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The Role of Climate and climatic factors on crop zoning agroclimatic sunflower cultivation in Hamedan province

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Abstract

Needs of human life from the beginning been an important factor We have been threatened by population growth, food security and human well- Men of science and technology with a new plan Maintain and improve their food security to make it work. In this investigation, meteorological data have been received from synoptic stations based on daily, monthly, and annually trend from Iran Meteorological Organization (IMO) at Hamedan 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 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 Hamedan, Nojeh, and Nahavand substations while this time is early September for Malayer 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 Nahavand substation than other substations in this region.

Key words: Agroclimate, Sunflower, Deviation from Optimum Percentage (DOP), Phenology, Hamedan

Introduction

In addition to plant's phenotype, yield of any plant is influenced by climatic conditions (Daneshian, 2008). Date of cultivation and its density also affected on elements of yield in such a way it was demonstrated that as cultivation is postponed, yield components reduced (Barros, 2004). Appropriate cultivation in various areas may increase photosynthetic efficiency and transfer photosynthetic substances and their storage in seeds and rising yield rather than affecting on rate of germinating and generative growth in plant; at the same time, due to many reasons including high temperature at early period of growth, flowering reduced time, weather coldness, and solar reduced radiations, seed yield is reduced with delayed cultivation (Daneshian, 2008). In addition to determination of appropriate time for cultivation and with selection of suitable density, which is affected by plant's genotype factors and ambient agents and essential in yield status, the possibility for optimal use of environmental factors and

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reduction of inter-species competition may be provided (Daneshian, 2008). Sunflower (*Helianthus annus L.*) as an annual plant from family of *Compositae* or *Asteraceae* and with about 40-50% oil content and high quality and adaptable to various climatic conditions and tolerant to drought may be cultivated under conditions of dry- farming and different irrigation regimes (Rahimzadeh and Najafi Mirak, 2004). The potential for production of dry- farmed sunflower under Mediterranean conditions strongly depends on available water supply and the yield ratio of consumption by the given plant (Karimzadeh et al, 2003). Overall, rather than its genotype, the yield of any plant is also influenced by climatic conditions (Mirshekari et al, 2001). In this regard, Stone et al (2001) declared that the rate of access to soil moisture is the paramount factor in determination of yield in farming plants in semi-arid regions. Pankovich et al (1999) stated that during budding stage up to the end of flowering phase, shortage of humidity may exert the maximum negative impact on yield of sunflower hybrids. In an experiment, Jaferzadeh Kenarsari and Poostini (1997) observed that occurrence of stress at graining phase might reduce seed yield but the intensity of this phase does not depend on period of flowering and pollination. Gomez et al (1991) noticed that period of germination of sunflower might reduce due to dry stress. Within study on effect of dry stress on some physiological features and elements of sunflower's yield, Kamel and Khiavi (2002) reported that water stress has reduced extremely seed yield, biomass, and period of germination period (Bang et al, 1997). The base temperature is about 6°C for growth of sunflower and it grows within mean temperature of 10 to higher than 32°C during day and night. The appropriate growth of sunflower occurs within daily mean temperatures (18-22°C). This plant may initially tolerate well to bud up to -5°C and then it becomes sensitive to coldness and will be frozen under -2°C and lower temperature at 6-foliated stage. Immature seeds may be damaged under icy condition while ripe seeds may be injured less. Sunflower has a developed rhizome, which makes this plant resistant to drought. This plant is resistant to dryness at germination growth stage and at the end of seed maturity, but it is sensitive to drought from stage of observing the calyx up to total coloration (pigmentation) of seeds. Production of sunflower under dry- farming conditions may need to at least 300-350mm precipitation during growth season (Khajehpoor, 2004; Aiken, 2005). Accordingly, any plant may reach to certain period of its growth when it has received certain rate of temperature from its ambience and this is expressed as thermal unit or temperature- day- growth so that this is exclusively a function of genotype (Gilmore and Rogers, 1985). Climatic impact on plant's growth is exerted through acceleration or retardation of growth phases. As a result, growth stages in plants may be predicted with access to the rate of needed temperature for any stage of growth in farming crops and with respect to temperature at studied region.

Materials and Method

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 Hamedan Province.

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:

$$a= \frac{\sum(y) \sum (X^2) - \sum(x) \sum (xy)}{N\sum X^2 - (\sum X)} \quad \text{(eq.1)}$$

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

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 (Shaemi, 1992).

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 knowledge 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 (Mirhaji et

al, 2006). To summate temperature, all diurnal temperature values (without subtracting base temperatures) and during active germination days are added.
The calculation formula is as follows:

$$\frac{TMin + TMax}{2} \quad if \quad \frac{TMin + TMax}{2} = Tt \qquad \text{(eq.3)}$$

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 (Ahmadi et al, 2010).

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 minimum temperature (Ahmadi, 2010):

$$n = \frac{A}{T - B} \qquad \text{(eq.4)}$$

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 maximum level in this optimal temperature. 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 (4) 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, Malayer station has the minimum deviation with higher optimal conditions. Then Malayer, Nojeh, and Hamedan substations have less deviation from this condition. As a result, compared to other substations, Malayer station has less deviation from optimum status and this means that the aforesaid station possesses optimal conditions for cultivation of sunflower.

Table 4: 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
	Optimum	Deviated from conditions	Optimum	Deviated from conditions	Optimum	Deviated from conditions	Optimum	Deviated from conditions	
Nojeh	17	-8.64	17.5	-6.24	18	-4.70	20.5	-4.71	-24.28
Hamedan	17	-8.19	17.5	-5.92	18	-4.26	20.5	-4.13	-22.50
Nahavand	17	-10.58	17.5	0.56	18	-5.82	20.5	-5.49	-21.34
Malayer	17	-8.37	17.5	-6.46	18	-4.79	20.5	-4.84	-24.46

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 (5).

Table 5: Annual correlation elements of Hamedan province selected substations during phenological phases (Thermal gradient) for sunflower

Period / Coefficients	Cultivation to budding phase	Flowering	End of flowering	Maturation
B	0.002	0.008	0.001	0.001
A	5.30	5.85	3.22	3
R	0.47	0.95	0,32	0.42

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 minimum 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 minimum 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 minimum and maximum 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 minimum biological threshold event was considered more than 10°C 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 (6), date of cultivation until budding, flowering, end of flowering, and maturation of sunflower crop start sooner respectively in Sanandaj, and Bijar substations than other stations. Given the related Table (6), date of cultivation until budding, flowering, end of flowering, and maturation of sunflower plant begin earlier correspondingly in Nahavand and Hamedan substations than other stations.

Table 6: 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
Nojeh	1348	27th April	9th May	11th June	11th July	19th August
Hamedan	1318	23rd April	4th May	6th June	4th July	11th August
Nahavand	1379	12th April	27th April	2nd June	3rd July	9th August
Malayer	1468	1st May	12th May	15th June	16th July	24th August

The date of completion for each of phenological stages is considered as the appropriate method to determine the best cultivation time (sunflower) based on its vital thresholds. The acquired dates are complied with temporal optimums.

The best cultivation calendar (sunflower)

Determination of cultivation of a crop is considered as one of the objective in agroclimatic studies for which optimum time is obtained for harvesting the crop by surveying climatic conditions. The climatic condition is deemed as the most major factor for harvesting calendar. Among climatic elements, temperature play essential role. With respect to the conducted analyses and based on various agroclimatic methods and phenological studies, the best calendar for crop harvest (sunflower) throughout the studied region that located in different areas are characterized in Table (7).

Table 7: Sunflower harvest calendar throughout the selected substations

Station	Date of harvest
Nojeh	19th August
Hamedan	11th August
Nahavand	9th August
Malayer	24th August

The computed results and findings are totally complied with comment of experts from farming sector at provincial Agri-Jihad Department within several areas. In fact according to the conducted interview with farming experts from various towns in the selected substations, they have considered the given climatic calendar as appropriate with respect to regional conditions and potential. Climate plays a determinant role at the beginning period of cultivation and harvest of crop (sunflower).

The appropriate regions for types of cultivation (sunflower)

Based on agroclimatic analyses, the best cultivation calendar (of sunflower) are respectively center, north, and southeast and northwestern areas at this province.

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 end of April. Sunflower is harvested in Hamedan, Nojeh, and Nahavand in mid August while it is harvested in Malayer substation at early 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 Nahavand and Hamedan than in other substations. In Hamedan substation, sunflower has the less deviation and more optimum conditions than other substations at total maturation stage. After Hamedan, Nojeh and Malayer stages have less deviation while compared to other stations, Nahavand substation has more deviation; as a result, in comparison with other substations, Hamedan substation has less deviation from optimum conditions; namely, this substation possesses optimal conditions for cultivation of sunflower.

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