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Biology impact of climate in Kurdistan province on sunflower

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Abstract

The present article is aimed at study on agroclimatic conditions of cultivation of sunflower throughout selected substations at Kurdistan Province by means of GIS system. In this investigation, meteorological data have been received from synoptic stations based on daily, monthly, and annually trend from Iran Meteorological Organization (IMO) at Kurdistan Province and then homogeneity of data has been explored by (Wald- Wolfowitz) Run Test. Methodology of the research is of statistical descriptive type. Data analysis was carried out by means of Growing Degree Day (GDD) technique and method of Deviation from Optimum Percentage (DOP) plus phenology index as well as thermal potential within environment of statistical software (EXCEL and SPSS). Under agroclimatic conditions, the results of this survey may indicate that the time period among July and September is considered as active months in terms of agriculture based on thermal potential in this region. The early days of May are the best calendar for cultivation of sunflower month in all the aforesaid substations. Time of harvesting sunflower crop is middle August for Divandareh, Dehgolan, and Saghez substations while this time is early September for Baneh substation. With respect to the phenological method, dates of cultivation until budding, flowering, and the end of flowering stage and maturation start respectively sooner in Dehgolan substation than other substations in this region.

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Introduction

It is now universally accepted that increased atmospheric concentrations of 'greenhouse gases' are the main cause of the ongoing climate change (Forster *et al.* 2007) and that these changes are expected to have important effects on different economic sectors (e.g. agriculture, forestry, energy consumptions, tourism, etc.) (Hanson *et al.* 2007). Since agricultural practices are climate-dependent and yields vary from year to year depending on climate variability, the agricultural sector is particularly exposed to changes in climate. In Europe, the present climatic trend indicates that in the northern areas, climate change may primarily have positive effects through increases in productivity and in the range of species grown (Alcamo *et al.* 2007), while in southern areas (i.e. the Mediterranean basin) the disadvantages will predominate with lower harvestable yields, higher yield variability and a reduction in suitable areas for traditional crops (Olesen and Bindi 2002). For climate change impact assessment, crop growth models have been widely used to evaluate crop responses (development, growth and yield) by combining future climate conditions, obtained from General or Regional Circulation Models (GCMs and RCMs respectively), with the simulation of CO2 physiological effects, derived from crop experiments. Many of these impact studies were aimed at assessing crop development shifts and yield variations under changes in mean climate conditions. These analyses showed that increasing temperatures generally shortened the growing period of commercial crops (Peiris *et al.* 1996; Harrison and Butterfield 1996; Singh *et al.* 1998; Gereña *et al.* 2001; Giannakopoulos *et al.* 2009), resulting in a shorter time for biomass accumulation. On the other hand, changes in yields were not homogeneous and dependent on crop phenology (e.g. summer and winter crops), crop type (e.g. C3 and C4 plants) or environmental conditions (water and nutrient availability) (Ainsworth and Long 2005; Thomson *et al.* 2005; Brassard and Singh 2008). Other studies stressed that changes in climate variability, as can be expected in a warmer climate, may have a more profound effect on yield than changes in mean climate (Porter and Semenov 2005). Furthermore, the changes in the frequency of extreme climatic events during the more sensitive growth stages have been recognized as a major yield-determining factor for some regions in the future (Easterling and Apps 2005). Temperatures outside the range of those typically expected during the growing season may have severe consequences on crops, and when occurring during key development stages they may have a dramaticimpact on final production, even in case of generally favourable weather conditions for the rest of the growing season. Many studies highlighted the potential of heat stresses during the anthesis stage as a yield reducing factor (Challinor *et al.* 2005), while others pointed out that the joint probability of heat stress-anthesis is likely to increase in future scenarios (Alcamo *et al.* 2007). Accordingly, both changes in mean climate and climate variability (including extreme events) should be considered for a reliable climate change impact assessment in agriculture. An example is the summer heat wave of 2003 (Schär *et al.* 2004), taken as an indicator of the future climate change, which reduced cereal production in Europe by 23 MT with respect to 2002. The reason for this reduction was attributed to the shorter growing season combined with a higher frequency of extreme events, both in terms of maximum temperatures and longer dry spells (Olesen and Bindi 2004).

The main aim of this study is to explain relation between the climatic parameters and of sunflower cultivation in Kurdistan province region .

Materials and methods

Data gathering

In the current research, the parameters of the maximum and minimum daily temperatures have been used relating to statistical period (2002-2011) as well as monthly temperature during statistical career (1991-2011) at Kurdistan Province.

Fig. 1. Study region.

Thermal (temperature) Gradient Method

In order to explore into the studied region in terms of temperature and in relation with rate of deviation from optimum conditions at various heights or optimal time states based on height, it was required adapting thermal gradient technique to determine temperature in height of some points which lacked measurement substation. Linear regression method has been utilized to derive these temperatures. By the aid of linear regression, coefficients of temperature variance plus their height have been calculated for months of a year and total year. To compute line equation, the following formula was used:

$$(y = ax + b)$$

In this formula, y (independent variable) is the most important variable based on which it is predicted for the expected value (dependent variable) x. (a) denotes a fixed coefficient that is called intercept and (b) is slope or thermal (temperature) gradient that represents temperature loss along with height.

The following formulas are employed 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 derive the results and calculation of the above formulas, first a table is drawn for correlation among the components for selected substations and the studied time zones formed for each of them so that they will be mentioned as monthly and annual correlation elements for the selected substations.

Deviation from Optimum Percentage (DOP) technique

There are 4 phenological phases in sunflower plant and it has one optimum or optimal temperature per phase where its maximum growth occurs at this optimum temperature. Through identifying and determination of these optimum values for any phenological phase and mean daily temperature derived from detection of minimum and maximum daily values, one could characterize spatial optimums within various temporal intervals, particularly months of a year and in fact the points with minimum deviation from optimum conditions serve as optimal location. To achieve several spatial optimums in this method, first the optimums or optimal temperatures were determined and then by considering daily statistical mean values, derived difference from the given values about optimum point was computed and at next step, the rate of deviation from optimum conditions were acquired for the above-said locations and their results were identified as tables.

Thermal coefficient method or sum of Growing Degree Day (GDD)

With respect to importance that is attached to temperature cumulative units (degree/day) in identification and topology of appropriate regions for sunflower cultivation and determination of cultivation and harvest dates for this crop based on the given thresholds, Growing Degree Day (GDD) technique has been adapted for this purpose. The above data were processed and analyzed by means of functions in Excel software. In this investigation, the active method (GDD) was used among the common techniques for approximation of thermal units. There are two major techniques for summation of temperature as follows:

Sum of effective and active degree day method where sum of active degree day technique has been employed in this study.

a) Sum of active degree day technique

Phenology or know ledge of phenomena is one of the scientific topics in ecology in which plant's life cycle, which ranged from time of germination to permanent hibernation, is explored. With respect to climatic variations, especially temperature and soil moisture, dates of start and termination points for each period may differ in several years. To temperature, all diurnal temperature values (without subtracting base temperatures) and during active germination days are added.

The calculation formula is as follows:

(eq.3)

$$\frac{TMin + TMax}{2} \quad if \quad \frac{TMin + TMax}{2} = Tt$$

Where in this formula, T_{max} and T_{min} are the maximum and minimum daily temperatures and T_t is biological temperature in this equation. In method of sum of active degree day, which has been also used in this research, sum of daily temperature degrees was used with positive values, but they have been used only for those days in which mean temperatures were higher than biological threshold or biological zero point. All values with quantities greater than 10°C will be calculated while the values with less than 10°C will be excluded from this computation.

b) The method determining interval within the stages in phenological studies

To improve efficiency and properly use from irrigation and implementation of farming operation at any phase of growing the sunflower plant, the needed planning may be executed for growth of crop with determination of the necessary period for both phenological phases based on statistical daily temperature and indentifying interval in the given stage. For this reason, the following formula is used in order to determine the necessary time interval between two phenological phases or (inside stage) based on min temperature:

(eq.4)

$$n = \frac{A}{T - B}$$

n denotes the needed time between two phenological phases, (A) is thermal coefficient for its completion at the given step, (B) as biological threshold of crops, and (T) is daily temperature.

Findings

Analysis of Deviation from Optimum Percentage (DOP)

Sunflower plant includes four phenological phases, which are important from agroclimatic point of view and reviewed in this investigation. These stages in sunflower are as follows: Cultivation till budding, flowering, end of flowering, and total maturation. Any phase includes an optimum or best temperature in which the plant may grow at max level in this optimal temperature.

Table 1. Determining deviation from optimum conditions at phenological phases in sunflower in selected substations.

Growth phases Substation	Cultivation to budding		Flowering		End of flowering		Total matured		Sum of deviations
	Opti-mum	Deviated from conditions	Optimum	Deviated from conditions	Optimum	Deviated from conditions	Optimum	Deviated from conditions	
Divandareh	17	-8.18	17.5	-6.10	18	-6.32	20.5	-7	-27.6
Saghez	17	-9.09	17.5	-7.06	18	-7.19	20.5	-6.68	-30.02
Baneh	17	-11.80	17.5	-8.09	18	-7.10	20.5	-7.87	-34.77
Dehgolan	17	-11.67	17.5	-9.55	18	-8.69	20.5	-5.86	-35.77

In order to conduct phenological study on sunflower and with respect to the executed investigation, the mid-matured varieties of this crop with the most frequency were considered as base crop. Table (3) shows the rate of deviation from optimum conditions at any phenological stage based on mean daily temperature throughout the selected substations. With respect to derived results from the following table for sunflower plant at flowering stage, compared to other substations, Dehgolan station has the min deviation with higher optimal conditions. Then Dehgolan, Divandareh, substations have less deviation from this condition. As a result, compared to other substations, Dehgolan station has less deviation from optimum status and this means that the aforesaid station possesses optimal conditions for cultivation of sunflower.

The rate of deviation from optimum conditions based on height

Thermal (temperature) gradient

In order to review on rate of deviation from optimum conditions at various heights or spatial optimum conditions based on height, initially coefficients of variance for daily temperatures in respect of height have been calculated for months of a year and total year by means of linear regression technique. To derive the given results and computation of above formulas, firstly correlation elements table was made for the selected substations and in all studied time intervals and a summary of its results has been illustrated as annual correlation elements for the selected substations in Table (2).

Table 2. Annual correlation elements of Kurdistan province selected substations during phenological phases (Thermal gradient) for sunflower.

Period / Coefficients	Cultivation to budding phase	Flowering	End of flowering	Maturation
B	0.003	0.006	0.003	0.001
A	6.77	6.44	2.98	4
R	0.68	0.89	0,65	0.54

Benefitted from regression formula, we calculated thermal gradient table, which denotes status of variable of daily temperature in several heights and moths of a year in Excel software environment and by means of the given linear regression regarding the relationship among rate deviation from optimum conditions at any phenological phase and all of its stages and drew its diagram. Due to high R^2, zoning operation became possible in GIS environment.

Results of phenology

Application of thermal coefficients in farming issues and codification of a farming calendar in various regions is crucially important. Despite of the absence of phenological primary studies in this field at large scale and with benefitting from the agroclimatic studies conducted by quanta engineers and through cooperation with Romanian advisors and employing their used techniques, active degree days and determination of the intervals within phenological stages are explored based on various thresholds.

Temporal optimum based on method of active degree days

Active temperature degrees are one of the other agroclimatic methods for determination of optimum times based on the date of latest min threshold events at any phenological stage (sunflower) that has been used in this investigation. Sum of daily temperatures was used with positive values but only for those days with temperatures, which are higher than average biological level or zero degree of activity. In this study, the basis point for calculation of active thermal coefficients is determined based on two modes: One is based on the min thresholds of the plant (sunflower) at each of phenological stages and the latter is zero point (0C°). Given these plant species extremely depend on temperature so statistical daily temperature has been used as min and max detection data for phenology of plant species (sunflower). Date of completion for each of phenological stages has been determined with identifying accurately each of thresholds in plant's phenological phases (sunflower) and daily temperatures. Date of the min biological threshold event was considered more than 10C° to activate the plant (sunflower) in each of substations. It requires using 100, 500, 1000, and 1800 thermal units (Btu) higher than zero degree (0C°) to achieve date of completion of phenological cultivation stage (sunflower) respectively in each of cultivation stage until budding, flowering phase, at the end of flowering step, and the maturation stage. With respect to Table (3), date of cultivation until budding, flowering, end of flowering, and maturation of sunflower crop start sooner respectively in Dehgolan, and Divandareh substations than other stations. Given the related Table (3), date of cultivation until budding, flowering, end of flowering, and maturation of sunflower plant begin earlier correspondingly in Dehgolan and Divandareh substations than other stations.

Table 3. Date of completion of phenological stages in sunflower plant.

Substation	Height	Date of minimum threshold event	Cultivation until budding	Flowering	End of flowering	Total maturation
Saghez	1485	15st May	28th May	18th June	17th July	27h August
Divandareh	1365	12st May	26th May	17th June	13th July	20th August
Dehgolan	75	29th April	15th May	5nd June	4rd July	11th August
Baneh	1806	12st May	30th May	28th June	22th July	22th August

The appropriate regions for types of cultivation (sunflower)

Based on agro climatic analysis, the best cultivation calendar (of sunflower) are respectively southeast, and north and western areas at this province.

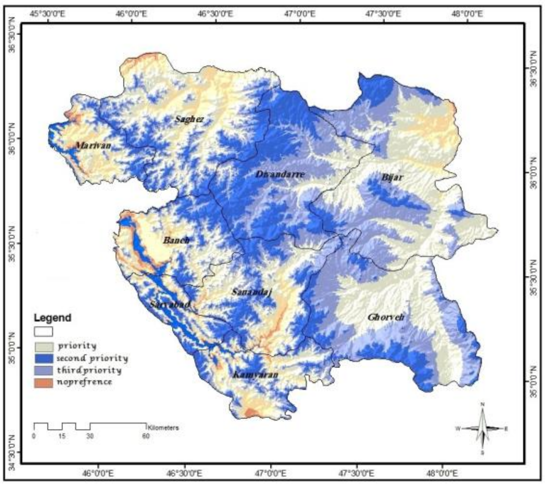

Fig. 2. Total deviation from the optimal conditions for sunflower.

Conclusion

Whereas one of the important problems in modern world is production of more foods and nutrients with higher quality and since producing agricultural crops and capabilities of any region depend on its weather and climatic and ambient specifications thus it is crucially important to study on the effective meteorological and environmental on agriculture. Today, It is deemed as a secured and undeniable platform for accurate development of agriculture. In terms of agroclimatic aspect, sunflower is considered as one of active monthly agricultural crops based on thermal potential method from June to mid October in this region. According to agroclimatic analyses, the best cultivation calendar belongs to the optimal cultivation calendar for sunflower plant in all substations at the early of may. Sunflower is harvested in Divandareh, Saghez, and Dehgolan in end August while it is harvested in Baneh substation at mid September. With respect to phenological method, dates of cultivation up to budding phase, flowering stage, end of flowering, and maturation of sunflower plant start sooner respectively in Divandareh and Dehgolan than in other substations. In Divandareh substation, sunflower has the less deviation and more optimum conditions than other substations at total maturation stage. After Divandareh, Saghez and Baneh stages have less deviation while compared to other stations, Dehgolan substation has more deviation; as a result, in comparison with other substations, Dehgolan substation has less deviation from optimum conditions; namely, this substation possesses optimal conditions for cultivation of sunflower.

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