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THE CLIMATIC FEASIBILITY OF SAFFRON CULTIVATION IN SOUTHERN PART OF *SABZEVAR*

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ABSTRACT

The correlation coefficient of climatic factors necessary for cultivation of saffron between Sabzevar stations and those of southern parts of Khorasan is strong. In October, no frost can be seen in Sabzevar, but it can be seen in other stations.

This study showed that there was no difference in viewpoints of climatic factors in cultivation stations in both areas. Comparing the correlation coefficient of climatic factors in southern and central parts of Khorasan with Sabzevar ones, it can be said that cultivation of saffron in Sabzevar is possible.

In all studied stations, all calculation factors showed high correlation coefficient (over 90%) showing temperature similarities in these areas with Sabzevar. Regarding to all studied climatic parameters, the highest correlation coefficient was related to the mean maximum temperature and the least was related to the absolute maximum temperature. Due to the high temperature in Sabzevar during the reproductive stage (phenology), the qualitative and quantitative of product is lower than product produced in southern parts of Khorasan. In Sabzevar, It is necessary for saffron to spent 25 days in order to receive daily energy.

KEY WORDS: *Agricultural climatic, Phenology, Physiological zero, daily energy*

Introduction

Saffron is the most expensive agricultural and medicinal plant in the world. It resists aridity and has a considerable role in the economic and social situation of the dry and low rain regions. The cultivation of this plant has been common in the southern areas of Khorasan province, Iran, since many years ago.

According to the geographical and ecological condition of Sabzevar, and the large number of the people employed in the agricultural and the rural population center of the region, it is essential to establish employment along with production and increase the rate of the villagers' income. Anyway, it should be noted that in order to increase productivity, rise in production and income, and reduce the social and economic gap and solve the employment problem, some appropriate options for the cultivation of crops such as Saffron should be made. This will specify if the cultivation of Saffron in parts of this city can act as a substitute production which not only generates jobs but also has a good income generation potential.

So the main purpose of this research is to identify the capabilities and limitations of the agricultural climate of Saffron in Sabzavar region.

Among different provinces, Khorasan province with 98% of cultivation has the first rank and after Khorasan, then comes Fars, Kerman and Yazd provinces as the second, third and fourth rank, respectively. The production of Saffron in Khorasan province is more common in the southern and central cities (90.04%). In recent years, due to its high rate of profitability, and low water requirment, the Saffron cultivation

has become common in many other regions of the province.

Saffron is a plant that its growth season among the cultivation pattern of the southern Khorasan province has the highest rate of adaptability with the precipitation pattern of the region.

Thus the percentage of climatic similarities or differences between the target regions and the regions of Saffron cultivation will determine the degree of risk taking of this farming (Kafi, 2002).

Materials and methods

In different stages of this research, the statistical data from many metrological stations have been collected. Due to the fact that the aim is to make a climatic feasibility studies for the cultivation and expansion of Saffron in the region with regard to its phenologic stages, the daily statistical data of metrological stations of Sabzevar and the southern part of Khorasan (Qayen and Birjand) in a common statistical period have been developed. Then efforts have been made to determine the occurrence of spring and fall freeze period for each of the stations. Afterwards, the best possible distribution for each of the dates of freezing occurrences has been calculated. Then, long term climatic parameters appropriate for the production of Saffron such as average temperature, precipitation and possible freezing period in the sensitive months of the growth at the origin stations as standard conditions have been selected. Following that, they have been compared with the climatic parameters of Sabzevar station. Next, the correlation coefficient of each has been calculated to determine their degree of risk taking of planting this product.

The duration of the growth period of this plant is 220 days (1-31 October) and has 4 stages. The different stages of its growth along with the duration of each period and botanical co-efficiency have been presented in the table 1.

Table 1: Botanical co-efficient and the growth length of Saffron (Kafi, 2002)

Stage	Duration of the period (day)	Botanical co-efficiency (Ke)
Initial	30 days (1-31 Oct.)	0.4
Development	55 days (1Nov.-25 Dec.)	0.65
Mid-season	105 days (26 Dec.-8 Apr.)	0.85
Late-season	30 days (9 Apr.-9 May)	0.55

Degree- Day

Most of the biological changes such as the growth of plants and some hydrological phenomena are subjected to thermal potential of the environment. For this purpose, the index of degree-day is used as the index of heat. If the number of degree-day is zero or negative, then that day will not have effect on the growth. Thus, the number of degree-day is the mean daily temperature minus the threshold temperature. If a plant could grow in a region, it will need certain number of degree day. That region should be able to supply it during the growth period. In order to determine the thermal needs of crops, two main methods are used in each phenology stage as follows:

1- The method of the total effective temperature

The base of the work in this method is to sum the degrees of the effective temperatures, i.e. the temperatures higher than the base zero of the biological zero of the plant. This temperature depends on the type of the plant. For the Saffron plant, the zero base is

calculated as 5 centigrade through the following equation:

$$Hu = \sum_{1}^{N}\left[\frac{T_M + T_m}{2} - T_t\right]$$

HU= is the thermal unit of the effective temperatures collected during N days.

T_M= Daily maximum temperature

T_m= Daily minimum temperature

T_t = the base thermal degree or physiologic zero

N= Number of days in a certain time duration.

2- The method of total active thermal degree

In this method, all quantities of the daily temperatures (without deducing the base temperature) during the time of the active growth of the plant are collected together. If the mean daily temperature is less than the base temperature, then that day will not be included in the set. The calculation equation is as follows:

$$Hu = \sum_{1}^{N}\left[\frac{T_m + T_m}{2}\right]$$

Possible situation of freezing

One of the atmospheric phenomena outside the tropical region found frequently and its effects seen in all living and non-living creatures is freezing which imposes damages on plants and humans. To study the quality of the occurrence and intensity of the freezing, it is necessary to have a knowledge about the possible situation of such events in the Saffron producing areas of the southern Khorasan and the studied area (Sabzevar). So in line with this objective, the date of the first occurrence of the fall freezing and the last freezing of spring was specified in each of the stations for each statistical year. Then on the basis of the number of Julius day (the beginning of January No. 1 and the end of December No. 365), each was allocated a digital date. After that, for each of the existing figures in the statistical series, the possibility of occurrence was calculated (in theoretical method). Finally, the normal statistical distribution over the series of data was presented by using the X=X+K.S equation.

Co efficient of correlation

In order to realize the relationship between two statistical communities, there is a need to calculate the coefficient of correlation. This coefficient has a mathematical value which determines the dependence, degree and rate of correlation in two communities having linkages with each other. The type of the relationship between two statistical communities and the type of correlation are different. If the changes will be towards positive, the correlation will be direct and if negative, then it will be reverse. If the relationship is 100%, the correlation is complete and if less than 50%, it is incomplete. The rate of correlation in two statistical communities varies from -1 to +1. Considering the importance of the geographical aspect of Saffron cultivation in this region, the quantitative method of calculation of correlation coefficient has been used. It will be calculated via the following formula.

$$r = \frac{N\sum xy - (\sum x_0 \sum y)}{\sqrt{\left[N\sum x^2 - (\sum x)^2\right]\left[N\sum y^2 - (\sum y)^2\right]}}$$

The results of the findings of the research

Determining the Degree-Day

Among the climatic parameters, the thermal regime has the highest effect on the plant growth and development. As it was discussed earlier, each plant will reach a certain stage of growth when got a certain quantity of heating from the environment. So in each subsequent stages of growth, a certain quantity of the heat is necessary which is

expressed in thermal unit or degree –day. For the Saffron plant, this quantity will be needed from the time of cultivation up to the beginning of the period of flowering for 416 degree day of energy (Nokandi, 1999). Considering the fact that Saffron begins its flowering period from the end of September to the beginning of November with a minimum rate of 10 degrees and less at night and the temperature of 22 degrees and less during the day, for Sabzevar and Qayen stations, from the beginning of the flowering period (15 October), we declined the value equal to the energy degree-day in each of the statistical years and took the mean. The results are presented in table 2 for Sabzevar station and the table 3 for Qayen station accordingly.

Table 2: The thermal needs of Saffron from the time of cultivation up to the beginning of the flowering period by degree-day, Sabzevar station

Phenology stage	Degree-day	Average temperature	Number of active degree-day	Number of effective degree-day
Initial (cultivation from the beginning of flowering)	25 days	21.9	541	423

Table 3: The thermal needs of Saffron from the time of cultivation up to the beginning of the flowing period by degree-day, Qayen station

Phenology stage	Degree-day	Average temperature	Number of active degree-day	Number of effective degree-day
Initial(cultivation from the beginning of flowering)	32 days	19.3	598	436

Comparing the contents of the above tables, it can be concluded that Sabzevar station receives less degree-day energy than Qayen station. So the date of cultivation in Sabzevar is at least 25 days before the beginning of flowering and in Qayen it should end at least 32 days to reach to the flowering stage. For other stages of Saffron, the number of degree-day of energy is not clear.

The date of occurrence of the first fall freezing and the last spring freezing

The calculation of the date of fall freezing occurrences for Saffron plant is important from this viewpoint that whether it is concurrent with the period of flowering of this plant or not. The date of the occurrence of spring freezing can have a considerable role at the final stage of the growth of this plant. So for this purpose, the date of the occurrence of such phenomenon with different possibilities has been calculated for the stations of Sabzevar and regions under Saffron plantations in the south and center of Khorasan and the results presented in tables 4 and 5.

Table 4: Estimation of the date of the occurrence of the last spring freezing of the existing stations with the possibility and different return periods using the normal distribution (1987-1999)

Percentage of occurrence		99	95	90	80	50	20	10	50	1
Return period (year)		1.01	1.05	1.11	1.25	2	5	10	20	100
Sabzevar station	Date of occurrence	17 Feb.	25 Feb.	1 Mar.	6 Mar.	15 Mar.	25 Mar.	30 Mar.	3 Apr.	11 Apr.
Qayen station		5 Mar.	13 Mar.	18 Mar.	23 Mar.	3 Apr.	13 Apr.	19 Apr.	23 Apr.	2 May
Birjand station		23 Feb.	2 Mar.	5 Mar.	12 Mar.	21 Mar.	2 Apr.	8 Apr.	16 Apr.	26 Apr.
Torbate Heydriyeh station		10 Mar.	17 Mar.	. 17 Mar	24 Mar	. 31 Mar.	. 10 Apr	16 Apr	23 Apr	30 Apr.

Table 5: Estimation of the date of the occurrence of the first fall freezing of the existing stations with possibility and different return periods using the normal distribution (1987-1999)

Percentage of occurrence		99	95	90	80	50	20	10	50	1
Return period (year)		1.01	1.05	1.11	1.25	2	5	10	20	100
Sabzevar station	Date of occurrence	7 Oct	22 Oct.	30 Oct.	8 Nov.	26 Nov.	14 Dec.	24 Dec.	1 Jan.	15 Jan.
Qayen station		20 Sept	27 Sept	. 1 Oct.	6 Oct	. 15 Oct.	. 24 Oct	. 29 Oct	2 Nov	1o Nov.
Birjand station		25 Sept.	30 Sept.	7 Oct.	18 Oct.	24 Oct.	2 Nov.	13 Nov.	19 Nov.	3 Dec.
Torbate Heydriyeh station		2 Sept.	16 Sept.	24 Sept.	3 Oct.	20 Oct.	10 Nov.	7 Nov.	12 Nov.	22 Nov.

According to the contents of the table 4, it can be stated that the possibility that the last freezing may occur after 17 February is 99%. Whereas, with the same possible percentage, it will be on 5 March onwards in Qayen. With the possibility of 90 percent, the last spring freezing in Sabzavar will be on 1 March onwards. In Qayen and with the same possibility, it will be on 18 March onwards. And with the possibility of 1 percent, the last spring freezing will be on 11 April onwards in Sabzavar. With the same percentage of possibility, it will be on 2 May onwards in Qayan. Or in other words, with the possibility of 99 percent, the last freezing will be before 11 April in Sabzavar and before 2 May in Qayen. In average, with 50 percent of the possibility - the last freezing in Sabzavar will be on 15 March and 3 April in Qayen. Also with the possibility of 99 percent for Birjand and Torbate Heydraiyeh stations, it will be on 23 February and after that on 10 March respectively. After that the possibility of 90 percent for the two mentioned stations will be 5 March onwards and 17 March onwards. Or in other words, with the possibility of 10 percent for Birjand and Torbate Heydariyeh stations, it will be before 5 March and before 17 March respectively.

Comparing the time of the last occurrence of freezing in Sabzevar station with the studied stations, it can be said that the date of occurrence of these kinds of freezing in Sabzevar ends sooner as compared with the

stations of Qayen, Birjand and Trobate Heydariyeh. So the final growth stage of Saffron plant will face the risk of freezing with a less possibility as compared with other stations. According to the contents of Table 5 which shows the beginning of the fall freezing in Sabzevar and other stations, it can be said that with 99%, the first fall freezing in Sabzevar will be on 7 October onwards and in Qayan, on 20 September onwards and with a 50% of possibility, the first freezing in Sabzevar will be 26 November onwards and in Qayen, on 29 October onwards. Or in other words, with the possibility of 90%, the beginning of the first freezing in Sabzevar will be before 24 Dec. and in Qayen with the same possibility, before 29 October.

Concerning the stations of Birjand and Torbateh Heydariyeh , it can also be said that with 99% possibility, the freezing will be on 25 September onwards and 2 September onwards and for the possibility of 90% for the two mentioned stations, it will be on 7 October onwards and 24 September onwards. In other words, with the 10 percent possibility, the first freezing for Birjand and Torbate Heydariyeh will be before 7 October and before 24 September. Comparing the time of the occurrence of the first fall freezing in Sabzevar station with other studied stations, it can be said that the date of the occurrence of this kind of freezing in Sabzevar will begin later as compared with stations of Qayen, Birjand , Trobate Heydriah. The possibility of its concurrency with the flowering period of Saffron is lower. It is such that if we accept the possibility of 80% as an acceptable percentage, the first freezing period will be after 8 November and if we consider the possibility of 50% acceptable, the first freezing period will be after 26 November.

Determining the dates of the occurrences of the thresholds of 5, 10 and 22 degrees and less

The temperature of the growth threshold for plants resistant to cold is 3 to 5 centigrade. Due to the fact that Saffron is one of the plants resistant to coldness and the beginning of flowering of Saffron is occurred in temperature threshold of 10 centigrade and less at night and the maximum temperature of 22 degree and less in day, the date of occurrence of the threshold of mentioned temperatures with different possibilities percentages was calculated for Sabzevar and Qayen stations. The results are presented in tables 6, 7 and 8.

Table 6: Estimation of the date of the occurrence of the first daily threshold of the 5 degrees and less in the existing stations with the possibility and different return periods by using the normal distribution (1987-1999)

Percentage of occurrence		1	50	10	20	50	80	90	95	99
Return period (year)		100	20	10	5	2	1.25	1.11	1.05	1.01
Sabzevar station	Date of occurrence	12 Jan.	2 Jan.	28 Dec.	20 Dec.	4 Dec.	24 Nov.	17 Nov.	12 Nov.	1 Nov.
Qayen station		30 Dec.	17 Dec.	10 Dec	1 Dec.	15 Nov.	30 Oct.	25 Oct.	14 Oct	1 Oct.

Table 7: Estimation of the date of the occurrence of the first minimum 10 degree and higher (the date of flowering of the existing stations) with the possibility and different return periods by using the normal distribution (1987-1999)

Percentage of occurrence		1	50	10	20	50	80	90	95	99
Return period (year)		100	20	10	5	2	1.25	1.11	1.05	1.01
Sabzevar station	Date of occurrence	2 Dec.	18 Nov.	11 Nov.	2 Nov.	15 Oct.	28 Sept.	19 Sept.	12 Sept.	29 Aug.
Qayen station		23 Sept.	14 Sept.	9 Sept.	3 Sept.	23 Aug.	12 Aug.	6 Aug.	1 Aug	23 Jul.

Table 8: Estimation of the date of the occurrence of the first maximum 22 degree and less (time of flowering) of the existing stations with the possibility and different return periods by using the normal distribution (1987-1999)

Percentage of occurrence		1	50	10	20	50	80	90	95	99
Return period (year)		100	20	10	5	2	1.25	1.11	1.05	1.01
Sabzevar station	Date of occurrence	27 Oct.	22 Oct.	19 Oct.	16 Oct.	9 Oct.	2 Oct.	29 Sept.	26 Sept.	21 Sept.
Qayen station		24 Oct.	17 Oct.	14 Oct.	10 Oct.	1 Oct.	23 Aug.	19 Sept.	16 Sept.	10 Sept.

With regard to the contents of the table 6 which shows the date of the threshold occurrence of 5 degrees, it can be stated that with the possibility of 1 percent, the date of the occurrence of the first 5 degree threshold occurrence and less for Sabzevar and Qayen stations will be on 12 January onwards and 30 December onwards. With the 99 percent possibility, for the mentioned stations, it will be on 1 November onwards and 1 October onwards. Or in other words, with the possibility of 1 percent, the first threshold of 5 degrees for the two stations will be before 1 November and 1 October, respectively. Also with the possibility of 50 percent (in average), the first threshold of the temperature of 5 degrees and less for Sabzevar will be on 7 December, and 15 November in Qayen. According to the contents of the table 7, with the possibility of 1 percent, the occurrence of the temperature 10 degrees and less will be on 2 December for Sabzaver and 23 September onwards for Qayen. Also with the possibility of 90%, the mentioned temperature will be occurred on 9 September onwards for Sabzever and 6 August onwards for Qayen. And with the possibility of 99%, it will be occurred on 29 August onwards for Sabzevar and 23 July onwards for Qayen. Or in other words, with the possibility of 1 percent, the first threshold of 10 degrees and less will be before 29 August for Sabzevar and with the same percentage of possibility, before 23 July for Qayen.

Reviewing the above-mentioned paragraphs, it can be concluded that with different possibilities, the flowering period in Sabzevar will begin with a delay as compared with Qayen. So there is a possibility for it to be faced to more fall freezing and also less flowers might be opened in Sabzevar station

as compared with Qayen. This will cause lower yield of this product in Sabzevar. According to the contents of table 8, it can be stated that with one percent of the possibility, the date of the occurrence of the first maximum 22 degrees and less than that will be on 27 October onwards in Sabzevar. With the same percentage of possibility, it will be 24 October onwards in Qayen. Also with the possibility of 90 percent, it will be on 29 September onwards for Sabzevar and Qayen stations, respectively. With the possibility of 99% possibility, in Sabzevar station, the 22 degree temperature and less will occur on 21 September onwards and on 10 September onwards in Qayen. Also it can be said that with the possibility of 80%, the mentioned temperature will happen on 2 October onwards in Sabzevar and on 23 August onwards in Qayen. In other words, it can be said that with a 90% possibility, it will happen before 19 October in Sabzevar and with the same possibility percentage before 14 October in Qayen. According to the above results, it can be said that the temperature of 22 degrees and less will happen in Qayen station sooner than Sabzever. Consequently, the duration of flowering period of this plant in the mentioned station will be more than Sabzevar station. So the number of opened up flowers of Saffron at the area unit in Sabzevar station will be less as a result of high temperature and delay in the occurrence of the threshold of 22 degree temperature .

Determining the date of end of minimum 10 degrees and higher at night and the maximum 22 degrees and higher in a day

The calculation of the date of the end of minimum 10 degrees and higher at night and the end of maximum 22 degrees and higher in a day is important because the duration of the occurrence of the mentioned thresholds up to the beginning of the fall freezing period can also specify the duration of the mass flowering period. That is to say, the longer is the duration the end of these thresholds with the date of the occurrence of autumn freezing, the greater the duration of mass flowering period. Consequently, the greater number of flowers will open up and the yield of Saffron product can increase. So with regard to the above mentioned materials, the tables 9 and 10 are made to present the estimation the date of the end of 10 degree and higher and the estimation of the date of the end of 23 degrees and higher.

Table 9: Estimation of the end of 10 degrees and higher (at least for the night) of the existing stations with the possibility and different return periods by using the normal distribution (1987-1999)

Percentage of occurrence		1	50	10	20	50	80	90	95	99
Return period (year)		100	20	10	5	2	1.25	1.11	1.05	1.01
Sabzevar station	Date of occurrence	6 Dec.	30 Nov.	27 Nov.	23 Nov.	16 Nov.	9 Nov.	5 Nov.	2 Nov.	27 Oct.
Qayen station		22 Dec.	4 Dec.	24 Nov.	14 Nov.	23 Oct.	1 Oct.	20 Sept.	11 Sep.	24 Aug.

Table 10: Estimation of the date of the end of 22 degrees and higher (maximum for the day) of the existing stations with the possibility and different return periods using the normal distribution (1987-1999)

Percentage of occurrence		1	50	10	20	50	80	90	95	99
Return period (year)		100	20	10	5	2	1.25	1.11	1.05	1.01
Sabzevar station	Date of occurrence	11 Dec.	3 Dec.	29 Nov.	24 Nov.	14 Nov.	5 Nov.	31 Oct.	26 Oct.	19 Oct.
Qayen station	Date of occurrence	12 Dec.	4 Dec.	29 Nov.	24 Nov.	13 Nov.	3 Nov.	28 Oct.	24 Oct.	16 Oct.

According to the table 9, it can be stated that with the possibility of 1%, the mentioned temperature will be on 6 December onwards and on 22 December onwards for Sabzevar and Qayen stations, respectively. With the possibility of 90%, it will be on 5 November onwards in Sabzevar and on 20 September onwards. Also with 99% possibility, it will be on 27 October and it will be on 24 August in Qayen. With 80% possibility, it will be on 9 November onwards in Sabzever. Also with the same percentage of possibility, it will be on 1 October onwards in Qayen. Concerning the average of its occurrence (50%) it will be on 16 November for Sabzevar and 23 October for Qayen. According to the table 10, it can be said that with the percentage of 1 percent, in Sabzevar station, the date of end of the temperature of 22 degrees and higher will be 11 December onwards and on 12 December onwards in Qayen station. Also with the possibilities of 90, 95 and 99%, it will be on 31 October, 26 October and 19 October onwards in Sabzevar. For Qayen, with the same possibilities, it will be on 28 October onwards, 24 October onwards and 16 October onwards. In other words, with the percentage of 99 possibility in Sabzevar, the temperature of 22 degrees and higher will occur before 11 December and before 12 December and with the same percent of possibility.

Comparing the climatic parameters of Saffron producing regions with Sabzevar region

It is necessary to know about the atmospheric conditions in a long period for each of the Saffron growing regions to identify the climatic situation of Saffron growth including the fluctuations of temperature, relative humidity, number of days along with the freezing periods, the number of sunny hours and rate of precipitation. So in line with this idea, the table 11 make a precise comparison among the climatic parameters of the main regions of Saffron production with that of the suggested region.

Determining the rate of correlation of different parameters in each of Saffron producing regions of Khorasan with that of Sabzevar

The correlation coefficient of long term climatic parameters of the cultivation and production regions of this product such as south of Khroasan with that of other regions have been used to make a climatic feasiblity studies of Saffron plantation. Table 12 shows the rate of correlation coefficient of different climatic parameters in each of the cities of Birjand, Torbate Heydariyeh, Ferdows, Qayen, Gonabad as compared with Sabzevar. In order

to calculate the correlation co-efficient, the following equation can be used.

$$r = \frac{N\sum xy - (\sum x_0 \sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

Table 11: A comparison of the climatic parameters of the main regions of Saffron production with the suggested region (Sabzevar)

Parameters	Present Saffron producing regions South of Khorasan)	Suggested region for cultivation (Sabzevar)
mean minimum temperature (annual)	5. to 23.8 °c	10.9 °c
Mean maximum temperature (annual)	21.4 to 28.8 °c	24.2 °c
mean maximum temperature (time of flowering from October to December)	<20°c	12.9 °c
Minimum absolute temperature(annual)	-9 to -22.6 °c	-10.49 °c
Maximum absolute temperature (annual)	40.6 to 48.8 °c	44.3 °c
Maximum absolute temperature of the time of green state (March)	<30°c	32 °c
Sunny days (annual)	3086 to 3251 hours	2938 hours
Annual precipitation	84 to 272.8 mm	206.7 mm
Number of freezing days	32 to 102 days per year	71 days
mean relative humidity	35 to 47% in a year	41 %
Maximum relative humidity	50 to 65% in a year	54 %
Minimum relative humidity	23 to 34% in a year	32 %

Table 12: Rate of correlations of different temperature parameters in each of the stations at the southern and central regions of Khorasan with that of Sabzevar station

The correlation coefficient of the absolute minimum temperature	Correlation coefficient of the absolute maximum temperature	Average Correlation coefficient of maximum temperature	Average correlation coefficient of minimum temperature	Qualifications of the station	Name of the station
0.98	0.96	0.99	0.98	λ= 59°-13 E Qm=32°-53 N H=1048	Birjand
0.97	0.91	0.99	0.99	λ= 59°-13 E Qm=35°-17 N H=1333	Torbate Heydariyeh
0.96	0.97	0.96	0.99	λ =58°- 10 E Qm=32°-01 N H=1235	Ferdows
0.93	0.96	0.99	0.99	= 59°-12 E Qm=34°-43 N H=1440	Qayen
0.98	0.93	0.99	0.99	λ=58°-41 E Qm=34°-21 N H=1105	Gonabad

With regard to the table 12, the rate of the correlation coefficient of each of these parameters and the climatic elements of the mean maximum temperature, the absolute minimum temperature for each of the stations of the Saffron producing regions in the south and center of Khorasan as compared with that of the target region ,i.e. Sabzaevar in a common statistical period were calculated. The results are as follows:

In the studied stations which were compared with Sabzevar, all computational parameters had a high rate of correlation coefficient (more than 0.9) and it shows the temperature similarities between these regions and that of Sabzevar region. Among the computational climatic parameters, the greatest degree of correlation belongs to the mean maximum temperature and the lowest (the least) rate of correlation also belongs to the absolute

maximum temperature. Among Birjand, Torbate Heidariyeh, Ferdows, Qayen, Gonabad stations, in total and in average, the highest rate of correlation coefficient belongs to Birjand and Qayen stations as compared with Sabzevar station. But due to the fact that the highest qualitative and quantitative level of Saffron products belongs to Qayen, so the farmers of Sabzevar region have transferred the plants from Qayen , so efforts have been made to make a comparison between the parameters of this station (Qayen) with that of Sabzevar in most cases.

Comparing the range of the fluctuations of temperature and thermal qualification of the sensitive months of growth among the stations of south Khorasan and Sabzever

The range of fluctuation of the temperature in September and October which is concurrent with the last days of the cultivation period and beginning of the flowering period and also the comparison between the thermal specifications of November which is concurrent with the peak of flowering of Saffron farming is important. Because, to the extent that the range of monthly fluctuations and the rate of temperature fall in the nights of these months are higher, to the same extent in the following morning, the greater number of flowers will be opened and thus the yield of the products goes up. The calculation of the total sunny hours in the sensitive months of growth can express the rate of receiving energy during the day for the purpose of growth and flowering of the plant (Tables 13 to 15).

Table 13: A comparison of the range of temperature fluctuations in Saffron producing regions of Khorasan with Sabzevar (1959-1984)

Station	Range of fluctuations of temperature	
	September	October
Birjand	19.6	19.3
Torbateheydarieh	16	16.4
Ferdows	19.4	18
Qayen	19.7	19.3
Gonabad	19.2	17.7
Sabzevar	16.5	15.3

Table 14: A comparison between the thermal specifications of November between Saffron growing regions in the South of Khorasan and Sabzevar Station

Parameter / Station	Statistical period	Average temperature			Absolute temperature	
		Maximum	Minimum	Daily	Maximum	Minimum
Birjand	1957-1984	18.9	2	10.5	29	-12
Torbate Heydariyeh	1959-1984	16.2	1	8.6	27	-14
Ferdows	1961-1984	15.9	1.8	8.9	28	-10.5
Qayen	1965-1975	17.5	-0.6	8.5	29	-9.5
Gonabad	1957-1984	19.1	2.7	10.9	39	-10
Sabzevar	1957-1984	17.5	3.1	29	-14	-14

Table 15: A comparison of the total sunny hours (hours) in September and November of the stations in the South of Khorasan with Sabzevar

Station	September	October	November
Birjand	334	272	236
Torbate Heydariyeh	327	274	225
Ferdows	336	299	243
Qayen	333	282	256
Gonabad	327	274	241
Sabzevar	306	272	214

With regard to the contents of the table 13 in Sabzevar station, the ranges of temperature fluctuations in September and October have been lower than other concerned stations. This indicates that the necessary minimum and maximum temperature can occur less in Sabzevar station as compared with other stations, so that it will have a negative impact on the yield of the product of Saffron.

On the basis of the table 14, it can be concluded that the mean temperature degree of Sabzevar station in November has better condition from the viewpoint of having the necessary temperature thresholds as compared with other stations. Table 15 also indicates that the number of sunny hours in Sabzevar station is less than other stations in the concerned months.

Determining the correlation coefficient of monthly precipitation and humidity of each of the stations of the South Khorasan and Sabzevar

The calculation of the monthly mean humidity and precipitation correlation coefficient for the purpose of supplying the water requirements of the plant without irrigation is of great significance. So in order to determine the correlation coefficient of the stations in the south of Khorasan and Sabzevar, the table 16 has been drawn:

Table 16: Estimation of the rate of monthly mean relative humidity and precipitation correlation coefficient of each of the stations in the South of Khorasan as compared with Sabzevar station

Name of the station Parameter	Gonabad	Qayen	Ferdows	Torbate Heydriyeh	Birjand
Correlation coefficient of annual percipitation	0.93	0.81	0.92	0.94	0.93
Monthly average humidity correlation co-efficiency	0.97	(1) 1	0.97	0.98	0.95

According to the obtained correlation coefficient from each of the monthly precipitation parameters and mean monthly humidity in the above table, it can be concluded that there is the highest correlation coefficient between Sabzevar and Torbate Heydaiyeh stations. Since the rate of precipitation in these two stations is higher as compared with other stations, so that they will have less difficulties in supplying of Saffron and have higher capabilities.

Estimation of the possibility of the occurrence of monthly freezing (by number of the days) in each of the stations of the south of Khorasan with Sabzevar

The calculation of the number of freezing days of each month, in particular in

the months that are concurrent with the growth and flowering of Saffron (initial stage of growth), i.e. October and November is of great importance. The number of the days without freezing state in each month can be almost specified which is necessary for rooting and flowering of Saffron.

Table 17: A comparison of the possibility of freezing occurrence (in terms of the percentages of days) in the studied stations

Station	Jan.	Feb.	Mar.	Apr.	Ma.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Birjand	70	43.3	13.3	3.3	0	0	0	0	0	3.3	30	0.70
Torbate Heydariyeh	86.6	66.6	20	3.3	0	0	0	0	0	6.6	40	80
Ferdows	76.6	56.6	30	0	0	0	0	0	0	6.6	30	70
Qayen	96.6	70	16.6	0	0	0	0	0	0	13.3	36.6	76.6
Gonabad	80	56.6	16.6	0	0	0	0	0	0	0	30	66.6
Sabzevar	73	53.3	16.6	0	0	0	0	0	0	0	22.3	70

With regard to the contents of the table 17, the possibility of the occurrence of freeze in October and November in Sabzevar station has a lower grade as compared with other stations. That is to say that fewer days of freeze is expected in the concerned months in this station and the possibility of any damage on farms at the time of flowering is less.

Conclusion and suggestions

Saffron is a plant resistant to cold, suitable for the dry and semi-dry areas in which aerial parts grow at the half cold part of the year. This plant can be planted from the early May to the middle of September-October in Iran. The flowering time of this plant is also the late October to the beginning of November with four growth stages (for 220 days from the 1 October to the 9 May). This plant , in its flower producing time needs a temperature of 10 centigrade and less at night and maximum temperature of 22 centigrade and less in a day. The threshold temperature of this plant, like other plants resistant to coldness, is above zero. The Saffron plant needs 412 degree-day energy from the time of cultivation to the beginning of flowering period. This rate of energy is received in 25 and 32 days in Qayen according to the tables 2 and 3. The fall freezing and thermal stress is factors reducing the yield of Saffron product. According to the table 5, the possibility that the first autumn freezing occurs after 7 October in Sabzevar region, after 20 September in Qayen, and after 25 September in Birjand and after 20 September in Qayen is 99%. The possibility that it occurs in Sabzevar after 8 November, after 18 October in Birjand, and after 6 October in Qayen is 80%. The possibility that it occurs in Sabzevar after 26 November, after 24 October in Birjand, and after 15 October in Qayen is 50%. With regards to the table 4, the possibility that the last spring freezing occurs after 17 February in Sabzevar, after 23 February in Birjand, and after 5 March in Qayen is 99%. The possibility that the last freezing occurs after 6 March in Sabzevar, after 12 March in Birjand and after 23 March in Qayen is 80%. And the possibility that the last freezing occurs after 15 March in Sabzevar, after 21 March in Birjand and after 3 April in Qayen is 50%. According to the tables 2 to 5,

it can be said that the cultivation of Saffron will be done as follows:

It should be planted at least 25 days before the flowering period, which is almost in the middle of October. The process of cultivation should end before 18 September in order to be able to receive the minimum degree-day of energy which is needed for the initiation of the period of flowering.

According to the table 7, with the possibility of 50%, the first threshold of the minimum degree 15 October and also the table 8, the first threshold of the maximum with the possibility of 50%, will occur on 9 October. If we consider 12 October as the average of these two thresholds for the beginning of flowering period and return 25 days back to the end of the period of cultivation, on 18 September and according the table 6, with the possibility of 50%, the end of the growth will be on 7 December. If the duration of flowering is about 25 days, and also the duration of the growth period which is about 25 days in Sabzevar, i.e. to deduce 50 days, we will again reach to the date of 18 September which is the date of the end of plantation.

Thus, with regard to the above cases, we can say that Saffron can be planted in Sabzevar from 22 August to 18 September. Comparing the climatic parameters of Saffron main producing regions with Sabzevar showed in table 11 indicates that the annual minimum absolute temperature of Sabzevar is lower than the minimum of Saffron cultivation in the South of Khorasan. Also, the maximum absolute of the temperature at the time of greening state (March) in Sabzevar is higher than the southern regions of Khorasan. This can have negative impact on the yield of the product. In other climatic factors of the mentioned table, there is no significant difference. Calculation of the correlation coefficient of the climatic parameters of the stations in the South of Khorasan with Sabzevar station in the table 12 indicates a strong correlation. With regard to the contents of the table 13, the range of the fluctuation of the temperature on September and October in Sabzevar station is lower than other concerned stations. It shows that the necessary thermal minimum and maximum temperatures in Sabzevar station occurs less as compared with other stations and thus it will have a negative effect on the yield. According to the table 14, it can be seen that the mean temperature of November in Sabzevar station as compared with other stations from the view point of having the essential temperature thresholds has a more ideal conditions.

According to the table 15, the number of sunny hours of Sabzevar station in the concerned months is less than other stations.

The correlation coefficient of monthly precipitation and humidity in the stations of southern Khorasan with Sabzevar station is so strong as shown in table 16. According to the contents of table 17, it can be concluded that October is freezing-free month in Sabzevar whereas in other studied stations, there is a possibility for freezing in October.

As different tables show, no significant difference is seen from the viewpoint of climatic elements and parameters necessary for Khorasan Saffron producing regions and Sabzevar region. By reviewing the correlation co-coeffficiency of the climatic parameters between the metrological stations of the south and center of Khorasan with that of Sabzevar and their significant relations, it seems that the growing of this product in the region will face no specific problem as compared with other regions of plantations and it is possible to plant Saffron in Sabzevar region.

With regard to the good quality of the Saffron products of Qayenat, the farmers import plants from that region greatly and try to imitate the date and method of cultivation of that region. Whereas based on the climatic parameters such as the date of the first fall freezing and the last spring freezing and the rate of prencipitation and evaporation at Qayen, we can not consider two regions as the same, therefore for this very reason, the quality and the yield of the product in this region (Sabzevar) is less than Qayen , so these shortages should be considered.

In line with the cultivation of Saffron in Sabzevar, the following matters are recommended:

1- In order to improve the quantity and the quality of the product, the irrigation of the product should be considered in summer. In the flowering season, two times of irrigation should be recommended.

2- In order to improve the quantitative and qualitative level of the product, the time of cultivation should be postponed up to July.

3- With the beginning of the fall freezing, it is necessary to take necessary measures to prevent the increase of chilling.

4- Efforts should be made to prevent the Saffron mono-cropping in the region and instead, muti-cropping should become common in the region. Because, due to the climatic limitations, in the event of monocopping, other resources of the farmers' incomes will be eliminated.

5- While localizing a site for the growing of Saffron, those regions should be selected that have less advantages for other plantations.

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