PHENOLOGICAL EFFECT OF CLIMATE CHANGE IN TURKEY

Serhat Sensoy[1], Necla Türkoğlu[2] , İhsan Çiçek[2]
[1] *Turkish State Meteorological Service*
ssensoy@mgm.gov.tr
[2] *Ankara University Faculty of Languages History and Geography*
Necla.Turkoglu@ankara.edu.tr, ihsan.cicek@ankara.edu.tr

Abstract: In this study we tried to find relationships between changes in temperature and phenological stages of fruit trees and field crops. Climatic and phenological data for 1971-2012 periods have been obtained from Turkish State Meteorological Service. After the data arranged in Excel, correlation coefficients between temperature and phenological stages have been calculated. Mann Kendall trend analyses have been used in order to detect trends in temperature and phenological data. Negative correlation between apple, cherry and wheat phenophases and February-May temperature have been found. This is shows that plants responds to increasing temperature as shift of their phenophases early. Calculated trends for apple, cherry and wheat harvesting are -25, -22, -40 days/100 years respectively. The regression coefficients show that an increase in air temperature between February and May of 1°C, lead to an advanced harvesting date of respective plants by about 5, 4, and 8 days. Climate projections for the end of the 21st century indicate more increase than observed. Accordingly, great changes in plant phenophases are expected.

Keywords: Phenology, apple, cherry, wheat, Turkey.

INTRODUCTION

In mid- and high latitudes, after the winter dormancy plant phenology is strongly depends on air temperature. The extension of growing season could have some positive effects for agriculture and horticulture (Chmielewski et al, 2002). Warmer temperatures promote increases in plant growth in mid-northern latitudes (Kadıoğlu et al, 2000).

The distinct increase in air temperature in Turkey since 1994 and the demand for indicators of climate change impacts caused a growing interest in phenological data. Although 1°C temperature anomaly doesn't appears as big changes in daily life, it means 60 degree-days in two months for the plant growth and has capacity to change phenological phases.

Changes in the timing of phenophases of fruit trees or field crops could be of great economical importance, because they could have direct impacts on yield formation processes.

METHODS

In order to describe the relationships between air temperature and plant development, 130 station's data of air temperature from 1971-2012 and approximately 80 phenological observation stations data of fruit trees (apple and cherry) and field crops (winter wheat) from 1979 to 2010 were used.

Between the air temperature from February to May which growth occurred and phenological data, correlation coefficients with Pearson product-moment correlation coefficients were calculated using the following formula (URL 1).

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{(n-1)s_x s_y}$$

Where; $\bar{x}$ and $\bar{y}$ are mean for X_i and Y_i ; Sx and Sy are Standard deviation for X_i and Y_i and Σ = total from 1 to n (URL 1).

It assumes that if **r** is in between ±0.10-0.29 correlation is weak, ±0.30-0.49 it's moderate and ±0.50-1.00 its high. **±** shows the direction of correlation (positive or negative). Both the point (station) and annual average correlation coefficient for Turkey were calculated. Trends for temperature and phenological phases were calculated via **Mann-Kendall** trend analysis method.

FINDINGS AND ARGUMENT

Mean temperature changes in Turkey

For the standard climatic period 1971-2000, the average annual air temperature in Turkey is 13.2°C. In the period 1971-2012 the temperature increased continuously.

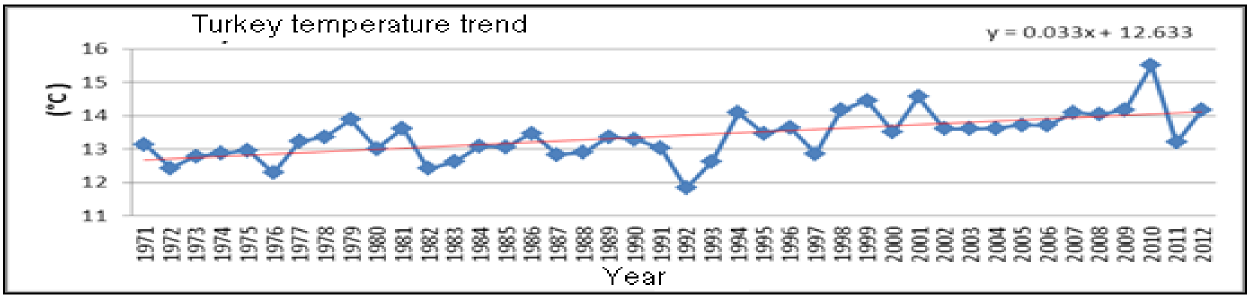

Figure 1. Mean annual temperature and its trend for Turkey, (1971-2012)

The linear trend in the data is 0.3°C/decade (Figure 1). This means that for the whole 42 years, the observed warming is 1.3°C (14.1-12.8 red line). The most interesting feature in this time series is the relatively strong change in air temperature since 1994, which corresponds well to similar trends in many parts of the world (Houghton et al., 2001). Since then nearly all years were warm except 1997.

Table 1. Trend Statistics of average monthly and annual air temperature in Turkey, 1971-2012

Time series	Begin year	Last Year	n	Mann-Kendall trend		Sen's slope estimate				
				Test Z	Signific.	Q	Qmin99	Qmax99	Qmin95	Qmax95
January	*1971*	*2012*	*42*	1,15		0,037	-0,04	0,11	-0,02	0,08
February	*1971*	*2012*	*42*	0,61		0,017	-0,06	0,09	-0,04	0,07
March	*1971*	*2012*	*42*	0,76		0,019	-0,04	0,08	-0,02	0,07
April	*1971*	*2012*	*42*	1,19		0,021	-0,03	0,07	-0,02	0,06
May	*1971*	*2012*	*42*	1,86	+	0,024	-0,01	0,06	0,00	0,05
June	*1971*	*2012*	*42*	4,64	***	0,048	0,02	0,07	0,03	0,06
July	*1971*	*2012*	*42*	4,25	***	0,052	0,03	0,08	0,03	0,07
August	*1971*	*2012*	*42*	4,60	***	0,065	0,03	0,10	0,04	0,09
September	*1971*	*2012*	*42*	2,41	*	0,031	0,00	0,06	0,01	0,05
October	*1971*	*2012*	*42*	2,04	*	0,038	-0,01	0,09	0,00	0,07
November	*1971*	*2012*	*42*	1,24		0,027	-0,03	0,09	-0,02	0,07
December	*1971*	*2012*	*42*	1,69	+	0,043	-0,02	0,10	0,00	0,08
Annual	*1971*	*2012*	*42*	4,53	***	0,033	0,02	0,05	0,02	0,05

Trend Significance level: ***p<0,001, **p<0,01, *p<0,05, +p<0,1

According to analysis carried out via Mann-Kendall trend analysis (Salmi et al, 2002) it's been found that in all the months, temperature trends are positive. Especially summer and annual temperature trends are significant at 99.9% level ($p<0.001$). It's occurred that September and October temperature trend are significant at 95% level. Also May and December temperature trends found significant at 90% level. Mann-Kendall trend in annual temperature is 0.33°C/decade (Table 1). These changes are consisted with the other regions in the world (Sensoy et al., 2007).

Changes in timing of phonological phases

Winter dormancy which is the first span of at least 6 days with T>5ºC, (Sensoy et al, 2013), flowering, fruiting, harvesting of apple and cherry, heading and harvesting of wheat were investigated.

Table 2. Statistical parameters for the timing of different phenophases in Turkey

Phenological stages	Begin year	Last year	n	Mann-Kendall trend		Sen's slope estimate				
				Test Z	Signific.	Q	Qmin99	Qmax99	Qmin95	Qmax95
winter dormancy	1979	2010	32	-1,41		-0,38	-1,13	0,31	-0,95	0,13
apple flowering	1979	2010	32	-1,76	+	-0,20	-0,47	0,10	-0,41	0,00
apple fruiting	1979	2010	32	-1,22		-0,13	-0,46	0,17	-0,36	0,08
apple harvesting	1989	2010	22	-2,02	*	-0,25	-0,59	0,10	-0,50	0,00
cherry blossoming	1996	2010	15	-2,43	*	-1,08	-1,92	0,05	-1,67	-0,38
cherry fruiting	1980	2010	31	-1,70	+	-0,12	-0,33	0,07	-0,29	0,01
cherry harvesting	1987	2010	24	-1,36		-0,22	-0,60	0,31	-0,53	0,14
wheat heading	1979	2009	31	-4,58	***	-0,40	-0,58	-0,24	-0,53	-0,29
wheat harvesting	1979	2009	31	-4,52	***	-0,40	-0,56	-0,20	-0,53	-0,25
Feb-May mean temp.	1979	2010	32	2,29	*	0,05	0,00	0,09	0,01	0,09

Trend significance level: ***$p<0.001$, **$p<0.01$, *$p<0.05$, +$p<0.1$ (Salmi vd, 2002)

According to analysis carried out via Mann-Kendall trend analysis (Salmi et al, 2002) it's been found that in all the phenophases trends are negative. Especially wheat heading and wheat harvesting trends are found as 4 days/decade and significant at 99.9% level ($p<0.001$). Also it's occurred that apple harvesting, cherry blossoming and February-May temperature trend are significant at 95% level. Also apple flowering and cherry fruiting trends were found significant at 90% level (Table 2).

Correlations coefficients between climate and phenological data

The correlation coefficients (r) between the February-May temperature and individual phenophases ranges between -0.18 r(apple flowering, T) and -0.71 r(cherry blossom, T). Both the Turkey and station level, cherry phenophases show strong correlation (r=-0.98 Amasya). Toward the last decade, clear changes in the phenophases are remarkable which explains the negative trends.

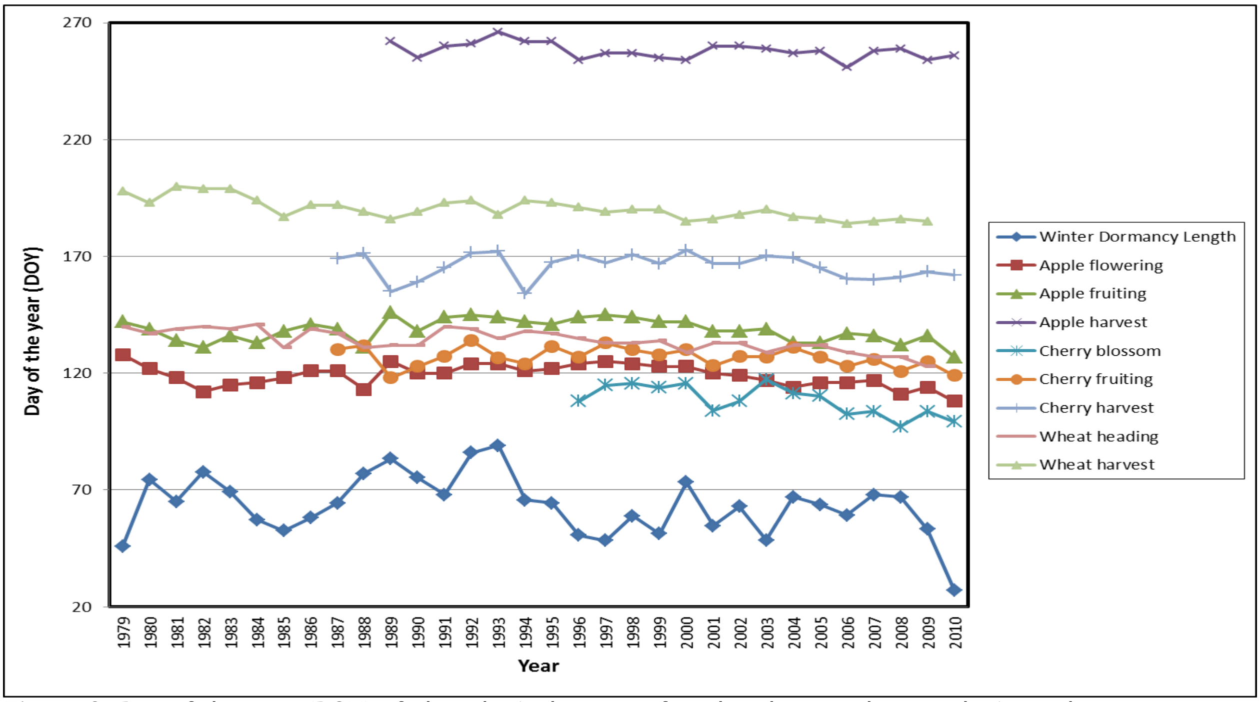

Figure 2. Day of the year (DOY) of phenological stages of apple, cherry, wheat and winter dormancy

It is been found that earliness is increasing in all phenophases consistent with rising temperatures. Plants respond to increasing temperature as shift of their phenophases early. Calculated trends for apple, cherry and wheat harvesting date are -25, -22, -40 days/100 years respectively.

CONCLUSIONS

There is a negative correlation between apple, cherry and wheat phenophases and February-May mean temperature. This is shows that plants responds to increasing temperature as shift of their phenophases early.

Calculated trends for apple, cherry and wheat harvesting are -25, -22, -40 days/100 years respectively. The regression coefficients show that an increase in air temperature between February and May of 1°C lead to an advanced harvesting date of respective plants by about 5, 4, and 8 days.

Shorter developmental periods for field crop and fruit trees could have rather negative effects on the formation of individual yield components, as for cereals: the crop density, the kernel number per ear, and the kernel weight. Advanced blossom of fruit trees can increase the risk of late-frost damages (Chmielewski et al, 2002).

According to result from climate indices study, there are increasing trends in temperature related indices such as summer days, tropical nights, warm days and nights and growing season length. (Sensoy et al, 2013).

Climate projections for the end of the 21st century indicate more increase than observed in the 20th century. In Turkey 3-4°C temperature increase are expected according to RCP 4.5 scenario (Demir et al, 2013). Accordingly, great changes in plant phenophases are expected towards the end of the century. Assessment of many studies covering a wide range of regions and crops shows that negative impacts of climate change on crop yields have been more common than positive impacts (IPCC SYR).

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