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Influence of Climatic Factors on Apricot (*Prunus armeniaca* L.) Yield in the Malatya Province of Turkey

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Abstract: Apricot (*Prunus armeniaca* L.) is one of the most important export crops in Turkey and Turkey is the leading fresh and dried apricot producer all over the world. Malatya province is the main production area in Turkey. Apricot yield has fluctuations because of climate in Malatya region. The study analyzed the relationship between climate factors and apricot yield by using time series data belong to the climatic variables such as temperature, humidity and precipitation during the time period of 1978-2006. All climatic variables were examined associated with the stages of planting, flowering and harvesting, separately. Linear regression method was used to estimate the model parameters. Research model showed that the most magnificence climatic factors on apricot yield were minimum temperature, precipitation and humidity in flowering period and maximum temperature in planting period. The study suggested that choosing suitable apricot variety and protecting the apricot orchards via technical measures in order to reduce adverse effects of fluctuations on climatic variables.

Key words: Agriculture, climate change, linear regression model

INTRODUCTION

It is known that climate change has a strongly impact on agriculture. Up to now, there has been much debate on the effects of climate factors on productivity of the agricultural products. Fluctuations on climatic variables such as temperature, precipitation, humidity etc. make the farmers conduct their activities under the risky environment, resulting in variation in farmers' income. Many researchers, therefore, focused on the effects of climate factors on the yield of agricultural product all over the world. Chmielewski *et al*. (1995) indicated that 33% of the variation in grain yield and 50% of the variation in straw yields could be explained by rainfall; rainfall in April to June had a positive effect on growth, whereas rainfall at other times exerted a negative influence on yield. Stephens and Lyons (1998) examined rainfall-yield relationships in agriculture: monthly rainfall was regressed on wheat yields from the surrounding shires for the period 1976-1987. Yields were found to be strongly related to fluctuations in total rainfall amount and seasonal distribution of rainfall through the year. Freckleton *et al*. (1999) analyzed the effect of weather conditions on sugar beet yield and their results showed that the sugar beet yield decreased when the temperature increased. Similarly, Islam *et al*. (1999) examined the effects of fluctuation in climate factor on the yield of wheat, sun flower and tobacco in Fitzroy region of Australia by using linear perturbation model. In same year, Saylan *et al*. (1999) explored the relationship between temperature variation and maize yield in Austria. Kavi-Kumar and Parikh (2001) has also established a functional relationship between farm level net revenue and climatic variables, with a view to estimate the climate sensitivity of crop production in Indian agriculture. Also, Pidgeon *et al*. (2004) inferred that drought that will be occurred future reduced the sugar beet yield by 50% in Europe. Torvanger *et al*. (2004) investigated the relationship between yields of potatoes, barley, oats and wheat per hectare, and temperature and precipitation for the period of 1958-2001 in Norway. Deressa and Hassan (2009) determined that climatic variables have a significant impact on the net crop revenue of farmers under Ethiopian conditions.

However, studies among relation between climatic factors and crop yield were rare in Turkey. Ozkan and Akcaoz (2002) estimated that the most significant climatic factor affecting deviations in crop yields were related in temperature at planting, flowering and harvesting time. Cobanoglu *et al*. (2007) determined that relative moisture value of July, wind speeds of July and September and sunshine times of September parameters have been had important effects on Turkey's the lowest dried fig quality grade exports. Bayramoglu *et al*. (2008) also estimated

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Fig. 1: The area of study, Malatya province in Turkey

Table 1: Monthly figures on climatic variables during the period of 1978-2006 for Malatya (TSMS, 2007)

	Janu.	Febr.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Minimum Temp. (ºC)	-8.9	-8.8	-4.7	1.6	5.5	10.6	15.1	15.4	10.0	3.7	-2.7	-7.0
Maximum Temp. (ºC)	10.3	12.9	19.8	26.2	30.9	35.3	38.6	38.1	34.6	29.2	19.5	12.1
Average Temp. (ºC)	0.5	1.9	6.8	13.0	17.9	23.2	27.5	27.0	22.4	15.3	7.2	2.2
Min. Av. Temp. (ºC)	-2.6	-1.7	2.2	7.6	11.7	16.1	20.1	19.9	15.4	10.0	3.4	-0.6
Max. Av. Temp. (ºC)	3.9	6.2	11.9	18.6	24.0	29.6	34.2	33.9	29.4	21.6	12.1	5.7
Humidity (%)	73.0	68.1	61.0	54.4	51.0	40.4	34.5	35.1	39.1	55.1	68.6	74.1
Total Rainfall (kg/m^2)	36.0	39.5	51.5	53.9	47.3	21.1	2.7	1.0	5.3	40.4	43.6	38.8

that temperature and humidty in flowering period were affected the hazelnut yield in Ordu and Giresun provinces of Turkey.

In Turkey, agriculture is still a relatively important sector. The agriculture sector contributed 12.9% of gross domestic product, and accounted for 32.9% of total employment (TURKSTAT, 2009). Apricot is one of the Turkish traditional export crops. Turkey is the leading fresh and dried apricot producer all over the world. Turkey produced approximately 558 thousand tons of fresh apricot in 2007, which is 17.6% of the total world fresh apricot production. Also, Turkish dry apricot production constitutes the 80% of the world production (FAOSTAT, 2007). Malatya province is the main production area in Turkey and produced 50% of fresh apricot and 95% of dried apricot production in Turkey. Approximately, 95% of the dried apricots produced in Malatya are exported to EU countries, USA and Russia (MARA, 2007).

Despite the climatic factors are main determinants of apricot production in Malatya, no previous studies have examined the relationship between climatic factors and yield of apricot. Whereas, (Asma, 2000; MFRI, 2006; ECSRC, 2009) emphasized that apricot production in Malatya was strongly depend on the climatic conditions, especially frost in flowering period and precipitation.

Therefore, the objective of this study was to explore the effects of climatic factors on apricot (*Prunus armeniaca* L.) yields using time series data.

MATERIAL AND METHODS

The research area and its climatic structure: The study was conducted in 2008 using secondary data of official records of MARA and TSMS for Malatya (38:19 E; 38:21 N), a province in southern part of Turkey,. Malatya Province encompasses 1.241.200 ha; of this area, approximately 34% is used for agricultural production, and there are 60.000 farms, approximately (MARA, 2007). Apricot production exists solely in Malatya. The selected study area had 50% of the total apricot production in Turkey (Fig. 1).

The Malatya was selected as the study area because all the apricot produced by its specialized farms is directed towards domestic and overseas large cities with high apricot demand such as Istanbul, Ankara, Izmir and cities in EU countries.

Malatya has typical terrestrial climate conditions. In summer, the weather is very hot while that of winter very cold. The statistics on some climatic variables for Malatya were given in Table 1.

Model for climatic factors fluctuations: Linear Regression Method (LRM) was used to explore the relationship between climatic factors and apricot yield. This model was used to updating forecast in previous studies (Freckleton *et al*., 1999; Islam *et al*., 1999; Torvanger *et al*., 2004; Ozkan and Akcaoz, 2002; Cobanoglu *et al*., 2007; Bayramoglu *et al*., 2008). The

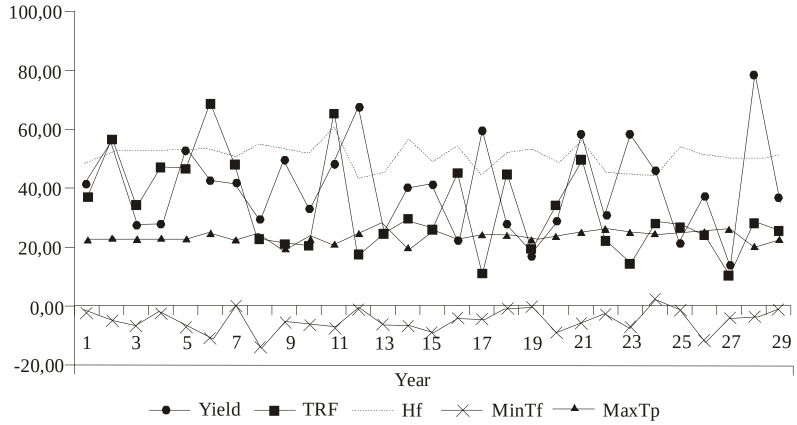

Fig. 2: Fluctuations of climatic factors and apricot yield

general form of linear regression model used in this study was as follows (Greene, 2003):

$$Y_t = \alpha + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + u_t \qquad (1)$$

where Y_t was the dependent variable of the model for the year t, X_i were the independent variables for the year t, α and β were the unknown parameters of the model and the u_t was the disturbance term. It was clear from the upper evidence that the effects of the variation on technology and innovation on the apricot yield should be ignored in the model.

Augmented Dickey-Fuller (ADF) test was used to check the stationary of the time series data. When determining the best suitable lag length, Akaike Information Criteria (AIC) was considered.

Stepwise selection method was followed for the selection and introduction of independent variables for regression equation. The model was estimated by using the statistical package of MINITAB 12.0.

Data: All variables used in the regression model were time series data covering the time period of 1978-2006. The climatic variables were obtained from the records of Turkish State Meteorological Service (TSMS, 2007). The data base of the Provincial Directorate of Ministry of Agriculture and Rural Affairs (MARA) was used to obtain annual apricot yield (MARA, 2007). Firstly, planting, flowering and harvesting times of apricot in the research region was determined (Table 2) and meteorological data used in the analysis were arranged according to phonological periods of the apricot investigated according to the examined period. All the data used in the study was related to the period 1978-2006.

Second, apricot yields were regressed on the climatic variables. Apricot yield (kg/ha) was the dependent variable of the regression model. Totally 21 different independent variables were used in the model. The independent variables in the model were calculated separately for planting, flowering and harvesting times of apricot. These independent variables were; maximum temperature (ºC), minimum temperature (ºC), average temperature (ºC), maximum average temperature (ºC), minimum average temperature (ºC), total rainfall (kg/m^2) and humidity (%) for planting, flowering and harvesting periods, separately.

Table 2: Planting, flowering and harvesting times of the apricot in Malatya Region (ECSRC, 2009)

Planting	Flowering	Harvesting
September-November	March-July	June-August

RESULTS AND DISCUSSION

Descriptive statistics of the variables used in the regression analysis were given in the Table 3.

The minimum and maximum temperatures in planting period were 0.48 and 24ºC, respectively, while that of the value of average temperature was approximately 10ºC. Humidity was 62% during the period. Rainfall was totally 38 kg/m^2. When glancing at the flowering period, it was clear that the minimum temperature was lower and maximum temperature was higher comparing to planting period. Humidity and rainfall in flowering period were lower than that of planting period. On the other hand, extreme temperatures and average temperature in harvesting period were higher comparing to planting and flowering period. However, humidity in harvesting period was lower than that of flowering and planting periods. Based on the results of the ADF test, most studied time series was stationary state in prevailing condition. There is no trend effect on the studied time series due to presence no unit root in most time series. However, maximum temperature and maximum average temperature in flowering were stationary state in first difference while average

Table 3: Descriptive statistic of variables

Variable	Code	Mean	Maximum	Minimum	S.D.
Yield (kg/tree)	Y	40,25	78,71	13,58	±15,54
In the planting period					
Minimum Temp. (ºC)	MINTp	0.48	3.75	-5.30	±1.87
Maximum Temp. (ºC)	MAXTp	23.78	27.84	19.74	±1.89
Average Temp. (ºC)	ATp	10.41	13.70	6.33	±1.47
Min. Average Temp. (ºC)	MINATp	6.70	8.25	4.95	±0.96
Max. Average Temp. (ºC)	MAXATp	16.06	19.98	10.87	±1.70
Humidity (%)	Hp	61.36	71.61	48.39	±6.34
Total Rainfall (kg/m^2)	TRp	37.19	90.59	3.44	±21.58
In the flowering period					
Minimum Temp. (ºC)	MINTf	- 4.67	2.60	- 13.90	±3.85
Maximum Temp. (ºC)	MAXTf	27.37	30.72	24.51	±1.65
Average Temp. (ºC)	ATf	13.66	17.06	10.94	±1.59
Min. Average Temp. (ºC)	MINATf	9.41	11.50	7.63	±0.90
Max. Average Temp. (ºC)	MAXATf	19.78	23.67	17.22	±1.57
Humidity (%)	Hf	50.90	59.08	43.83	±3.90
Total Rainfall (kg/m^2)	TRf	32.94	68.77	10.52	±15.41
In the harvesting period					
Minimum Temp. (ºC)	MINTh	15.22	18.50	12.25	±1.47
Maximum Temp. (ºC)	MAXTh	38.34	41.34	35.10	±1.39
Average Temp. (ºC)	ATh	27.24	28.90	25.40	±1.03
Min. Average Temp. (ºC)	MINATh	19.98	21.85	18.65	±0.90
Max. Average Temp. (ºC)	MAXATh	34.07	36.45	31.44	±1.28
Humidity (%)	Hh	34.75	48.08	24.41	±4.49
Total Rainfall (kg/m^2)	TRh	3.68	12.80	0.00	±3.83

Table 4: The results of the unit root test

Variable with codes	Intercept	Lag lenght	Variable with codes	Intercept	Lag lenght
YIELD	- 7.08* I(0)	0	MINATf	- 4.59* I(0)	0
TRp	- 4.86* I(0)	0	MINATh	- 3.26** I(0)	0
TRf	- 4.68* I(0)	0	MINTp	- 6.31* I(0)	0
TRh	- 3.32** I(0)	0	MINTf	- 6.42* I(0)	0
ATp	- 6.160 I(1)	2	MINTh	- 4.44* I(0)	0
ATf	- 4.940 I(1)	5	MAXTp	- 5.61* I(0)	0
ATh	- 3.57** I(0)	0	MAXTf	- 4.82* I(0)	1
Hp	- 4.05* I(0)	0	MAXTh	- 3.87* I(0)	0
Hf	- 5.65* I(0)	0	MAXATp	- 3.90* I(0)	0
Hh	- 3.33** I(0)	0	MAXATf	- 4.58* I(0)	1
MINATp	- 4.69* I(0)	0	MAXATh	- 3.49** I(0)	0

*, **: indicates that signicantly at 1 and 5% , respectively; MacKinnon (1996) 5% critical values are -3.69, -2.97 and -2.63 at 1, 5 and 10%, respectively; I(0) and I(1) show that the series are stationary at level and first difference, respectively

temperature in planting and flowering period were stationary state in second and fifth lag, respectively (Table 4). Therefore, these variables were excepted from the model.

The selection and introduction of independent variables for regression equation were performed by using stepwise selection method. Stepwise selection process revealed that the most important climatic variables were rainfall, humidity and minimum temperature in flowering period and maximum temperature in planting period. This finding was confirmed the results of MFRI (MFRI, 2006). MFRI (2006) reported that rainfall, humidity and minimum temperature were the critical variables in flowering and planting period. Research results showed that there was strong relationship between climatic variables and the yield of apricot. The fluctuations of selected climatic variables and yield were in given in Fig. 2. The figure also shows that important relation between climate change and apricot yield.

Table 5: Estimated coefficients, standard deviations and their t values for the model

Predictor	Coefficient	StDev	t
Constant	340.090	70.930	4.79***
TRf	0.433	0.188	2.30**
Hf	- 3.649	0.924	- 3.95***
MAXTp	- 5.631	1.565	- 3.60***
MINTf	- 1.196	0.685	- 1.75*
R^2 = 0,439	S = 12.58	F = 4.69*	dw = 2.57

*, **, ***: indicates that significantly at 0.10, 0.05 and 0.01, respectively

The regression result indicated that the climatic variables have significant impacts on the apricot yield. The estimated coefficients, standard deviations and their t values for the model were presented in Table 5.

In the model, F-value (4.69) was important at the 95% significance level. This suggests that this model is meaningful according to F-value. Durbin Watson value was found 2.57 and there is no autocorrelation. The multiple determination coefficient of the model was 0.44,

Table 6: Marginal effects of climatic variables on the apricot yield

Marginal effects	
Constant	340.09
TRf	0.35
Hf	- 4.62
MAXTp	- 0.05
MINTf	- 3.33

indicating that the 44% of the total variation in apricot yield was explained by the variation in the variables of rainfall, humidity and minimum temperature in flowering period and maximum temperature in planting period. This result suggested results of Lobell and Field (2007) and determined that at least 29% of the variance in year-to-year yield changes was explained by the climatic variables.

All the estimated coefficients were statistically significant. Total rainfall in flowering period affected the apricot yield positively. Similarly, Agbola and Ojeleye (2007) and Deressa and Hassan (2009) estimated that positively correlation between crop yield and rainfall and temperature. However, the variables of humidity and minimum temperature in flowering period and maximum temperature in planting period had the negative effects on apricot yield. Bayramoglu *et al*. (2008) determined that humidity in the flowering period was positively the productivity of hazelnut in Giresun province of Turkey. Deressa and Hassan (2009) also estimated temperature in the spring season was negatively affected to the net revenue of farms in Ethiopia. Humidity was the other important climatic factor. Similarly, MFRI reported that higher humidity in flowering period caused the infections called Monilia (*Sclerotinia laxa*) and stain on the fruit and leaves (*Wilsonomyces carpophilus*), resulting in yield loss. Maximum temperature in planting period was the most important climatic factor having negative effects on the apricot yield. The negative coefficients of minimum temperature in flowering period and maximum temperature in planting period indicated that frosty in flowering period and high temperature in planting period led to reduction of apricot yield. This finding confirmed the results of Batmaz (2005). Batmaz (2005) stated that the frost occurred in late spring was the most important climatic factors for apricot yield.

To interpret the climate coefficients, we calculated marginal climate impacts at the mean of climatic factors for apricot yields (Table 6).

When increased a kg/m^2 rainfall during the flowering period the apricot yield would increase 0.35 kg/tree. Increase in the Hf and MinTf marginally during the flowering season reduces the apricot yield per tree by 4.62 and 3.33 kg, respectively. Increase in the MaxT marginally during the planting season reduces the apricot yield per tree by 0.05 kg.

CONCLUSION

The influence of climatic variables on apricot yield for Malatya region of Turkey was studied for three phonological (planting, flowering and harvesting times) periods. The Linear Regression Model was used to determine relations between yield and the climatic variables (explanatory variables) temperature, rainfall, and humidity. The selection and introduction of the explanatory variables for equation were done by using a stepwise selection method. All the data used in the study was related to the period 1978-2006.

The study analyzed the effects of the climatic factors on apricot yield and explored that there was strong relationship between climatic variables and apricot yield. In the model, R^2 value was found 0.44 with F-value of 4.69.

The results of the study revealed that total rainfall in flowering period affected the apricot yield positively while the variables of humidity and minimum temperature in flowering period and maximum temperature in planting period had the negative effects on apricot yield.

The study, therefore, suggested that choosing suitable apricot variety and protecting the apricot orchards via technical measures in order to reduce adverse effects of fluctuations on climatic variables. Using special heater in apricot orchards, the mixing the air in apricot orchards by using wind machine, spraying water to the tree, burning the waste into the orchards may reduce the adverse effects of freeze. On the other hand, modern irrigation system should be used against to the overflowing temperature. Also, the insurance application against frost and hail should be encouraged.

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