression correlation between the bioclimatic factors and almond yield with values of ($R^2 = 0.831$, 0.801) as the compensated thermicity index and annual ombrothermic index respectively (Fig. 3d, f), while the value of ($R^2 = 0.438$, 0.429), with a lower in case of water deficiency and soil water reserve respectively (Fig. 3i, b), although almonds tolerate drought somewhat, it is clear that almonds are affected by high temperatures and lack of water in the soil, especially in the summer (Ighbareyeh et al. 2015a, 2015b), in addition to some of the diseases and insects that infected the plant, pollination processes, and other factors.

Canonical correlation analysis

PCA has key role to canonical correlation analysis (CCA). CCA is a coordinate systems that optimally explain the cross covariance between two data sets or variables (Hsu et al. 2008). However, CCA has been applied; it was done by comparing the independent variables and almond production. We observed that the almond production as soft and hard yield were affected positive by all climate and bioclimate factors except the water deficit located at the left of axis 2; it is probably due to the amount of rainfall and the high temperature, and the length of the water deficit period, which is extended for more than 6 months during the year in Palestine. Otherwise, the bioclimatic belts in the occupied Palestinian territories since 1967 form (45–50%) of inframediterranean, (35–40%) of thermomediterranean and less than (5–10%) of mesomediterranean (Ighbareyeh et al. 2014b).

Moreover, Hebron was influenced positively by annual ombrothermic index, simple continentality index, precipitation, water soil reserve, and mean annual temperature, with a large proportion of the variance explained by axis F1 (72.48%), while axis F2 (22.38%) and symmetric plot axes F1 and F2 (94.86%) (Fig. 4).

The almonds are based on deep roots and therefore need deep and fertile soils to grow and yield high productivity, although the almond tree grows successfully in a wide range of soil in the world, the sandy soil is the best. However, the almond tree needs 200–500 h of cold during the year to break the dormancy of the buds; almond trees require a dormancy period with temperatures between 0 to 2.2 °C, and it cannot be planted in tropical climates, it needs annual temperature of 10.5 to 19.5 °C and pH of 5.3 to 8.3. Consequently, climate is the most important factor in limiting almond production to consumption, the almond bloom and young nut are very frost sensitive, any frost which occurs reduce of yield. Otherwise, the blooming of almonds can bloom at a temperature of 20–25 °F, in the pink bud stage, 28–30 °F and in full bloom, with 31 °F (Meith and Rizzi 1966). Finally, they are the two variables deemed most important for almond production and most of plants; the first precipitation and mean temperature of months as climate factors and the second, the bioclimate factors as annual ombrothermic index and water deficit.

Conclusion

Hebron is particular geographic location, in junction with a series of environmental variables makes this a very important and fertile land. Almond production in Hebron area represents an economically and culturally important that contributes substantially to national production of Palestine. Otherwise, the canonical correlation analysis (CCA) in all cases separates of types plot: Hebron, whose almond production depends on the

climate factors as precipitation, mean temperature of months and soil water reserve, and bioclimate factors as water deficit, which is the result of annual ombrothermic index more than 3, compensated thermicity index (220/220 to 350/350), simple continentality index between (14–20), in areas where the average annual temperature between (15–20 °C). Almonds give high production, where the environmental areas mesomediterranean thermotype and they are available in high-land Hebron and Palestine in general.

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