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Modeling of Climate Effects on Sugar Beet Growth in Kurdistan Province

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Abstract

Climate is one of the most important factors that influence the quality and quantity of crops. Understanding the natural features of any region, especially about the climate, can play a major role in making plans and land use planning. Sugar beet, is one of the major industrial plants, that in addition to producing one of the most fundamental basic needs of society, namely sugar, it can have other valuable byproducts. This study was conducted to evaluate the agro-climate of cultivation of sugar beet in Kurdistan province, using the daily temperature over a period of 10 years. Agro-climatic calculations and analysis were performed using the degree of active days index, thermal gradients and deviations from optimal conditions methods. In this study, data of the synoptic meteorological stations in Kurdistan province (daily and monthly and annual reports) were received from National Meteorological Organization. This research is done in a descriptive statistics way. Data analysis is performed using phenological index (GDD) method. The results show that based on analysis of thermal gradients and deviations from optimal conditions at different altitudes, Saghez station, amongst all selected stations, has more suitable conditions for cultivation. Based on the temperature thresholds of phenological stages of sugar beet, climatic calendar would be in form of sugar beet sowing season late in March and crop harvest season in late October.

Keywords: Modeling, Sugar beet, Thermal gradient, Deviation from optimal conditions, Phenology, Kurdistan province

Introduction

While modelling sugarbeet technological processes, a focus should be placed on agroclimatic parameters, soil physical maturity, crop growth stages, and physiological needs [16]. When spring is early, sugar beet is sown earlier, which provides a longer period of sunshine interception for crops [13], but does not always mean an early beginning of vegetation. The lowest base air temperature at the sugar beet field was recorded to be +3–5°C [6, 18, 12]. Sugar beet sowing time also depends on the cultivation technology chosen and is influenced by soil moisture. Some authors indicate that soil surface can be loosened when the soil moisture is 20.0–25.0%[17]. For most plants, phenological development is strongly related to the. accumulation of heat or temperature units above a threshold or base temperature below which little growth occurs. This lower threshold temperature varies with plant species [2, 3]. Growing degree days

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have proven useful for scientists, crop consultants, and producers who use them to predict plant development rate and growth stage [11, 5]. Sugar beets emerge the fastest when the soil moisture in the seedbed is 20–23 %, and air and soil temperature ranges between 15–25°C [4, 20, 19]. In Europe, sugar beets are sown from March 20 to May [19]. Depending on the geographical region of sugar beet cultivation, the yield potential can range from 11–40 % [14]. A delay in sowing by on average one day results in a root yield loss of 300 kg ha-1, and 50 kg ha-1 of white sugar [1, 9]. In Lithuania, during the period 1934–1975, the early-sown sugar beet crops produced 22.3–8.1% of bolters, which deteriorated technological crop properties [10]. Root biomass potential of sugar beet varieties ranged from 35 t ha-1 [6, 8, 13]. Early sown sugar beets always have enough time to mature, therefore their technological properties are better [15]. Sugar beet varietal disease resistance increases their biopotential [13, 7]. Sugar beet biomass potential is influenced by crop stand density or seed germination [18].

Materials and Methods

In this study, the mini and maxi daily temperatures during the period of 2001-2011 from synoptic stations of Kurdistan province have been used. (Kurdistan Province Meteorological Organization, 1986-2011) Table (1).

Table 1. Characteristic of Kurdistan Province Meteorological Stations

Altitude, m	Longitude		Latitude		Station
	degree	minute	degree	minute	
1522.8	46	16	36	15	Saghez
1906	47	48	35	10	Ghorveh
1373.4	47	00	35	20	Sanandaj
1883.4	47	37	35	53	Bijar

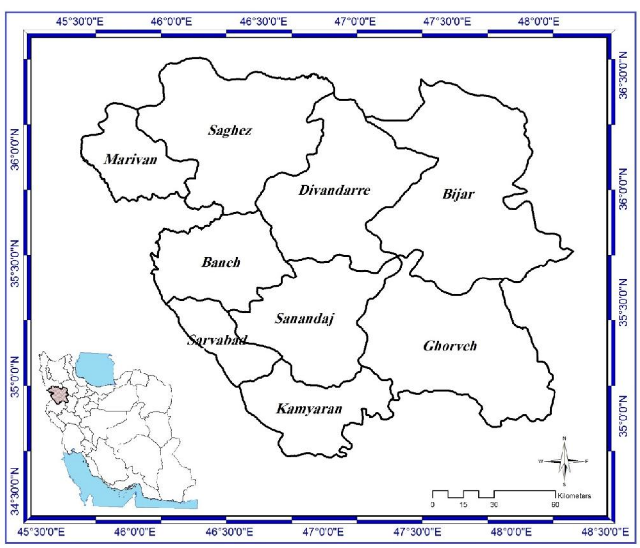

Figure 1. Study Area

1- Thermal Gradient Method

In order to study the relationship of temperature of study area with deviation from optimal condition in different altitudes or time optimal conditions, it was necessary to use the thermal gradient to obtain the temperature of altitude points where there was no station.

To obtain the temperatures, the linear regression method was used. Using linear regression, coefficients of variation of temperature with altitude, were calculated for the months of the year and the whole year. Following equation was used to calculate the curve equation (b+ ax= y).

In this equation, (y) the expected value (dependent variable), (x) the most important variable which predictions will be based on that (the independent variable), (a) constant coefficient known as intercept and (b) line slope or thermal gradient slope showing the thermal decrease with altitude.

Following equations are used to calculate a and b:

Eq (1)

$$a= \frac{\sum(y) \sum (X^2) - \sum(x) \sum (xy)}{N\sum X^2 - (\sum X)}$$

Eq (2)

$$b= \frac{N\sum XY - (\sum X) (\sum Y)}{N\sum X^2 - (\sum X^2)}$$

To achieve results and calculate the above equations, first, table of correlation elements for selected stations and time intervals was formed; that will be mentioned as the monthly and annual correlation elements of selected stations.

2- Method of deviation from the optimal conditions

Determination of the optimal time for each area, based on weather stations' data and daily temperature of crop growth is important. There are three phenological stages for sugar beet plant and each stage has an optimal temperature, at which the maximum growth rate occurs at this temperature. Identifying and determining the optimal point for each phenological stage and the mean daily temperature resulted from monitoring mini and maxi daily temperatures; one can determine various optimal times, particularly months of a year, and actually, the time which has the least deviation from the optimal condition, would be considered as the optimal time. In this method, to obtain the optimal of different time intervals, optimal points or optimal temperatures were first determined and then, considering the average of daily data, deviations from the optimal conditions were calculated for 3 decades of each month. For this reason, first, each month was divided into three different decades, and then, the average of each decade was calculated, that in total, the averages of 36 decades are calculated for each station. Next, the deviations of the averages from the optimal points are calculated; consequently, the deviations from the optimal conditions are obtained for the above time intervals and the results are tabulated.

3- Method of thermal coefficient or total degrees of active days

Most biological changes such as the growth of plants and some hydrological phenomena are a function of the ambient temperature. For this purpose, the index of degree - days will be used as thermal need. Each process is activated from a certain temperature threshold, and the growth value depends on the number of degree - days more than this threshold. If the number of degree – days is zero or a negative value, that day would have no effect on growth. In order to grow in a specific area, each plant requires a certain number of degree-days that the area must be able to supply throughout the growth period. Other wise, even if water is available in the area, the plant should not be recommended for planting in agricultural projects. Therefore, growth season in each area is defined as the longest continual period in which the number of degrees - days required to supply the plant is provided. To determine the thermal need of plants, method of the total of effective temperatures is implemented.The principle of this method is to calculate the total summation of effective temperatures, i.e.temperatures above the base zero biological zero of a plant. This temperature depends on the type of the plant. $4C^{\circ}$ for sugar beet is calculated by the following equation.

$$H_U = \sum_{i}^{n} \left[\frac{T_M + T_m}{2} - T_t \right]$$ Eq (9)

H_U : Thermal unit (degree-days) accumulated in N days.

T_M : Maximum daily temperature

T_m : Minimum daily temperature

T_t : Base temperature

N: Number of days in a selected period

In order to cultivate sugar beets must positive total the temperature of $2900C^{\circ}$ awakening to harvesting - arrives the degree-days. Therefore, in this study we have used the method of calculating degree-days. In this study, the active method, amongst the most common methods to estimate thermal units, is used. To calculate the summation of temperature, there are two main methods including effective total and active total, and active sum method is used in this study.

A – Sum of degrees of active days

To sum up the temperature, the values of all daily temperature (without subtracting the base temperature) and during the period of active growth, are added together. Computational equation is as follows.

$$\frac{TMin + Tmax}{2} \quad \text{If the} \quad \frac{TMin + TMax}{2} >= Tt$$ Eq (4)

In this equation, tmin, tmax are the mini and maxi daily temperature, respectively, and Tt is a biological temperature. In active temperatures method that has been used in this study, the total sum of positive daily temperature is used; but only for the days when the average temperature is greater than the biological threshold or biological zero point. All values more than $5C^{\circ}$ will be considered and values less than $5C^{\circ}$ will not.

Results

Phenology results

Application of thermal coefficients in agricultural problems and the regulation of agricultural calendars in different areas are of significance. In spite of lack of the extensive phenological studies, using agricultural meteorological studies conducted by Quanta engineers with cooperation of Romanian consultants an applying their methods, active days degree and determination of length of phenological stages were studied according to various thresholds.

Optimal time, based on active days degree method

Another method to determine the optimal time for agricultural climate, based on the latest incidence of mini thresholds at each phenological stage of sugar beet, is active temperatures' method is that it is used in this study. The total daily temperatures with positive values are used, but only for the days when the temperature is greater than the average of biological thresholds or zero point of activity. In this study, the basis for calculating the thermal coefficients has two types: one based on a mini threshold of sugar beet plants at each stage, and the other is zero degrees Celsius. Thermal thresholds of sugar in different phenological stages are illustrated in table (2).

Table 2. Temperature thresholds of sugar beet in phonological stages

Desired temperature	Lowest degrees Celsius	Phonological stages
20-25	-5 to -7	germination
27-30	-1 to -2	growing
16-20	-	fully ripen

Since plant species are highly dependent on temperature, the monitored daily mini temperature is used for phenology of the sugar beet plan. By specifying thresholds of phenological stages of sugar beet and accurate daily temperatures, completion date of each stage is calculated. For all stations, incidence date of mini threshold of sugar beet cultivation at $4C^{\circ}$ is considered. In order to obtain the completion date of phenological stages of sugar beet in germination stage 125, the juvenile stage (growth) 1000, fully ripen stage of sugar beet, 2900 thermal units is necessary. According to Table 3, the earliest date of germination and growth and ripening of sugar beet occurs in Saghez, Ghorveh, Sanandaj and Bijar stations, respectively. Completion dates of phenological stages of sugar beet in selected stations are shown in Table (3).

Table 3. Completion date phenological stages of sugar beet in selected stations

Fully ripening date	Growth date	Germination date	Minimum threshold incidence date	Altitude	Station
30 September	29 June	3 May	8 April	1906	Ghorveh
23 September	24 June	21 April	23 March	1522	Saghez
3 October	12 July	7 May	13 April	1373	Sanandaj
5 October	17 July	9 May	11 April	1883	Bijar

Completion date of each phenological stage is also considered a suitable method for determining the best time for sowing of sugar beet, based on its critical threshold. Obtained dates are consistent with their optimal time.

Deviation from optimal conditions

Three phenological stages have been considered in beet plant; each stage has an optimum temperature, in which, the maximum growth rate occurs. In order to study the sugar beet plant species, according to this study, plant varieties are suitable for mid-mature product. Table 4 shows the deviation from the optimal conditions for each phenological stage of sugar beet based on the average daily temperature at selected stations. According to the results of germination stage of sugar beet cultivation, Saghez station has less deviation and more optimal conditions than the other stations. In the juvenile stages (growth), Saghez and Ghorveh station have less deviation than the other stations; however, there are not significant differences in terms of deviations from optimal conditions. The fully ripening stages of sugar beet, Saghez and Ghorveh Stations have lower deviations; consequently, in all stages, Saghez station has least deviation from optimal condition, this means that this station has the optimum conditions for the cultivation of sugar beet.

Table 4. Determining the deviation from optimal condition of sugar beet phenological stages in selected stations

Total deviations	Fully ripening		growth		germination		Growth stages / station
	Deviation from condition	optimum	Deviation from condition	optimum	Deviation from condition	optimum	
-34.43	-10.66	16-20	-16.18	27-30	-7.59	20-25	Ghorveh
-32.56	-9.85	16-20	-15.86	27-30	-6.85	20-25	Saghez
-3446	-11.09	16-20	-16.39	27-30	-6.98	20-25	Sanandaj
-34.74	-11.05	16-20	-16.20	27-30	-7.44	20-25	Bijar

Deviation from optimal conditions based on altitude

Thermal gradient

In order to evaluate the deviation from optimal conditions at different altitudes, or the optimal spatial position based on the altitude, first, using the linear regression, coefficients for changes in daily temperature as a function of altitude are calculated for months and whole year. To achieve results, and calculate the above relationships, first, table of correlation elements for selected stations and all time periods of study, were formed, that results are summarized in Table (5) as the annual correlation of the selected stations.

Table (5). Elements of annual correlation of selected stations in Kurdistan province in phenological stages (thermal gradient)

Sugar beet ripening	Growth	Germination	Stage / Coefficients
0.001	-0.0006	-0.0087	B
-0.28	15.95	27.78	A
0.41	0.0015	0.29	R

Areas suitable for cultivation of sugar beet

Based on the analysis of climatic factors for the cultivation of sugar beet, and agro-climatic conditions according to mentioned methods, favorable and unfavorable areas for a variety of sugar beet cultivation (springtime) in different months of study area are as follows. Early spring is the best time for sowing of sugar beet (springtime) in Kurdistan province. According to figure (2), suitable areas for sugar beet cultivation in this province includes the northwestern, northern and central regions. These areas are suitable due to their environmental characteristics and living conditions for sugar beet plant; while other areas such as the southeastern regions are not suitable for cultivation of this crop.

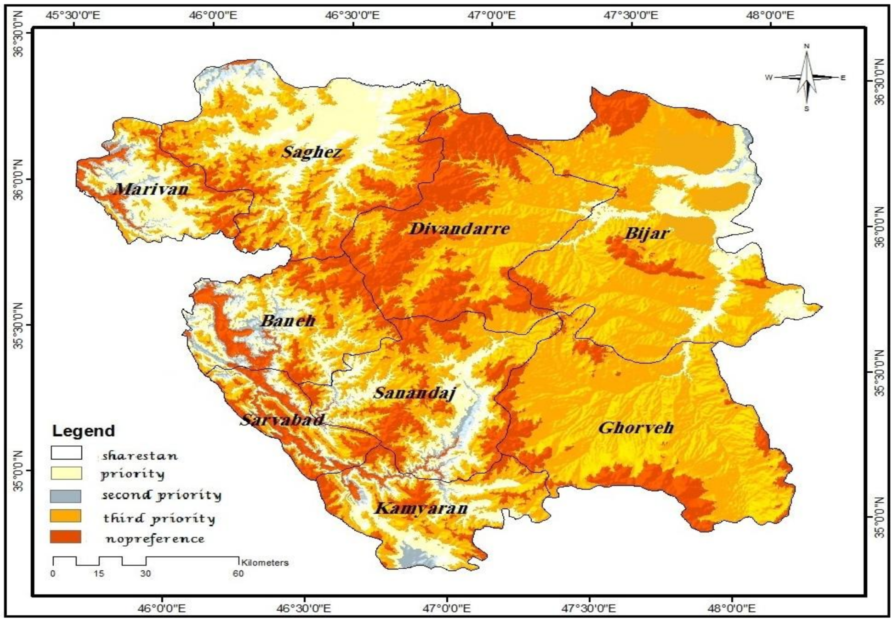

Figure (2). Total deviation from the optimal conditions for sugar beet

Conclusions

The environment, in which we live, consists of a series of factors including weather conditions and climatic related phenomena Weather conditions, is one of the factors determining the type of plants that are cultivated in any region. Agricultural activities are highly interconnected with natural factors and climate and environmental conditions. Weather condition is on top of the natural factors affecting agricultural activities, by which it affects the agriculture, either with a single element or a combination of several elements. Iran, having a special climate in each area, has suitable ground for production of various strategic agricultural crops and climatic parameters, illustrate different types of climates in the territory. Knowing the God-given gifts and the need of the region for researches like this, which shows the local agro-climatic potentials for cultivation of sugar beet, this study is conducted. The results are as follows.The optimal place to grow sugar beets in the Northwestern region has a significant potential. In fact, Saghez station has a lower deviation from the optimal conditions, resulting in favorable conditions for the cultivation of sugar beet in comparison with the other stations. Completion date of phenological stages in sugar beet ripening time occurs earlier in Saghez station than other stations. In total, Saghez station experiences supplementary phenological stages of other phenological periods, earlier, as well. Best calendar for sugar beet cultivation by agro-climatic analysis, is mid-April, is for Saghez, Ghorveh, Sanandaj, Bijar stations. Best calendar for sugar beet harvesting is late September for Saghez, Ghorveh, Sanandaj, Bijar stations, respectively. Based on analysis of thermal gradients and deviations from optimal conditions at different altitudes of the stations, Saghez station has better conditions for planting, among selected stations. This is important in terms of the timing of sowing and commercial crops cultivation. Areas suitable for sugar beet cultivation in the province are located in northwestern, northern and central regions. Mentioned areas include Saghez, Ghorveh and Sanandaj.

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