Frost Calendar of Turkey

Technical Report · April 2014

DOI: 10.13140/RG.2.2.23436.00648

1 author:

Mücahit Karaoğlu
Igdir Üniversitesi
33 PUBLICATIONS **48** CITATIONS

Frost Calendar of Turkey

Mücahit Karaoğlu[1*]

Abstract: *This study determined the frost calendar of Turkey by using thresholds values for lowest air temperature (-4, -2, 0 °C), minimum grass temperature (0 °C) and daily average temperature (5 °C) of 81 meteorological stations for the reference period of 1978-2012. Critical periods (cold, the riskiest, the safest and the longest vegetative period) were revealed by determining the values of earliest and latest dates of minimum air temperature (0 °C), grass minimum temperature (0 °C) and daily average air temperature (5 °C) for spring and autumn. These critical periods were illustrated via schemas in order to make easy provide easy of use and comparison among stations. Two frost maps were drawn for Turkey by using the dates of late spring (0 °C) and early autumn (0 °C). According to the results obtained from frost calendar, critical periods and frost maps; Turkey is a country having a large variety of frost events. There are cold region stations which have only two frost-free months along with maritime stations where no frost event is observed throughout the year. Stations that have few frost events and shorter frost period compared to their surroundings, and stations which have more frost events and longer frost period are different on maps. The fact that hidden icing (taking place when grass minimum temperature is 0 °C or below) can occur at nearly mid-year is an important and serious problem for traffic and applied meteorology. The main results of this study are the determination of moderate and severe frost dates and frequencies, the dates of hidden icing, the length and variation of maximum growing season, and the maps of frost dates. All this information forms a relevant and useful set of tools for analysis and planning of farm activities.*
Keywords: *frost calendar, critical periods, hidden icing, frost maps.*

Riassunto: *Questo studio ha prodotto il calendario delle gelate della Turchia utilizzando i valori delle soglie di temperatura minima dell'aria (-4 °C, -2 °C, 0 °C), temperatura minima erba (0 °C) e la temperatura media giornaliera (5 °C) di 81 stazioni meteorologiche per il periodo di riferimento 1978-2012.*
Sono stati rivelati i periodi critici (di freddo, a maggior rischio, il più sicuro e la stagione vegetativa più lunga) determinando per la primavera e l'autunno la prima e l'ultima data con le temperature minime giornaliere dell'aria, dell'erba e la temperatura media giornaliera sotto una determinata soglia (rispettivamente 0 °C, 0 °C e 5 °C). Questi valori dei periodi critici sono stati riportati in tabelle in modo da agevolarne l'utilizzo e il confronto tra i dati delle diverse stazioni meteorologiche. Sono state prodotte due mappe delle gelate per la Turchia in base alle date delle gelate terdive (0 °C) e precoci (0 °C). Dai risultati ottenuti dal calendario delle gelate, dai valori dei periodi critici e delle mappe delle gelate, la Turchia risulta essere un paese con una grande varietà nell'ambito degli eventi di gelata. Infatti ci sono stazioni in regioni fredde che hanno solo due mesi in cui non si verificano eventi di gelata e stazioni marittime in cui non se ne registrano affatto. Altre stazioni presentano pochi eventi di gelata e il periodo sottoposto a gelate più breve rispetto alle circostanti, e lesono diverse nelle mappe le stazioni che hanno più eventi di gelata e il più lungo periodo di gelata. Le gelate occulte, che si verificano quando la temperatura minima dell'erba è minore o uguale a 0 °C, possano presentarsi a circa metà anno è perciò rappresentano un notevole ed impegnativo problema sia per il traffico che per la meteorologia applicata. I principali risultati di questo studio sono stati la determinazione del calendario delle gelate (moderate e gravi) e le loro frequenze, le date in cui si sono verificate le gelate occulte, la lunghezza e la variazione massima della stagione vegetativa, le mappe delle gelate. Tutte queste informazioni costituiscono un insieme utile e rilevante di strumenti per l'analisi e la pianificazione delle attività agricole.
Parole chiave: *calendario di gelata, periodi critici, gelate occulte, mappe delle gelate.*

1. INTRODUCTION

Being a solution under pressure, the living cell, freezes at temperature values below 0 °C (Nichols, 1920). But the water located in intercellular spaces is pure or nearly pure, and therefore freezes at temperature values just below 0 °C (Nichols, 1920; Kacar, 1996). As a result, ice formation is very common in intercellular spaces. When this happens, water is taken out from the cell. Due to mechanical damage, the protoplasm loses its water and thus can be broken easily or the cell can be wrinkled and the protoplasm is damaged (Tosun *et al*., 1977). When the dormancy period begins, water amount in plants reduces and plant can withstand without damage at temperatures below -20 °C. But when perennial plants start to take in water after dormancy or the growing season starts for annual crops, temperatures several degrees below 0 °C can be fatal. Consequently, it is obvious that frost damage depends primarily on water amount in the plant (Gloyne and Lomas, 1980).

The decrease of air temperature to 0 °C and below is considered as the beginning of the frost event (Cittadini *et al*., 2006; Karaoğlu 2002; Lindkvist and Chen, 1999; Glossary of Meteorology, 1959). If air

* Corresponding Author e-mail: mucahitkaraoglu@hotmail.com
[1] Assist. Prof. Dr., Iğdir University, Iğdir Agricultural Faculty.

temperature is between -2 and -4 °C, it is expressed as moderate frost; and if air temperature is lower than -4 °C, it is expressed as severe frost (Jacobsen *et al*., 2006). The period when daily average temperature is equal and higher than 5 °C is regarded as vegetative period for various crops (Field Crops, 2009; Lindkvist *et al*., 2000; Kacar, 1996; Odin *et al*., 1983).

If grass minimum temperature is 0 °C or below during the morning hours when air temperature value is above 0 °C, "hidden" icing occurs at surface level (Bootsma, 1976; Baier and Edey, 1970; Georg and Wallis 1968). The risk dates of hidden icing are very important in terms of traffic and applied meteorology. Determination of the frost calendar will significantly contribute primarily to agricultural activities and other planning and studies (Connor, 1949). Cold period, vegetative period, and the riskiest and safest periods in the longest vegetative period are reported in frost calendar (Karaoğlu, 2002).

Comprehensive climate mapping provides convenience for numerous climate studies (Joos, 1960; Ellenberg *et al*, 1956). Preparing frost and frost risk maps is a method used by some researchers. It is possible to compare stations, to see the distribution and frequency of frost dates, and to determine adaptation and deviations to geographic regions on a frost map. Pouteau *et al*. (2011) drew frost maps using GIS. Karaoğlu (2002) made up frost maps of Turkey based on earliest and latest dates of frost event. Lindkvist *et al*. (2000) determined frost risk and its map by utilising other meteorological data. Lomas *et al*. (1989) created local frost risk maps by using a great number of long term temperature values.

2. MATERIAL AND METHOD

Minimum temperature values (-4, -2, 0 °C), grass minimum temperature data (0 °C) and daily average temperature values (5 °C) which belonged to 81 city stations in the study and were measured for the long term (1978-2012), were obtained daily by using databank of General Directorate of Meteorological Service of Turkey. While daily minimum and average temperature values were measured in a standard shield at the height of 2 m, grass minimum temperature values were measured in open air at the height of 10 cm.

2.1. The Determination of Frost Calendar of Turkey

Tab. 1 illustrates the Frost Calendar of Turkey. Distribution of severe and moderate frost events was determined by selecting dates of late spring and early autumn for long term (1978-2012) -4 °C and -2 °C minimum temperature values used for 81 stations. Probable dates were revealed for frost, hidden icing and vegetative period by using the earliest and latest dates for spring and autumn for 0 °C minimum temperature, 0 °C grass minimum temperature and 5 °C daily average temperature.

2.2. The Determination of Critical Periods

The critical periods were obtained by coinciding the earliest and latest dates specified in the study period. The critical periods show the worst possible situation for each station and possibility of experiencing them is very low.

Temperature value required for starting of vegetative period is different for each plant species. This value varies between 0-25 °C. (Field crops, 2009). Daily average temperature of 5 °C determined in the study is a representative value and according to objective of the study, different values could be used.

These critical periods were illustrated via schemas as number of days (Fig. 1) in order to make ease of use and to compare the stations.

2.2.1. Cold Periods

It is the period when there is no plant growth, daily average temperature is below 5 °C and frosts are more common. It was determined as the period between January 1 and the date when daily average temperature was continuously 5 °C and above, and between December 31 and the date when daily average temperature was latest 5 °C and above. These periods were calculated for winter and fall by using the following two formulas:

Julian day (5 °C$_{ave}$ E.) - 1 January (I)

31 December (365) - Julian day (5 °C$_{ave}$ L.) (II)

where 5 °C$_{ave}$ E is the earliest date of daily average temperature for 5 °C, and 5 °C$_{ave}$ L is the latest date of daily average temperature for 5 °C.

2.2.2. The Most Risky Period

Julian day (0 °C L.) - Julian day (5 °C$_{ave}$ E.) (III)

Julian day (5 °C$_{ave}$ L.) - Julian day (0 °C E.) (IV)

where 0 °C L is the latest date of minimum temperature for 0 °C, 5 °C$_{ave}$ E is the earliest date of daily average temperature for 5 °C, 5 °C$_{ave}$ L is the latest date of daily average temperature for 5 °C, and 0 °C E is the earliest date of minimum temperature for 0 °C.

2.2.3. The Safest Period

There is no frost risk in this period. It was specified as the period from the date when the latest minimum temperature was 0 °C for spring to the date when the

	MİNİMUM TEMPERATURES				HIDDEN ICING		GROWING SEASON				HIDDEN ICING		MİNİMUM TEMPERATURES			
STATIONS	-4°C L.	-2°C L.	0°C E.	0°C L.	G.M. E.	G.M. L.	5°C E.	5 °C L.	5 °C E.	5 °C L.	G.M. E.	G.M. L.	0°C E.	0°C L.	-2°C E.	-4°C E.
ADANA	05/02	03/03	03/02	11/04	01/01	12/04	04/01	06/03	25/11	28/12	10/11	25/12	14/11	29/12	17/12	-
ADIYAMAN	20/03	24/03	01/01	12/04	06/03	06/05	07/02	10/04	07/11	25/12	06/11	12/12	12/11	27/12	13/11	06/12
AFYON	11/04	01/05	15/03	09/05	02/04	16/05	20/03	17/05	02/10	18/11	18/09	11/11	04/10	20/11	19/10	19/10
AĞRI	02/05	25/05	09/04	16/06	14/04	05/07	29/03	13/05	27/09	11/11	01/09	19/10	19/09	30/10	29/09	03/10
AKSARAY	11/04	26/04	21/03	04/05	11/04	20/06	20/03	05/05	18/10	03/12	17/09	06/11	04/10	11/11	19/10	19/10
AMASYA	27/03	28/04	21/02	02/05	14/03	03/05	10/03	25/04	13/10	21/11	08/10	15/11	26/10	07/12	28/10	01/11
ANKARA	20/04	20/04	09/03	01/05	02/04	23/05	20/03	05/05	18/10	10/12	04/10	13/11	19/10	30/11	01/11	08/11
ANTALYA	15/02	22/02	05/01	15/03	03/01	26/03	05/01	16/03	07/12	26/12	11/11	27/12	07/12	27/12	-	-
ARDAHAN	15/06	15/06	01/05	25/06	10/05	30/06	26/04	20/06	04/08	28/10	01/07	24/09	16/08	09/10	05/09	05/09
ARTVİN	01/04	17/04	13/02	02/05	16/03	11/05	15/03	01/05	18/10	09/12	27/10	07/12	03/11	21/12	10/11	15/11
AYDIN	14/03	15/03	24/01	10/04	21/02	15/04	18/01	24/03	08/11	27/12	30/10	17/12	12/11	26/12	25/11	-
BALIKESİR	24/03	10/04	01/03	26/04	15/03	10/05	20/02	22/03	07/11	27/12	18/10	16/11	19/10	29/12	02/11	11/11
BARTIN	01/04	25/04	06/03	15/05	30/03	15/05	14/03	25/04	26/10	27/12	30/09	18/11	27/10	30/11	01/11	12/11
BATMAN	28/03	17/04	04/02	21/04	16/03	02/05	06/02	16/04	06/11	19/12	19/10	12/12	06/11	23/12	06/11	15/11
BAYBURT	02/05	24/05	23/03	15/06	11/04	29/06	02/04	23/05	25/09	06/11	01/08	08/10	05/09	31/10	05/09	15/10
BİLECİK	10/04	11/04	06/03	29/04	25/03	16/05	23/03	04/05	25/10	13/12	07/10	16/11	27/10	23/12	08/11	11/11
BİNGÖL	17/04	20/04	10/03	27/04	23/03	02/05	12/03	30/04	18/10	04/12	06/10	26/11	21/10	15/12	30/10	12/11
BİTLİS	21/04	01/05	26/03	03/05	03/04	07/06	25/03	07/05	27/09	01/12	06/10	12/11	19/10	05/12	30/10	05/11
BOLU	20/04	01/05	15/03	20/05	30/03	23/05	24/03	05/05	17/10	03/12	26/09	09/11	04/10	19/11	07/10	02/11
BURDUR	11/04	11/04	26/02	05/05	27/03	15/05	02/03	17/05	27/10	10/12	24/09	07/11	27/10	17/12	04/11	09/11
BURSA	25/03	25/03	03/03	25/04	15/03	14/05	20/02	18/04	07/11	27/12	19/10	22/11	03/11	08/12	10/11	05/12
ÇANAKKALE	24/03	24/03	14/02	10/04	06/03	25/04	20/02	14/04	07/11	26/12	29/10	27/12	09/11	26/12	12/11	09/12
ÇANKIRI	23/04	03/05	18/03	15/05	30/03	20/05	14/03	04/05	18/10	17/11	23/09	05/11	29/09	06/11	07/10	27/10
ÇORUM	02/05	20/05	24/03	23/05	25/04	25/05	20/03	09/05	18/10	20/11	05/09	27/10	24/09	05/11	02/10	19/10
DENİZLİ	15/03	11/04	08/02	11/04	07/03	26/04	20/02	10/04	07/11	29/12	19/10	11/12	10/11	25/12	11/11	25/11
DİYARBAKIR	12/04	23/04	19/02	24/04	21/03	07/05	25/02	16/04	06/11	15/12	21/10	12/12	02/11	13/12	07/11	10/11
DÜZCE	25/03	11/04	22/02	25/04	22/03	11/05	14/03	16/04	26/10	18/12	20/10	23/11	29/10	01/12	02/11	11/11
EDİRNE	16/03	10/04	27/02	10/04	21/03	08/05	03/03	17/04	22/10	19/12	07/10	10/11	18/10	26/12	30/10	09/11
ELAZIĞ	12/04	23/04	23/02	06/05	13/03	06/05	16/03	25/04	29/01	02/12	19/10	02/12	26/10	14/12	06/11	12/11
ERZİNCAN	20/04	26/04	08/03	06/05	30/03	24/05	15/03	30/04	18/10	19/11	23/09	06/11	15/10	18/11	20/10	02/11
ERZURUM	03/06	03/06	18/03	22/06	10/05	30/06	12/04	04/06	25/09	04/11	03/07	07/10	19/08	19/10	05/09	05/09
ESKİŞEHİR	23/04	05/05	10/03	23/05	16/04	21/06	22/03	22/04	20/11	20/11	12/09	05/11	23/09	05/11	12/09	13/10
GAZİANTEP	20/03	12/04	18/02	12/04	30/01	26/04	27/01	11/04	06/11	18/12	19/10	11/12	06/11	20/12	06/11	13/11
GİRESUN	03/03	06/03	20/01	23/03	11/03	26/04	10/03	25/04	07/11	27/12	08/11	27/12	04/12	30/12	-	-
GÜMÜŞHANE	23/04	02/05	13/03	25/05	09/04	13/06	27/03	23/05	03/10	12/11	05/09	05/11	07/10	13/11	20/10	20/10
HAKKARİ	17/04	23/04	17/03	13/05	26/03	13/05	31/03	08/05	19/10	03/12	17/10	05/12	19/10	12/12	28/10	06/11
HATAY	03/03	04/03	24/01	20/03	01/01	11/04	08/01	24/03	13/11	27/12	08/11	28/12	14/11	29/12	14/11	-
IĞDIR	23/04	24/04	04/03	25/04	27/03	08/05	15/03	22/04	18/10	23/11	24/09	13/11	07/10	13/11	21/10	02/11
ISPARTA	11/04	19/04	07/03	03/05	11/04	30/05	02/03	04/05	26/10	10/12	19/09	01/11	04/10	17/11	04/10	29/10
İÇEL	-	28/02	02/01	03/03	23/01	17/03	04/01	16/03	24/12	26/12	20/09	27/12	25/12	25/12	-	-
İSTANBUL	07/03	16/03	22/01	24/03	01/03	29/04	20/02	15/04	07/11	27/12	04/11	18/12	12/11	26/12	09/12	-
İZMİR	20/02	07/03	19/01	17/03	20/02	10/04	22/01	23/03	08/11	30/12	13/11	27/12	10/12	24/12	-	-
K.MARAŞ	20/03	26/03	23/01	12/04	28/02	16/04	07/02	10/04	11/11	26/12	06/11	14/12	12/11	26/12	13/11	06/12
KARABÜK	25/03	26/04	19/03	27/04	23/03	09/05	16/03	14/04	04/11	21/11	22/10	25/11	22/10	07/12	10/11	10/11
KARAMAN	16/04	02/05	24/03	15/05	11/04	24/05	10/03	17/05	18/10	02/12	13/09	30/10	29/09	06/11	08/10	19/10
KARS	10/05	03/06	15/04	11/06	03/05	12/06	10/04	23/05	26/09	05/11	05/09	13/10	05/09	18/10	13/09	03/10
KASTAMONU	25/04	09/05	22/03	20/05	02/04	21/05	29/03	13/05	14/10	11/11	12/09	04/11	03/10	13/11	07/10	01/11
KAYSERİ	26/04	09/05	23/03	15/06	24/04	15/06	15/03	14/05	04/10	11/11	01/09	16/10	11/09	31/10	26/09	02/10
KIRIKKALE	11/04	24/04	03/02	28/04	22/03	06/05	10/03	05/05	26/10	25/11	04/10	06/11	08/10	23/11	01/11	03/11
KIRKLARELİ	19/03	10/04	12/03	18/04	18/03	04/05	13/03	17/04	22/10	26/12	03/10	30/11	29/10	26/12	02/11	05/11
KIRŞEHİR	20/04	26/04	01/03	16/05	28/03	17/05	20/03	08/05	18/10	20/11	30/09	11/11	10/10	18/11	19/10	01/11
KİLİS	07/03	20/03	03/02	12/04	10/03	26/04	07/02	10/04	11/11	25/12	19/10	14/12	13/11	31/12	13/11	06/12
KOCAELİ	07/03	19/03	06/02	10/04	06/03	11/04	20/02	14/04	06/11	27/12	05/11	30/12	09/11	28/12	12/12	12/12
KONYA	24/04	24/04	14/03	15/05	26/03	30/05	16/03	17/05	20/10	20/11	24/09	29/10	08/10	14/11	13/10	03/11
KÜTAHYA	22/04	01/05	22/03	15/05	19/04	07/06	22/03	17/05	02/10	15/11	08/09	30/10	04/10	11/11	13/10	19/10
MALATYA	11/04	12/04	27/02	23/04	16/03	12/05	08/03	20/04	03/11	12/12	06/10	03/12	06/11	14/12	09/11	12/11
MANİSA	07/03	10/04	20/01	11/04	07/03	01/05	06/02	10/04	07/11	27/12	18/10	22/11	05/11	27/12	11/11	08/12
MARDİN	21/03	11/04	04/02	20/04	28/02	21/04	02/03	20/04	07/11	31/12	08/11	31/12	11/11	31/12	12/11	13/11
MUĞLA	15/03	10/04	20/02	17/04	07/03	02/05	19/02	18/04	07/11	29/12	28/10	12/12	01/11	20/12	11/11	25/11
MUŞ	17/04	01/05	20/03	07/05	01/04	24/05	23/03	02/05	18/10	01/12	01/10	08/11	09/10	05/12	20/10	02/11
NEVŞEHİR	25/04	02/05	11/03	16/05	11/04	15/06	27/03	17/05	03/10	10/11	05/09	29/10	02/10	21/11	15/10	19/10
NİĞDE	12/04	26/04	13/03	05/05	03/04	30/05	24/03	14/05	14/10	01/12	03/10	06/11	06/10	15/11	19/10	02/11
ORDU	09/03	09/03	04/02	27/03	25/02	06/05	20/02	25/04	06/11	24/12	04/11	23/12	12/11	25/12	05/12	-
OSMANİYE	27/01	17/03	02/02	18/03	17/02	06/04	07/03	07/03	-	31/12	24/11	11/12	10/11	11/12	12/12	13/12
RİZE	20/03	05/04	23/01	05/04	06/02	17/04	18/02	24/04	08/11	24/12	09/11	28/12	04/12	31/12	27/12	28/12
SAKARYA	16/03	19/03	11/02	21/04	26/02	06/05	19/02	10/04	30/10	27/12	19/10	22/12	09/11	31/12	20/11	12/12
SAMSUN	06/03	19/03	04/02	11/04	20/02	29/04	20/02	16/04	06/11	27/12	08/11	29/12	12/11	25/12	12/11	-
SİİRT	20/03	22/03	13/02	17/04	16/03	01/05	22/02	16/04	05/11	19/12	02/11	18/12	12/11	27/12	12/11	13/11
SİNOP	03/03	19/03	07/01	28/03	06/02	21/04	22/02	16/04	06/11	27/12	06/11	28/12	12/11	17/11	24/12	-
SİVAS	26/04	01/05	19/03	20/05	19/04	15/06	28/03	16/05	03/10	10/11	05/09	28/10	28/09	23/12	07/10	15/10
Ş.URFA	07/03	20/03	24/01	05/04	02/03	17/04	25/01	10/04	12/11	25/12	06/11	20/12	12/11	07/12	13/11	06/12
ŞIRNAK	21/03	19/04	16/03	19/04	19/03	14/04	27/02	05/04	12/11	23/12	09/11	05/12	30/10	24/12	18/11	19/11
TEKİRDAĞ	07/03	19/03	22/01	10/04	06/03	27/04	20/02	17/04	28/10	26/12	26/10	27/12	30/10	20/11	11/11	23/11
TOKAT	10/04	11/04	05/03	09/05	29/03	15/05	10/03	08/05	27/10	21/11	02/10	22/11	27/10	14/11	27/10	04/11
TRABZON	20/03	05/04	20/01	05/04	06/02	20/04	24/02	24/04	08/11	27/12	18/11	28/12	04/12	30/12	05/12	-
TUNCELİ	12/04	17/04	28/02	27/04	24/03	09/05	15/03	20/04	27/10	05/12	03/10	14/12	20/10	14/12	06/11	11/11
UŞAK	11/04	25/04	05/03	14/05	27/03	26/05	20/03	04/05	26/10	09/12	04/10	08/11	18/10	11/12	27/10	08/11
VAN	23/04	24/04	06/03	03/05	13/04	30/05	31/03	23/05	18/10	01/12	18/09	12/11	11/10	02/12	19/10	20/10
YALOVA	16/03	25/03	04/02	25/04	19/03	11/05	20/02	09/04	07/11	27/12	24/09	31/12	13/11	31/12	13/11	12/12
YOZGAT	26/04	09/05	07/03	20/05	25/04	23/05	30/03	18/05	02/10	09/11	05/09	03/11	02/10	11/11	19/10	19/10
ZONGULDAK	14/03	19/03	06/02	10/04	11/03	25/04	20/02	21/04	26/10	27/12	05/11	30/12	09/11	31/12	12/12	-

Tab. 1 - Frost calendar of Turkey (1978-2012). G.M.: Grass minimum temperature (0°C), E.: Earliest, L.: Latest.
Tab. 1a - Calendario delle gelate in Turchia (1978-2012). G.M.: Temperatura minima dell'erba (0°C), E.: Earliest, L.: Latest.

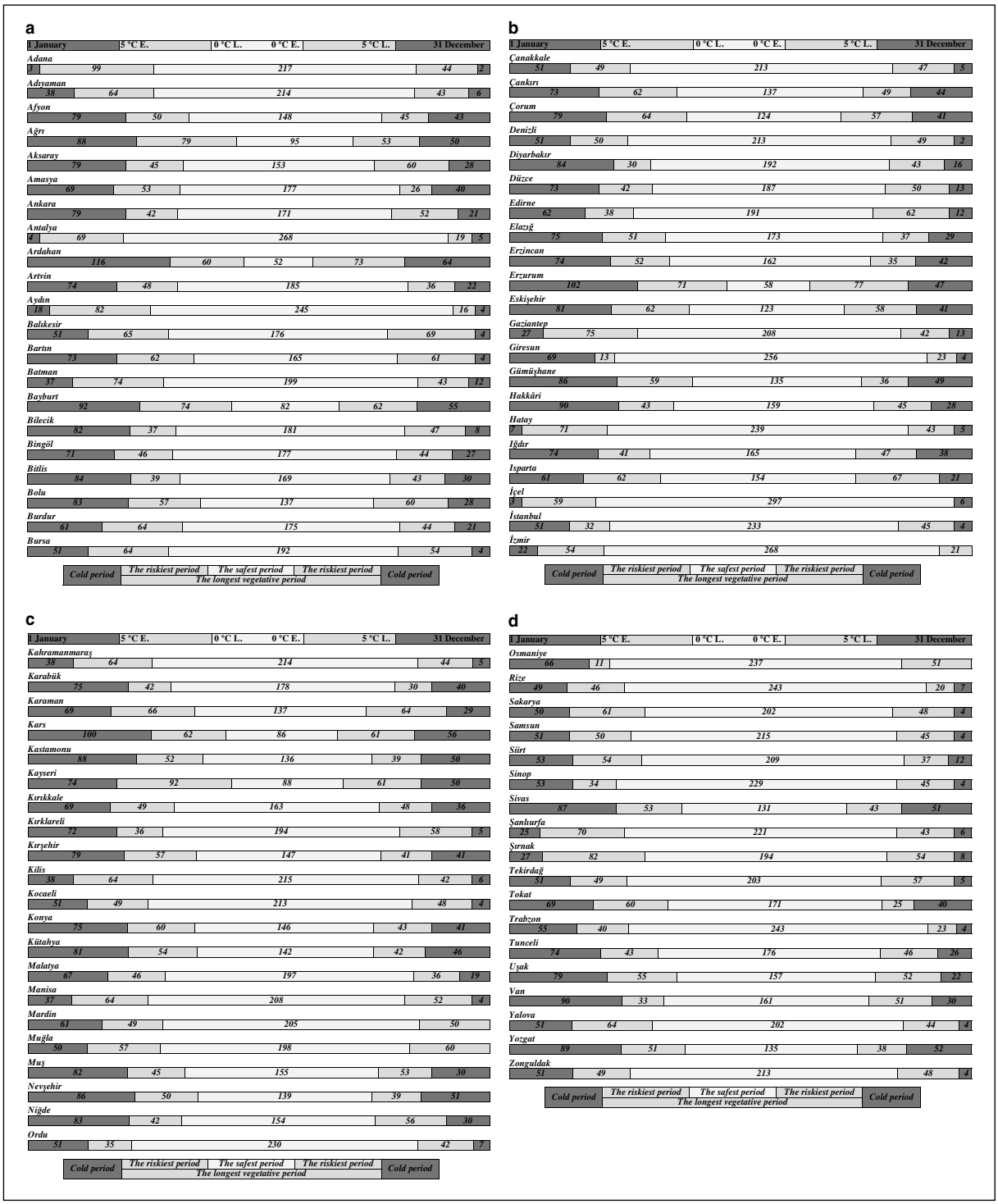

Fig. 1a-b-c-d - Critical periods for cities.
5 °C E.: The earliest date of daily average temperature for 5 °C. **5 °C L:** The latest date of daily average temperature for 5 °C.
0 °C E.: The earliest date of minimum temperature for 0 °C. **0 °C L.:** The latest date of minimum temperature for 0 °C.
Fig. 1a-b-c-d - Periodi critici per le aree urbane.
5 °C E.: *Il primo giorno con la temperature media giornaliera uguale a 5 °C.* ***5 °C L:*** *L'ultimo giorno con la temperature media giornaliera uguale a 5 °C.*
0 °C E.: *Il primo giorno con la temperature minima uguale a 0 °C.* ***0 °C L.:*** *L'ultimo giorno con la temperature minima uguale a 0 °C.*

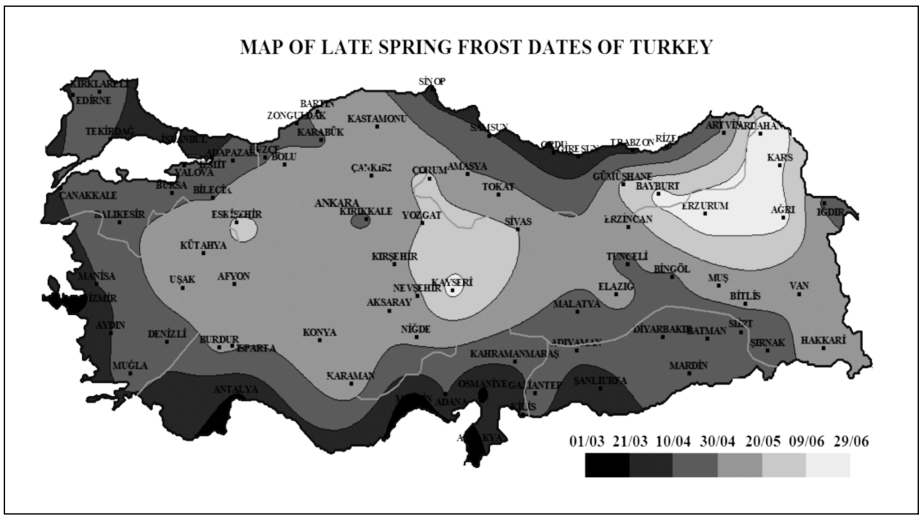

Fig. 2 - Map of late spring frost dates of Turkey.
Fig. 2 - Mappa delle date di gelate tardive primaverili in Turchia.

earliest minimum temperature was 0 °C for fall. This period was calculated via the following formula:

Julian day (0 °C E.) - Julian day (0 °C L.) (V)

where 0 °C E is the earliest date of minimum temperature for 0 °C, and 0 °C L is the latest date of minimum temperature for 0 °C.

2.2.4. The Longest Growing Season

There is frost risk particularly in the periods of late spring and early autumn. It was defined as the period between the date when the earliest daily average temperature was continuously 5 °C and above for spring and the date when the latest daily average temperature was continuously 5 °C and above for fall. This period was calculated by using the following formula:

Julian day (5 °C$_{ave}$ E.) - Julian day (5 °C$_{ave}$ L.) (VI)

where 5 °C$_{ave}$ E is the earliest date of daily average temperature for 5 °C, and 5 °C$_{ave}$ L is the latest date of daily average temperature for 5 °C.

2.3. Frost Mapping

Two frost maps were drawn by using Surfer 8.0 software in order to reveal the distribution of late spring and early fall frosts (Figs. 2-3.). In these maps, frost curves were drawn with 20-day intervals.

3. RESULTS AND DISCUSSION

Examining the Tab. 1, it is seen that 0 °C minimum, 0 °C grass minimum and 5 °C daily average temperatures have two values as earliest and latest. These two values indicate the earliest and latest dates specified in study period. In other words, it is possible to see aforementioned temperature value between two dates.

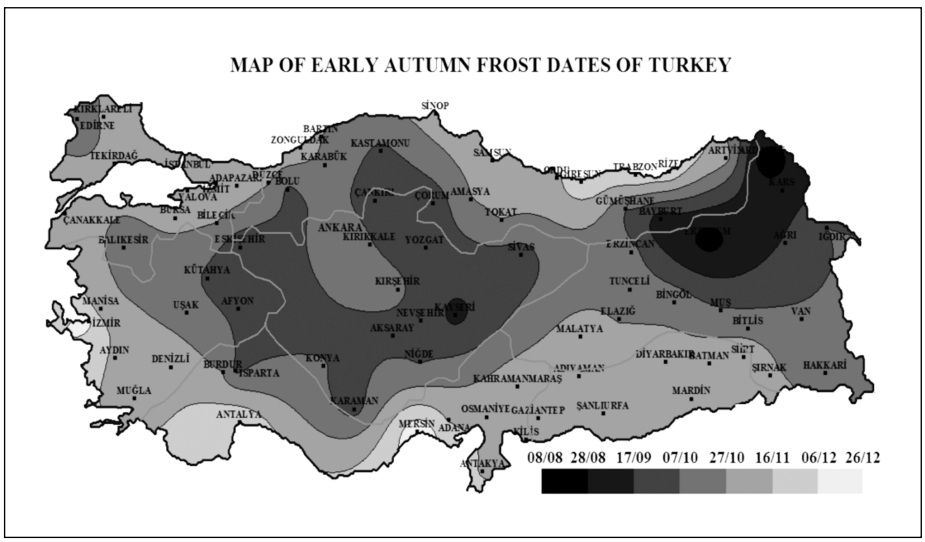

Fig. 3 - Map of early autumn frost dates of Turkey.
Fig. 3 - Mappa delle date di gelate precoci autunnali in Turchia.

Regarding 0 °C minimum temperature values, it is understood that frost risk might always be present between earliest and latest dates. Hidden icing, which is referred as the decrease of grass minimum thermometer value to 0 °C and below, can be seen between these two dates. This hidden icing in warm period should never mislead us. Hidden icing may occur early in the morning and disappear with the first radiation. One of the reasons for traffic accidents occurring in the morning hours is the hidden icing. The earliest and latest dates of growing season are considered to be useful in agricultural planning.

The critical periods shown in Fig. 1 include cold, riskiest, safest and maximum vegetative periods for each station. The safest period was determined by comparing the dates of latest spring and earliest fall. These results might never come true, but they are possible for stations. It was calculated in order to reveal the worst possible situation for stations. Rare frosts in dates of latest spring and earliest autumn can adversely affect agricultural planning. Therefore, it will be more realistic to use maximum vegetative periods. Although there are frost risks in maximum vegetative period, this period can be seen more frequently for stations. Determination of consecutive and high frequency frost events in the riskiest periods (Desjardins and Siminovitch, 1968) will make contribution to agricultural practices.

Fig. 2 and 3 illustrate the distribution of late spring and early fall frosts throughout Turkey. The marine stations have less frost risk and shorter frost period. On the contrary, the inland stations have more frost risk and longer frost period.

Iğdir station located on high inland region has less frost risk and shorter frost period compared to its surrounding. Similarly, Kayseri and Eskişehir stations located on inland region also have more frost risk and longer frost period compared to their surroundings. North-eastern Anatolia Region is coldest, and has maximum frost risk in these two maps.

It is possible to reproduce frost maps for minimum -4, -2 °C and grass minimum 0 °C as the latest and earliest to determine the distribution of hidden icing dates (Karaoğlu, 2002).

4. CONCLUSION

a. Frost studies should be renewed frequently by taking climate changes and fluctuations into account.
b. Studies on frost prediction and determination of frost risk should be conducted in smaller scales in countries like Turkey, which has very rich geography.
c. Agricultural activities should not be done in the regions that have high frost risk. If any region has high agricultural potential and high frost risk, active and passive frost prevention methods should be applied.
d. Monitoring moderate and severe frost dates and frequency is very important in order to direct agricultural studies in the right way.
e. The dates of hidden icing are very significant in terms of traffic and applied meteorology, and these dates should never be ignored.
f. Identifying the length and variations of maximum vegetative period is considered to be very beneficial for agricultural planning.
g. It is concluded that the safest period cannot be very useful in frost calendar studies. Using maximum vegetative period and identifying consecutive and high frequency frosts in the riskiest periods of maximum vegetative period would be more proper.
h. Mapping frost events by region or country is significant in terms of assessing and comparing many different features.

REFERENCES

Baier W., Edey S.N., 1970. Grass minimum temperatures. Greenhouse-garden-grass, Vol. 9, No. 2. Ottawa, Ontario.

Bootsma A., 1976. Estimating grass minimum temperatures from screen minimum values and other climatological parameters. Agricultural Meteorology, Volume 16, Issue 1, February 1976, Pages 103-113.

Cittadini E. D., de Ridder N., Peri P.L., van Keulen H., 2006. A method for assessing frost damage risk in sweet cherry orchards of South Patagonia. Agricultural and Forest Meteorology 141 (2006) 235-243.

Connor A.J., 1949 (English). The frost-free season in British Columbia. Canadian Department of Transport, Meteorological Division. Toronto. 20 pp.

Desjardins R.L., Siminovitch D., 1968. Microclimatic study of the effectiveness of foam as a protection against frost. Agr. Meteorol. 5 (4), pp. 291-296.

Ellenberg H., 1956. Wuchsklima-Gliederung von Hessen 1:20000000, nördl. Und südl. Teil. Stuttgart: Reise und Verkehrsverlag.

Field Crops, 2009. Ankara University Agricultural Faculty Publications. Public. No: 1569. Textbook: 521.

Georg J.G., Wallis W.R., 1968. Soil surfaces temperatures vs. two inch air temperature. (Unpublished research report, National Weather Service, Lakeland, Florida).

Glossary of Meteorology, 1959 (English). American Meteorological Society, Boston, Mass. 638 pp.

Gloyne R.W., Lomas J., 1980. Lecture notes for training class II and class III agricultural meteorological personnel. WMO-No. 551, p. 142-149.

Jacobsen S. E., Monteros C., Christiansen L., Bravo L.A., Corcuera L.J., Mujica A., 2005. Plant responses of quinoa (*Chenopodium quinoa* Willd.) to frost at various phenological stages. Europ. J. Agronomy 22 (2005) 131-139.

Joos L.A., 1960. Freeze probabilities in Illinois. Bulletin 650 Illinois Agr. Expt. Stn. Urbana Illinois. 16 pp., 10 maps.

Kacar B., 1996. Plant physiology. Ankara University Agricultural Faculty Publications. Public. No: 1447. Textbook: 427. Ankara, Turkey.

Karaoğlu M., 2002. Frost and Frost Calendar of Turkey. Turkish State Meteorology Service Publications. Public. No. 2002/01. 114 pp. Ankara, Turkey.

Lindkvist L., Chen, D., 1999. Air and soil frost indices in relation to plant mortality in elevated clear-felled terrain in Central Sweden. Climate Res. 12, 65-75.

Lindkvist L., Gustavsson T., Bogren J., 2000. A frost assessment method for mountainous areas. Agricultural and Forest Meteorology 102 (2000) 51-67.

Lomas J., Shashhoua Y., Cohen A., 1989. Mobile surveys in agrotopoclimatology. Meteorologische Rundschau 22, 96-101.

Nichols E.S., 1920. Notes on damage to fruit by low temperatures; prediction of minimum temperatures. Monthly Weather Review 16, Supplement, pp. 37-45.

Odin H., Eriksson B., Perttu K., 1983. Temperature climate maps for Swedish forestry. SLU-Swedish University for Agricultural Sciences, Dept. For. Ecol. For. Soils, 451-57 (in Swedish with English abstract and figure text).

Pouteau R., Rambal S., Ratte J. P., Gogé F., Joffre R., Winkel T., 2011. Downscaling MODIS-derived maps using GIS and boosted regression trees: The case of frost occurrence over the arid Andean highlands of Bolivia. Remote Sensing of Environment 115 (2011) 117-129.

Tosun O., Gökçora H., Şehirali S., 1977. Plant breeding. Ankara University Agricultural Faculty. Duplication No:7. Ankara, Turkey.