The Impact of Climate Change on the Growing Season of Vegetable Crops in Dhi Qar Governorate

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Abstract

This study aims to analyse the impact of climate change on the growing season of vegetable crops in Dhi Qar Governorate by examining selected summer and winter vegetable crops through two main axes. The first axis involved analysing climatic factors (solar radiation, minimum and maximum temperatures, rainfall, relative humidity) based on climate cycles to assess changes over the study period. The second focus centred on assessing the impact of these climatic changes on the thermal suitability of the growing season, where daily data on minimum and maximum temperatures for each crop were analysed and compared with the minimum and maximum thermal limits suitable for the growth of the crops studied, which included summer vegetable crops (aubergines, okra, aubergines, and watermelons) and winter crops (lettuce, spring onions) to determine the suitability of climatic conditions during the growing seasons in Dhi Qar Governorate. Results showed a general trend towards higher solar radiation and temperatures, accompanied by a decrease in relative humidity and a decline in rainfall, particularly during the final years of the study period. These changes have affected planting dates and growing season conditions, as it was found that March is characterised by varying suitability for the growth of aubergines, okra, and watermelon, as minimum temperatures remain within relatively acceptable limits, whilst maximum temperatures fall short of the optimum level, leading to a poor growth response from these crops during this month. Suitable conditions gradually improve during April, becoming more conducive to growth as temperatures approach the optimum range. The study also showed the study indicates that September is unsuitable for the growth of summer crops, as maximum temperatures exceed the upper suitable limit, leading to heat stress that negatively affects growth and productivity. As for winter vegetable crops (lettuce and spring onions), it was found that October is unsuitable for growth due to maximum temperatures exceeding the optimal thermal limits and the lack of suitable thermal conditions for sufficient periods. It is clear from this that farmers need to adopt flexible agricultural strategies that are compatible with climatic conditions by adjusting planting dates—either earlier or later—according to the appropriate

thermal requirements of each crop, to ensure healthy crop growth and minimise climate-related risks that may affect productivity or cause damage to the crop**.**

Keywords: *Climate Change, Climatic Factors, Summer and Winter Vegetables, Growing Season, Dhi Qar Governorate*

Introduction:

This study examines the relationship between climatic factors and the growth of crops, in terms of their impact on the various stages of growth, the length of the growing season, and productivity. These factors, particularly temperature, play a fundamental role in determining the rate of plant growth and the duration of their stay in the field through what is known as accumulated temperature, on which plants rely to complete their life cycle. Climate change also plays a role in this relationship, as it leads to changes in climatic factors, particularly temperatures, which have a direct impact on crop growth. Higher temperatures may accelerate growth and shorten the growing season, whilst lower temperatures may slow growth and prolong its duration, which in turn affects planting dates and production efficiency. Consequently, understanding this relationship illustrates how climate change does not affect crops directly, but rather through its impact on the climatic elements that control their growth, particularly temperature, which is the key factor in determining the length of the growing season and the success of agricultural production.

The research addressed the following research question:

Does climate change affect the growing season of vegetable crops in Dhi Qar Governorate, and what are its implications for agricultural production ?

The research hypothesis is summarised as follows:

1- Climate change is causing noticeable changes in climatic factors in the study area.
2- Climate change is affecting the growing season of vegetable crops, leading to reduced yields and changes in growing times in the study area.

This study aims to analyse the variation and trends in key climatic parameters in Dhi Qar Governorate, with a focus on temperature (minimum and maximum), and to determine their impact on the length of the growing season for vegetable crops by comparing daily climate data with the minimum and maximum temperature thresholds suitable for the growth of these crops.

The significance of the research can be summarised as follows:

1- It quantifies the impact of climate change on agricultural production, thereby assisting in the formulation of appropriate agricultural policies.

2- It contributes new insights to the field of agricultural climate studies by establishing a link between climate change and the growing season of agricultural crops.

3- It provides farmers with accurate scientific indicators regarding changes in the length of the growing season, thereby helping them to choose appropriate planting and harvesting dates.

There are scientific justifications for selecting the subject under study:

1- The growing phenomenon of climate change and its negative impact on the agricultural sector, which is one of the most important sources of income and food in Iraq.

2- The urgent need to develop agricultural strategies in line with new climatic conditions to ensure the continuity of agricultural production and achieve local food security.

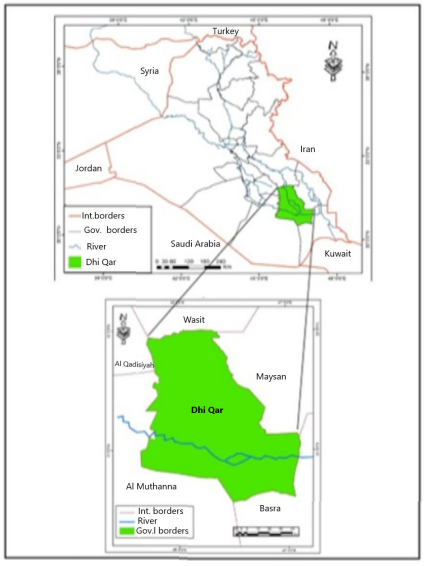
3- The scarcity of studies addressing the specific impact of climate change on vegetable crops in Dhi Qar Governorate, particularly regarding crop growing season requirements.

2. Geographical definition of the study area:

The study area is Dhi Qar Governorate. Geographically, Dhi Qar Governorate is situated in the southern part of Iraq, bordered to the north by Wasit Governorate, to the east and north-east by Maysan Governorate, to the south and south-east by Basra Governorate, and to the west and south-west by Muthanna Governorate, and to the north-west by Al-Qadisiyah Governorate. The study area comprises five districts and fifteen administrative sub-districts under their jurisdiction. The governorate covers an area of 12,900 km², accounting for 3.1% of the total

area of Iraq, which is approximately 314,438 km². Geographically, it lies between latitudes 30°40′ and 31°50′ north and longitudes 45°30′ and 12°47′ east .

Map 1: Location of Dhi Qar Governorate in Iraq



Source: Compiled by the researcher using ARCGIS 10.8

First: The impact of climate change on climatic factors in Dhi Qar Governorate

The study of climatic characteristics in the study area is an important and influential factor in agricultural activity, given its direct role in determining the quantity and quality of agricultural production; indeed, an understanding of the nature of the prevailing climatic elements, particularly the direction of change and the overall magnitude of such changes, provides a clear picture of the climatic characteristics that influence the success of growing various crops. These characteristics certainly affect the quantity and quality of crops, as they constitute key determinants that must be met in a manner suited to the needs of each of the crops under study. Accordingly, this study will rely on analysing the most significant climatic elements prevailing and determining the extent of the changes that have occurred during the study period, as follows:

Temperature: Temperature is one of the most important climatic elements, as it has a direct impact on other climatic elements such as atmospheric pressure, general wind movement and wind patterns, and the associated cloud movement, rainfall and snowfall. The variation between one region's climate and another is due to variations in temperature, and it also has a direct impact on the biosphere and its living organisms (Al-Anzi, Mustafa Kazim Kharbat, 2019, p. 31).

A. Minimum temperature: This is the lowest temperature recorded during the day and usually occurs just before sunrise, when the Earth's surface has lost as much of its thermal radiation as possible (Jouda Hussein Ghazi, 2017, p. 441). The minimum temperature is a fundamental environmental factor that directly influences the physiological processes of plants, such as germination, vegetative growth and flowering. Each plant has a minimum temperature below which it will not grow; if this temperature is exceeded, the plant tends to stagnate and enter dormancy, a state known as 'zero growth'. This temperature varies according to the type, variety, nature and resilience of the plant .

° (2.6 ,1.5)C. It is evident from the data in Table (2) and Figure (2) that the difference in the minimum temperature at the Nasiriyah station trended positively for most of the climatic cycles studied, as the difference between the second and first cycles (1985–1996) (1974–1985) was positive for all months from September to August, with the difference being as follows, respectively: (0.4, 1.4, 0.7, 0.1, 0.3, 0.8, 2.0, 1.3, 0.7, 1.0, 1.6), except for January, when the difference was negative, amounting to (0.4). As for the difference for the third and second climatic cycles (1996–2007) (1985–1996) was positive for all months from September to August, with the differences being as follows, respectively: (0.0, 1.8, 0.3, 0.8, 0.6, 1.3, 1.1, 1.3, 1.5) m, with the exception of the months (November – December – April), where the difference was negative, amounting to (0.1-, 0.8-, 1.2–) m. As for the difference for the fourth and third cycles (2007–2018) (1996–2007), it trended positively for all months from September to August,

with the difference amounts as follows, respectively: (2.2, 0.5, 1.9, 3.5, 0.6, 0.5, 1.4, 1.2, 0.4, 1.1, 0.8, 1.2) m, whilst the difference for the last and first cycles (2018–2023) (1974–1985) trended positively for all months from September to August, with the differences being as follows, respectively ,3.4 ,4.4 ,3.8) : (5.0 ,4.3 ,4.2 ,3.0 ,2.3 ,2.2 ,2.3 ,1.6 ,3.1.

Table 1: Difference in minimum temperature (°C) for the climatic cycles at the Nasiriyah station for the period 1974–2024

Climatic Period	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Average of the First Cycle (1974–1985)	23.7	18.0	12.0	7.4	6.4	7.9	11.8	17.4	22.4	25.6	27.2	25.9
Average of the Second Cycle (1985–1996)	24.1	19.4	12.8	7.5	6.0	8.2	12.6	19.4	24.0	26.3	28.2	27.5
Difference Between the Two Cycles (1985–1996) and (1974–1985)	0.4	1.4	0.7	0.1	-0.4	0.3	0.8	2.0	1.3	0.7	1.0	1.6
Average of the Third Cycle (1996–2007)	24.1	21.2	12.6	6.7	6.3	9.0	13.2	18.2	25.0	27.4	29.5	29.0
Difference Between the Two Cycles (1996–2007) and (1985–1996)	0.0	1.8	-0.1	-0.8	0.3	0.8	0.6	-1.2	1.3	1.1	1.3	1.5
Average of the Fourth Cycle (2007–2018)	26.4	21.7	14.5	10.2	6.9	9.5	14.6	19.4	25.3	28.5	30.3	30.2
Difference Between the Two Cycles (2007–2018) and (1996–2007)	2.2	0.5	1.9	3.5	0.6	0.5	1.4	1.2	0.4	1.1	0.8	1.2
Average of the Fifth Cycle (2018–2023)	27.5	22.4	15.5	10.5	8.0	10.1	13.9	19.7	25.4	29.8	31.5	30.9

Difference Between the Two Cycles (2018–2023) and (1974–1985)	3.8	4.4	3.4	3.1	1.6	2.3	2.2	2.3	3.0	4.2	4.3	5.0

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

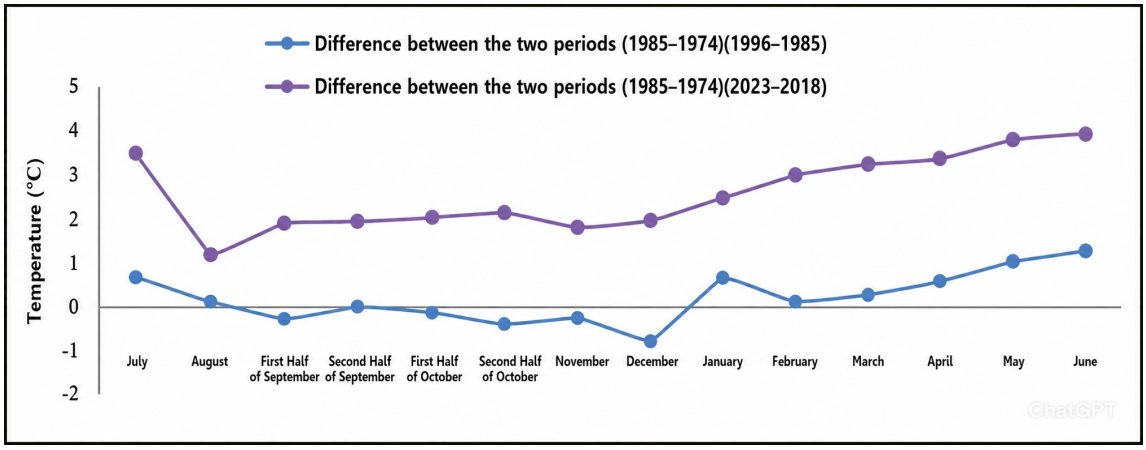


Figure 1: Change in the average minimum temperature (°C) for the climatic cycles at the Nasiriyah station for the period 1974–2024

b) Maximum temperature: This is the highest temperature recorded during the day, when net radiation is positive from sunrise onwards and continues into the afternoon (Shahada Numan, 2009, p. 75) The maximum temperature is related to plant growth, as each crop has an upper temperature limit necessary for its growth. This varies depending on the type of crop or the conditions of the region in which it is grown, with crops being more tolerant of high temperatures in their later growth stages and less tolerant in their early stages. Furthermore, crops' ability to tolerate this temperature varies during their growth period. Furthermore, when the temperature reaches its maximum limit, it leads to rapid crop growth until it reaches the point of destruction; when the maximum temperature reaches 45°C, most plant cells may die (Al-Amouri, Faleh, Hassan, Kazim et al., 2015, p. 419.(

It is evident from the data in Table (3) and Figure (3) that the difference in the average maximum temperature at the Nasiriyah station tends towards a positive trend for most of the climate cycles studied, as the difference between the second and first cycles (1985–1996) (1974–1985) was positive for most months (September, October, November, January, May, June, July, August), with the difference

being as follows, respectively: (0.0, 0.9, 0.2, 0.2, 0.8, 0.3, 0.7, 1.3). As for the remaining months (December – February – March – April), the difference was negative, amounting to (0.2-, 0.1-, 0.1-, 0.8-). As for the difference for the third and second periods (1996–2007) (1985–1996) was positive for all months from the start (September–August), with the difference amounts as follows, respectively: (0.3, 1.9, 0.2, 0.2, 1.2, 2.7, 1.9, 1.5, 2.0, 1.3, 1.7). However, except for January, the difference was negative, amounting to (0.7). As for the difference between the fourth and third cycles (2007–2018) (1996–2007), the difference was positive for all months from September to August, with the difference being as follows, respectively: (1.4, 1.3, 1.7, 1.8, 1.1, 1.0, 0.8 ,

Controversy (2): The magnitude of the difference in the mean maximum temperature (°C) of climatic cycles at the Nasiriyah station for the period 1974–2023

Climatic Period	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Average of the First Cycle (1974–1985)	41.8	34.3	25.7	19.0	16.9	20.0	24.8	31.6	37.7	42.1	44.1	43.4
Average of the Second Cycle (1985–1996)	41.8	35.2	26.0	18.7	17.1	19.9	24.7	30.8	38.5	42.5	44.9	44.8
Difference Between the Two Cycles (1985–1996) and (1974–1985)	0.0	0.9	0.2	-0.2	0.2	-0.1	-0.1	-0.8	0.8	0.3	0.7	1.3
Average of the Third Cycle (1996–2007)	42.1	37.1	25.3	19.0	17.3	21.1	27.4	32.7	40.0	44.5	46.1	46.5
Difference Between the Two Cycles (1996–2007) and (1985–1996)	0.3	1.9	-0.7	0.2	0.2	1.2	2.7	1.9	1.5	2.0	1.3	1.7
Average of the Fourth Cycle (2007–2018)	43.5	36.8	26.6	20.7	19.1	22.2	28.3	33.5	39.9	44.5	46.7	47.2
Difference Between the Two Cycles	1.4	-0.3	1.3	1.7	1.8	1.1	1.0	0.8	0.0	0.0	0.6	0.8

(2007–2018) and (1996–2007)												
Average of the Fifth Cycle (2018–2023)	45.0	37.9	27.0	20.9	19.0	22.3	26.7	33.7	40.4	45.4	47.5	47.2
Difference Between the Two Cycles (2018–2023) and (1974–1985)	3.2	3.6	1.2	2.0	2.1	2.2	1.9	2.1	2.8	3.2	3.4	3.8

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

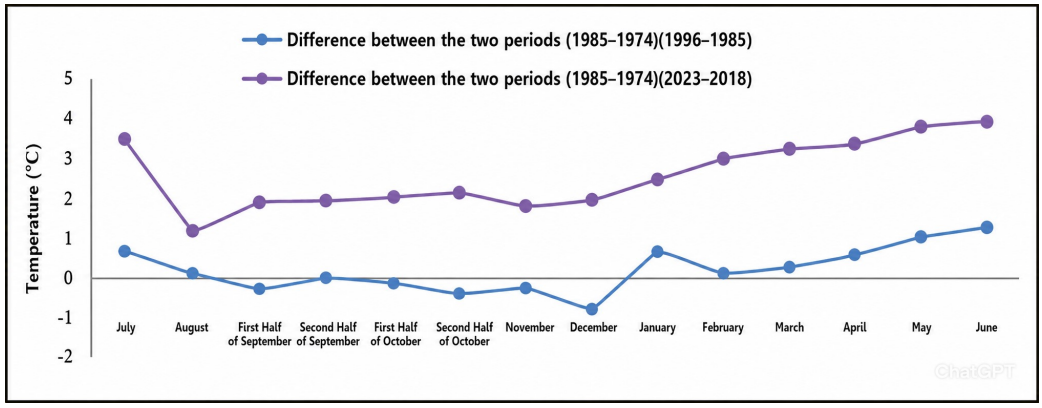


Figure (2) shows the difference in the mean maximum temperature (°C) for climatic cycles at the Nasiriyah station for the period

(2024–1974)

Relative humidity: This is a factor that has a significant impact on the various stages of plant growth. A lack of humidity disrupts the water balance and slows down physiological processes at different stages of growth; a deficiency can lead to stunted growth, small leaves, flowers and fruits, and also increases the risk of fruit and flower drop and the drying out of flower stigmas. Conversely, high atmospheric humidity results in fruits that are relatively large, thin-skinned and juicy, with a lower content of soluble solids and less colour. Air humidity should ideally be moderate, i.e. neither exceeding nor falling below its limits. For the growth of trees and their fruit, the amount of humidity must be moderate, as both excess and deficiency relative to the appropriate level harm tree growth and fruiting (Al-Silaawi, 2023, pp. 85–86) .

It is evident from the data in Table (4) and Figure (4) that the difference in humidity levels at the Nasiriyah station tends towards a negative trend for most of the climatic cycles studied, as the difference between the second and first cycles (1985–1996) (1974–1985) was positive for all months from September to August, with the difference being as follows, respectively: (0.1, 2.8, 1.5, 0.7, 5.2, 3.5, 3.4, 0.0, 2.7, 0.2, 0.9) mm, with the exception of December, when the difference was negative, amounting to (1.0) mm. As for the difference between the third and second climatic cycles (1996–2007) (1985–1996) was negative for most months (September–October–November, February–March–May–June–July–August), with the changes being as follows, respectively: (0.1-, 1.7-, 1.4-, 0.1-, 5.3-, 1.1-, 1.1-, 1.7-, 2.0-, 0.9-) mm. As for the other months (November – December – April), the difference in the humidity rate tended towards a positive trend, with the difference amounting to (2.5, 1.3, 0.1) mm. As for the difference for the fourth and third cycles (2007–2018) (1996–2007), the difference was negative for all months from September to August, with the differences being as follows, respectively: (3.7, 4.8, 5.5, 10.6-, 8.9-, 11.7-, 7.0-, 8.7-, 4.2-, 4.2-, 3.0-, 3.6-) mm. As for the difference between the most recent and first climate cycles (2018–2023) (1974–1985) is negative for all months from September to August, with the differences being as follows, respectively: (6.3, 5.7, 3.2, 1.4, 6.6, 4.8, 5.1, 7.1, 9.2, 4.4, 5.7, 5.1) mm .

Analysis of relative humidity data at the Nasiriyah station shows that it records low levels; this is attributed to its location in the hot and dry southern alluvial plain, high temperatures, and distance from sources of moisture, which increases evaporation and reduces humidity. Furthermore, the decline in the area of the marshes has contributed to the drought, and this decline is reflected in increased accumulated heat, accelerated crop maturation and a reduction in their growing season.

Table (3) Difference in relative humidity (%) for the climatic cycles at the Nasiriyah station for the period 1974–2023

Climatic Period	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Average of the First Cycle (1974–1985)	26.7	36.5	52.0	67.4	68.4	56.6	48.1	39.3	30.8	21.0	21.5	22.5
Average of the Second Cycle (1985–1996)	26.8	39.4	53.5	66.4	69.1	61.8	51.5	42.6	30.8	23.7	21.7	23.4
Difference Between the Two Cycles (1985–1996) and (1974–1985)	0.1	2.8	1.5	-1.0	0.7	5.2	3.5	3.4	0.0	2.7	0.2	0.9

Average of the Third Cycle (1996–2007)	26.7	37.7	56.0	67.7	67.7	61.8	46.3	42.8	29.8	22.0	19.8	22.5
Difference Between the Two Cycles (1996–2007) and (1985–1996)	-0.1	-1.7	2.5	1.3	-1.4	-0.1	-5.3	0.1	-1.1	-1.7	-2.0	-0.9
Average of the Fourth Cycle (2007–2018)	23.0	32.9	50.5	57.1	58.7	50.1	39.3	34.1	25.5	17.8	16.7	18.9
Difference Between the Two Cycles (2007–2018) and (1996–2007)	-3.7	-4.8	-5.5	-10.6	-8.9	-11.7	-7.0	-8.7	-4.2	-4.2	-3.0	-3.6
Average of the Fifth Cycle (2018–2023)	20.4	30.8	55.2	66.0	61.8	51.8	43.0	32.2	21.6	16.6	15.8	17.4
Difference Between the Two Cycles (2018–2023) and (1974–1985)	-6.3	-5.7	3.2	-1.4	-6.6	-4.8	-5.1	-7.1	-9.2	-4.4	-5.7	-5.1

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

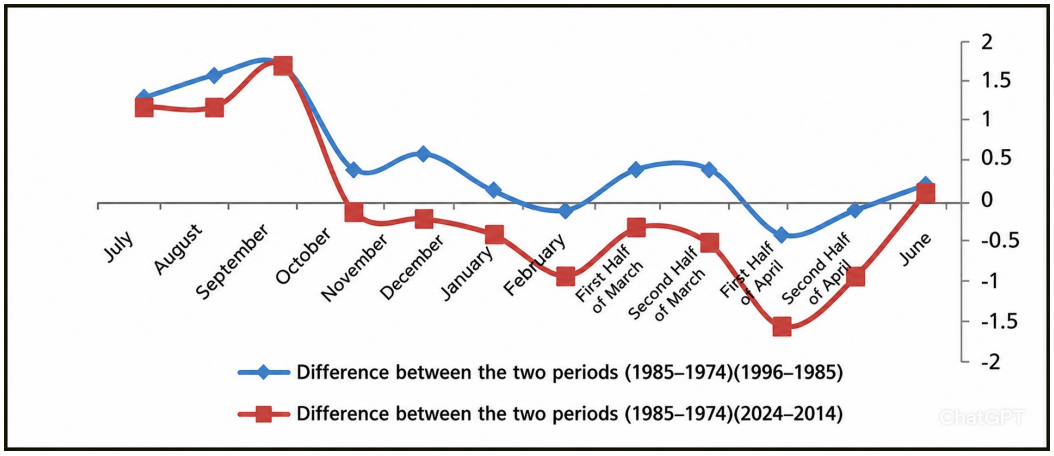


Figure (3) shows the difference in relative humidity (%) for the climatic cycles at the Nasiriyah station for the period 1974–2023

Rainfall: Rainfall is one of the most important primary sources of surface water resources in arid and semi-arid regions, on which rain-fed agriculture depends; this is because higher rainfall during wet years contributes to increased surface runoff and a higher rate of water inflow (Al-Khaza'i, Fares Salem Makhif, 2024, p. 43). The importance of this factor for crop growth stems from the fact that it is the main source of the fresh water required by plants; consequently, rainfall affects agricultural production. The importance of rainfall is not limited to the physiological needs of plants but extends to its role as the basis for energy exchange between plant parts to maintain their temperature, and keeping it within the limits required for growth. Crops usually grow in areas where rainfall is sufficient to aid plant growth (Al-Rabie, Samah Ismail Najm, 2015, p. 41).

Analysis of the data in Table 5 and Figure 5 shows that the difference in total rainfall at the Nasiriyah station for the second and first climatic cycles (1985–1996) (1974–1985) tends to be positive for most months (September – October – November – February – March – April), with the difference amounting to (25.8, 9.1, 45.1, 46.8, 64.8, 64.4) mm/year respectively. As for the other months (December – January – May), the difference tends towards a negative trend, with the differences being as follows, respectively: (–20.8, –35.6, –87.0) mm/s. As for the differences for the third and second cycles (1996–2007) (1985–1996) was negative for most months (September – October – November – January – February – May), with the differences being as follows, respectively: (25.8-, 34.9-, 48.9-, 75.7-, 69.2-, 21.5) mm/s. As for the other months (December – March – April), the difference was positive, amounting to the following, respectively: (104.2, 54.5, 157.3) mm/h. As for the difference for the fourth and third cycles (2007–2018) (1996–2007), it varied between positive and negative trends; the difference for the months with a positive trend (September – October – November – May) was as follows: (0.2, 38.7, 112.6, 67.0) mm/h. As for the other months (December – January – February – March

– April), the difference tended towards a negative trend, with the values as follows, respectively: (–195.1, –113.9, –58.8, 137.1, 190.4) mm/h, whilst the difference for the first and last cycles (2018–2024) (1974–1985) was negative for all months from October to May, with the differences being as follows, respectively: (50.1, 56.7, 247.4, 50.3, 30.4, 25.1, 106.1) mm/h. With the exception of November, when the difference was positive at 75.0 mm/h. It is clear from the above that Dhi Qar Governorate has witnessed a marked decline in rainfall rates during the final years of the study period. This is attributed to the diminishing influence of frontal and Mediterranean low-pressure systems and a shift in their trajectories due to climate change and rising temperatures. This has led to an increase in periods of drought and a decline in soil moisture, which has had a significant impact on agricultural activity through a reduction in cultivated areas, increased reliance on irrigation and lower productivity (Al-Kanani, Malik Nasser Abboud, 2013, pp. 278–279).

Table (4) Difference in total rainfall (mm) for climatic cycles at the Nasiriyah station for the period (1924–1974)

Climatic Period	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Average of the First Cycle (1974–1985)	0.0	73.0	150.1	227.0	351.9	180.3	166.0	82.7	114.5
Average of the Second Cycle (1985–1996)	25.8	82.1	195.2	206.2	316.3	227.1	230.8	147.1	27.5
Difference Between the Two Cycles (1985–1996) and (1974–1985)	25.8	9.1	45.1	-20.8	-35.6	46.8	64.8	64.4	-87.0
Average of the Third Cycle (1996–2007)	0.0	47.2	146.3	310.4	240.8	157.9	285.3	304.4	6.0
Difference Between the Two Cycles (1996–2007) and (1985–1996)	-25.8	-34.9	-48.9	104.2	-75.5	-69.2	54.5	157.3	-21.5
Average of the Fourth Cycle (2007–2018)	0.2	85.9	258.9	115.3	126.9	99.1	148.2	114.0	73.0
Difference Between the Two Cycles (2007–2018) and (1996–2007)	0.2	38.7	112.6	-195.1	-113.9	-58.8	-137.1	-190.4	67.0
Average of the Fifth Cycle (2018–2024)	0.0	22.9	225.1	170.3	104.5	130.0	135.6	57.6	8.4

Difference Between the Two Cycles (2018–2024) and (1974–1985)	0.0	-50.1	75.0	-56.7	-247.4	-50.3	-30.4	-25.1	-106.1

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

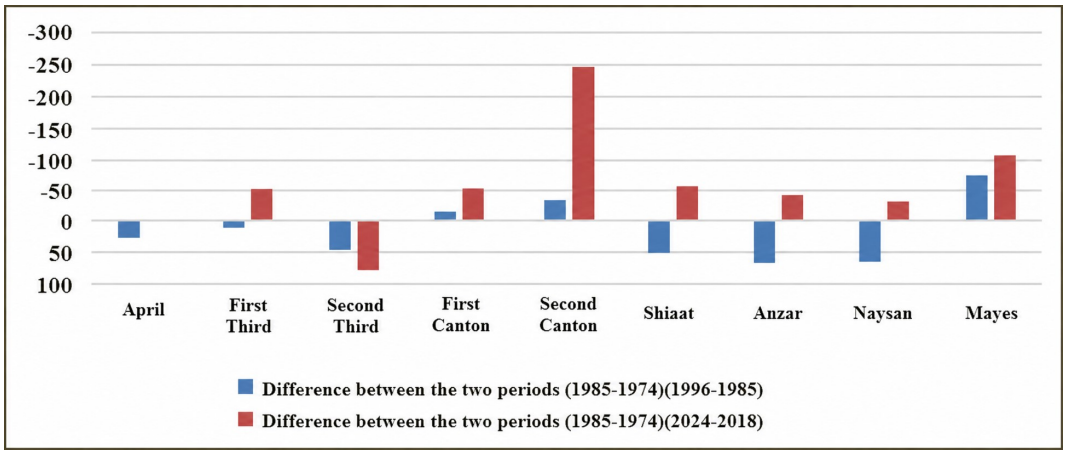


Figure (4) shows the difference in total rainfall (mm/year) for the climatic cycles at the Nasiriyah station for the period 1974–1924

Secondly: The impact of climate change on the growing season of vegetable crops in Dhi Qar Governorate.

Climatic requirements for growing summer vegetable crops.

*Tables 5 and 6 outline the thermal requirements and planting dates for each crop.

Tomatoes: Tomatoes are a summer crop that requires a frost-free environment to grow, and the frost-free period must be at least 2–4 months in order to produce ripe fruit. Tomato plants are unable to tolerate frost during the germination stages; therefore, it is recommended to grow them in small nurseries or inside polytunnels, and seedlings should not be transplanted into the ground until the frosts in the area have ended (Abdel-Aal Zidan Al-Sayed et al., 1975, p. 72) .

Aubergines (Solanum melongena L): Aubergine is a crop of the Solanaceae family and is a vegetable of economic importance, particularly in the hot and temperate regions of the world. It has been known since ancient times, having grown wild in both India and China, which are considered its native habitats (Abbas, 2016, pp. 788–789) .

Cucumber (Cucumis sativus L.) is a horticultural plant that grows as a climber or a trailing plant. It belongs to the Cucurbitaceae family, which includes crops such as watermelon, melon, pumpkin, courgette and muskmelon. It is an annual crop usually sown directly from seed; it prefers warm climates and is primarily grown for its edible fruit (Jamil Ahmed Mohammed Ismail, 2021, p. 18).

The other pepper, the bell pepper, is considered an important vegetable crop in terms of marketing and exports. It belongs to the Solanaceae family and ranks third in importance among the crops of this family (Al-Aboudi, Zainab Musadq Muhammad, 2024, p. 81).

Table 6: Minimum, optimum and maximum temperatures and accumulated heat for summer vegetable crops.

Crop	Minimum Temperature (°C)	Optimum Temperature (°C)	Maximum Temperature (°C)	Harmful Minimum Temperature (°C)	Harmful Maximum Temperature (°C)	Accumulated Heat Units (°C)
Tomato	18	21–27	35	13	45–55	1000–1600
Eggplant	15	21–29	38	10	45	1050–1100
Cucumber	13	18–24	32	5–7	40	1115
Sweet Pepper	18	21–27	35	2–10	45	1050–1100
Squash	13	18–24	32	-1 (plant death)	45	1050–1100
Okra	15	21–29	38	2–10	50	1120
Watermelon	15	21–29	38	1	40–50	1100
Melon	15	21–29	38	-0.5	40–50	1125

Source: Compiled by the researcher based on

1- Ali Ahmad Ghanem, Applied Climatology, 1st ed., Dar al-Masira for Publishing, Distribution and Printing, Amman, 2010, p. 157.
2- Ahmad Hilal Hamoud al-Salmany, Spatial Variation in the Cultivation of Summer Vegetable Crops in the Rural Areas Surrounding Ramadi City Centre for the Period (1999–2018), Al-Adab Journal, Issue 132, University of Anbar, 2020, p. 286.
3- Abdul-Kazim Ali Jaber Al-Halo, The Impact of Thermal Extremes on Vegetable Crops in Najaf Governorate, Journal of Geographical Research, Issue 25, 2017, p. 285.

4- Abbas Fadhil Al-Saadi, The Geographical Origins of Agriculture, Vol. 1, Dijlah Library for Printing, Publishing and Distribution, University of Baghdad, 2019, pp. 206–207.

5- Wafa Mohan Ajil, The Geographical Perspective on Climate and Its Impact on the Cultivation and Production of Summer Vegetables in Al-Qadisiyah Governorate', Maysan Research Journal, Vol. 18, No. 36, 2022, p. 201.

Table 6: Planting dates for summer vegetable crops and growing season lengths

Crop	Growing Season (Days)	Length of Growing Season	Sowing Dates for Summer Vegetables	Crop Type
Tomato	212 days	September – March	August, September, October, February, March	Tomato
Eggplant	212 days	September – March	February, March, June, August, September	Eggplant
Cucumber	214 days	March – September	February, March, April, August, September, October, November	Cucumber
Sweet Pepper	212 days	September – March	August, September, October, February	Sweet Pepper
Squash	214 days	March – September	July, August, September, March, April	Squash
Okra	76 days	March – May 15	February, March, August	Okra
Melon (Raqi)	93 days	March 15 – June 15	February, March, August, September	Melon
Watermelon	93 days	March 15 – June 15	February, March, August, September	Watermelon

Source: Compiled by the researcher based on

1. Republic of Iraq, Ministry of Agriculture, Agricultural Statistics Department, Baghdad, unpublished data, 2025.
2. Haifa Nouri Issa Al-Ankoushi, The Relationship between Climatic Characteristics and Agricultural Crop Cultivation in Najaf Governorate, Master's thesis, Faculty of Education, University of Kufa, 2004, p. 21.

Pumpkin Pumpkins are an important summer vegetable crop belonging to the Cucurbitaceae family and include several varieties such as honeydew melon, grey gourd and bitter gourd. This crop is heat-

loving, although it is less sensitive to cold than some other crops in the Cucurbitaceae family, such as cucumbers, watermelons and courgettes**.**

Okra (Abelmoschus esculentus L) is an annual herbaceous plant belonging to the Malvaceae family. It is an important summer vegetable crop grown in the hot and warm regions of Asia and Africa and is known by several names, including (Bohnert, 2008). Okra is widely cultivated in various regions of Iraq (Hamza Musa Muhammad, 2010, p. 60)**.**

Watermelon belongs to the Cucurbitaceae family and is an annual herbaceous plant with a branched root system extending into the soil and a creeping stem covered in dense hairs with a ribbed cross-section, large, serrated leaves, and produces round or oval fruits rich in water (Hassan Ahmed Abdel Moneim, 1994, p. 132) **.**

Raki: 7 Raki is classified as a summer crop and belongs to the Cucurbitaceae family. It is a herbaceous plant that completes its life cycle within a single growing season. Its roots are characterised by their ability to penetrate deep into the soil, reaching a depth of around two metres, which helps it withstand various environmental conditions. (Abboud Fawaz Al-Hajji, 2020, p. 394)**.**

Thirdly: The thermal requirements of selected summer crops and an analysis of daily temperatures (minimum and maximum) at the Nasiriyah station for the period 1985–2023.

Aubergines, okra, aubergine and watermelons.

A. Daily minimum temperature and its suitability for the thermal requirements of aubergine, okra, radish and watermelon crops in Dhi Qar Governorate.

Daily minimum temperatures in March for the period(2023–1985)

Table 7 and Figure 6 show the number of days with minimum temperatures suitable for growing aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the climatic period (1985–2023) that March is considered one of the suitable months for the growth of aubergine, okra, radish and watermelon crops, as the minimum temperatures exceed the minimum threshold suitable for growth of (15°C). There is also a clear variation between the years studied in the number of days suitable for growth, reflecting the impact of climate change in the study area. The data indicate that recent years have recorded an increase in the number of days suitable for growth compared to earlier years, particularly in 2008, 2010, 2013, 2014, 2018, 2020, 2021 and 2023, with the number of days in each year as follows, respectively

Table 7: Number of days with minimum temperatures suitable for growing aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period 1985–2023

Year	Mar.	Apr.	May	Sep.	Oct.
1985	11	24	31	30	27
1986	4	30	31	30	28
1987	5	20	31	30	29
1990	4	26	31	30	31
1991	6	28	31	30	31
1992	1	23	31	30	25
1994	10	27	31	30	31
1995	6	25	31	30	29
1996	7	26	31	30	26
1997	—	24	31	30	31
1998	6	27	31	30	30
1999	6	29	31	27	30
2000	—	29	31	30	30
2001	11	29	31	30	31
2002	9	26	31	30	29
2003	—	—	—	—	—
2004	8	21	31	30	—
2005	6	25	31	30	—
2006	10	27	31	30	31
2007	9	30	30	28	31
2008	16	29	31	22	31
2009	7	25	31	30	31
2010	20	28	31	28	31
2011	7	26	30	30	27
2012	8	30	31	30	31
2013	18	29	31	30	31
2014	20	26	31	30	31
2015	12	26	28	30	31
2017	10	28	30	30	31
2018	18	29	31	24	31
2019	7	27	31	25	29
2020	16	30	31	27	31

2021	14	29	28	25	31
2022	7	30	31	20	31
2023	14	25	31	25	31

Source: Research conducted by the author based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

*** The minimum temperature suitable for the growth of aubergines, okra, eggplant and watermelons (15°C)**.

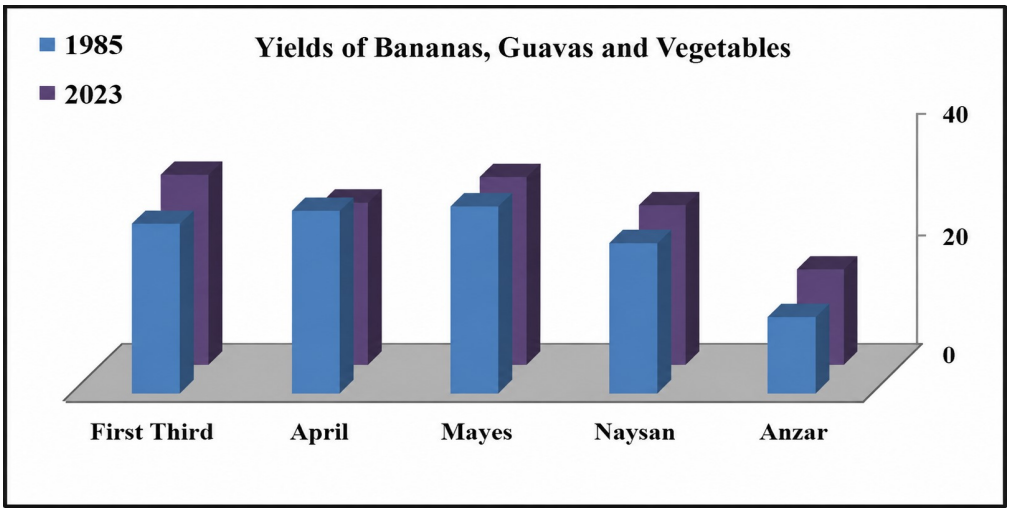


Figure 6: Number of days with minimum temperatures suitable for growing aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period 1985–2023

(1614 ,14 ,16 ,18 ,20 ,18 ,20 , days) suitable for growth. An example of this is the year 2018, which is a clear model of suitability, as minimum temperatures were recorded that exceeded the minimum suitable for the growth of aubergine, okra, radish and watermelon crops, as follows (17.2, 16.2, 16.0, 18.0, 19.8, 16.6, 16.4, 17.4°C) on days 5, 6, 7, 10, 15, 16, 21 and 22 respectively. This pattern applies to the other suitable years. A comparison between 1985 and 2023 shows that in 1985 11 days suitable for growth, whilst the number rose to 14 days in 2023, an increase of three days. This is a result of the impact of climate change in the study area, which contributed to a rise in minimum temperatures, thereby positively reflecting an increase in the number of days suitable for growth. The year 2023 is considered a model of suitability, having recorded minimum temperatures as follows (17.0, 20.8, 18.0, 17.0, 17.8, 20.2, 17.6 °C) on days 4, 7, 9, 14, 15, 19 and 26 respectively.

Daily minimum temperature for April over the period 1985–2023

It is evident from Table (8) and Figure (6) that April is one of the most suitable months for the growth of aubergines, okra, radishes and watermelons in Dhi Qar Governorate for the period 1985–2023, as the minimum temperatures exceeded the minimum threshold suitable for growth, which is approximately 15°C. It is noted that the number of days suitable for growth increased, ranging from 21 to 30 days during the study period, indicating clear climatic suitability for this month in terms of summer crop growth. The year 1991 is a clear example of thermal suitability, recording 28 days suitable for growth, with minimum temperatures as follows, respectively: (18.0, 17.8, 18.0, 20.2, 18.9, 20.8, 21.6 and 19.2 °C) on days 1, 2, 3, 4, 5, 17, 27 and 30. The year 2012 also represents another example of suitability, with minimum temperatures recorded as follows (18.6, 18.2, 20.2, 19.0, 18.8, 19.8, 19.2 °C) on days 1, 2, 3, 8, 18, 25, 26) respectively, reinforcing the trend of an increase in the number of suitable days in recent years of the study; and 2023 confirms the same trend, with minimum temperatures recorded as follows (19.4, 19.8, 18.2, 19.3, 21.0 °C) on days 7, 10, 17, 18 and 25 respectively. When compared with Nineveh Governorate, it is clear that April in Dhi Qar Governorate is characterised by a greater rise in minimum temperatures and a higher number of days suitable for growth, whereas Nineveh Governorate records lower values due to its geographical location and its exposure to colder air masses, making it less thermally suitable for summer crops during this month compared Dhi Qar Governorate, which is an indication of climate change in both governorates.

Daily minimum temperature for May over the period 1985–2023

Table 8 and Figure 6 show the number of days with minimum temperatures suitable for growing aubergines, okra, radishes and watermelons in Dhi Qar Governorate for the period 1985–2023. The month of May recorded full suitability in all years of the study, with 31 days suitable for growth, indicating the availability of suitable minimum temperature conditions for uninterrupted cultivation, with the exception of the years 2015 and 2021, which recorded a slight decline in the number of suitable days (28 days), 28 days, whilst the years 2007, 2011 and 2017 recorded 30 days each. Thus, the month of May is considered a stable period in terms of minimum temperatures in Dhi Qar Governorate and can be safely relied upon for the cultivation of aubergines, okra, watermelons and melons throughout the study period. The years 1992, 2010 and 2023 serve as illustrative examples of suitability, as these years recorded minimum temperatures exceeding the minimum threshold suitable for the growth of these crops, which is approximately (15°C). In 1992, minimum temperatures were recorded as follows (20.8, 21.0, 21.1, 21.3, 22.3, 19.2, 20.5, 21.0 °C) on days 1, 2, 3, 4, 5, 12, 23, 24) In 2010, temperatures ranged between (19.8, 20.0, 20.0, 20.2, 21.0, 22.0, 23.2 °C) on days (2, 3, 4, 5, 6, 25, 26), and also in 2023, minimum temperatures were recorded as follows (21.8, 21.0, 19.6, 21.0, 20.2, 23.5 °C) on days (1, 2, 3, 4, 5, 6) respectively.

Daily minimum temperature for September over the period 1985–2023

It is evident from Table (8) and Figure (6) that September is one of the most suitable months for the growth of aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period (1985–2023), with most years recording 30 days suitable for growth, reflecting the availability of suitable climatic conditions for cultivation. However, recent years have seen a decline in the number of suitable days, as follows: 2007 and 2010 recorded 28 days each year, 2008 (22 days), 2018 (24 days), 2019, 2021 and 2023 (25 days) each, and 2022 recorded 20 days suitable for growth. When comparing the years 1985 and 2023, it is noted that 1985 recorded 30 days suitable for growth, whilst 2023 recorded 25 days, meaning the number of days decreased by 5 days. This decrease is attributed to the rise in minimum temperatures and their approach to the upper limit suitable for the growth of these crops, which is approximately 38°C, particularly in the later years of the study, indicating climate change in Dhi Qar Governorate. As for the values not counted among the days suitable for growth in 2023, they ranged as follows, respectively: (31.0, 32.0, 32.0, 31.0, 34.0 °C) during the (3, 6, 9, 11, 12 days) unsuitable for growth.

Daily minimum temperature for October over the period 1985–2023

Table 8 and Figure 6 show that October is one of the most suitable months for the growth of aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period (1985–2023), with most years in the study period being fully suitable for growth (31 days), except for certain years in which the number of suitable days for growth decreased, as follows: 1985 and 2011 (27 days) for each year, 1986 (28 days) and 1987, 1995, 2002, 2019 (29 days) for each year, whilst the number of suitable days decreased more markedly in 1992 and 1996, reaching 25 days and 26 days respectively. When comparing the years 1985 and 2023, it was noted that 1985 recorded 27 days, whilst October 2023 recorded full suitability with 31 days, an increase of 4 days, indicating a clear improvement in the minimum thermal conditions suitable for growth in recent years

The year 2008 serves as an illustrative example of suitability, as minimum temperatures exceeded the minimum threshold suitable for the growth of these crops, which is approximately 15°C, as follows: 20.0, 17.0, 18.0, 17.0, 22.9, 21.0, 21.5, 22.5, 20.8, 20.5, 19.0 °C) on days 2, 3, 4, 5, 6, 9, 10, 11, 15, 18 and 21 respectively. The year 2014 is another example of suitability, with values ranging from (21.5, 22.0, 21.0, 20.0, 21.0, 19.0, 18.4 m) during days (1, 7, 8, 9, 17, 18 and 19) respectively. This general trend towards an increase in the number of days suitable for growth in October during the final years of the study period is attributed to climate change in Dhi Qar Governorate, characterised by a rise in minimum temperatures.

b) Daily maximum temperatures and their suitability for aubergine, okra, eggplant and watermelon crops in Dhi Qar Governorate.

Daily maximum temperature for March over the period 1985–2023

Table 9 and Figure 7 show the number of days with maximum temperatures suitable for growing aubergines, okra, eggplant and watermelons in Dhi Qar Governorate during the period (1985–2023) that March is considered a transitional month, as thermal conditions begin to rise gradually during this period; however, its thermal suitability for growth was not stable during the study years, particularly in the early years. Most years recorded a limited number of days suitable for growth, as follows: 1985 and 1990 recorded one day, 1991 and 1999 recorded three days, and 1994, 2009, 2014 and 2015 recorded four days each, whilst other years such as 2012 and 2020 recorded two days respectively. Conversely, a relative increase in the number of suitable days was observed in recent years, with 2008 and 2013 (11 days) for each year and 2010 recorded (10 days), whilst the highest value was reached in 2018 (14 days) suitable for growth. This variation is attributed to maximum temperatures not reaching the upper limit suitable for crop growth, which is approximately (38°C). In terms of the temporal trend, it is worth noting that 1985 recorded one day suitable for growth, whilst 2023 showed a relative improvement in the number of days suitable for growth, reflecting the beginning of the impact of climate change in gradually raising maximum temperatures during March in the study area .

Daily maximum temperature for April over the period 1985–2023

Table 9 and Figure 7 show that April is one of the most suitable months for the growth of aubergines, okra, radishes and watermelons in Dhi Qar Governorate during the study period (1985–2023), as the month recorded clear thermal suitability for growth in all study years. However, a variation in the number of days suitable for growth was observed across the study years; some years recorded a lower number of suitable days, namely 1985, 1991, 1992, 1996, 1997, 2002, 2004, 2017 and 2019, with the number of suitable days in these years being 15, 11, 13, 14, 14, 14, 21 and 7 days respectively. In contrast, other years showed a clear increase in the number of days suitable for growth, as follows: 2000 and 2010 (26 days) each year, 2001 (22 days) and 2011, 2013, 2017, 2023 (21 days) each, 2012 (20 days), 2022 (30 days). When comparing the years 1985 and 2023, it is clear that the number of days suitable for growth has risen from (15 days) in 1985 to (21 days) in 2023, an increase of (6 days) suitable for growth. This increase in the number of days is attributed to the general trend of rising maximum temperatures during April , as this month represents an advanced transitional phase towards summer, during which temperature values approach the upper limit suitable for growth in a more stable manner. The years 2005 and 2013 are considered examples of thermal suitability, as 2005 recorded suitable minimum temperatures as follows (35.8, 36.5, 35.5, 36.8, 38.0,

36.0, 37.5 °C) on days (1, 2, 10, 12, 13, 14, 25 and 29) respectively. The year 2013 is another example of suitability, with minimum temperatures ranging from (34.8, 36.0, 37.4, 38.4, 34.2 and 38.0 °C) on days 1, 2, 4, 8, 9 and 16 respectively.

Table 9: Number of days with maximum temperatures suitable for growing aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period 1985–2023

Year	March	April	May	September	October
1985	1	15	22	11	25
1986	—	17	24	—	25
1987	—	18	18	8	19
1990	1	17	15	10	10
1991	3	11	26	13	21
1992	—	13	26	9	29
1994	4	17	20	8	26
1995	—	15	15	11	27
1996	—	14	15	8	19
1997	—	14	16	7	19
1998	—	18	22	6	25
1999	3	19	15	9	19
2000	—	26	12	8	24
2001	8	22	18	—	30
2002	7	14	19	—	29
2003	—	—	—	—	—
2004	10	14	17	7	—
2005	6	17	8	8	—
2006	3	16	18	9	17
2007	—	14	15	5	28
2008	11	18	19	5	20
2009	4	15	18	10	27
2010	10	26	12	18	22
2011	5	21	16	—	21
2012	2	20	16	5	15
2013	11	21	19	8	14

2014	4	19	18	6	18
2015	4	19	13	—	18
2017	1	21	14	—	29
2018	14	15	19	—	11
2019	—	7	14	—	17
2020	2	18	14	2	29
2021	5	17	7	6	23
2022	2	30	22	9	20
2023	4	21	17	—	24

Source: Research conducted by the author based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

* The optimum maximum temperature for the growth of okra, aubergine, eggplant and watermelon (38 m).

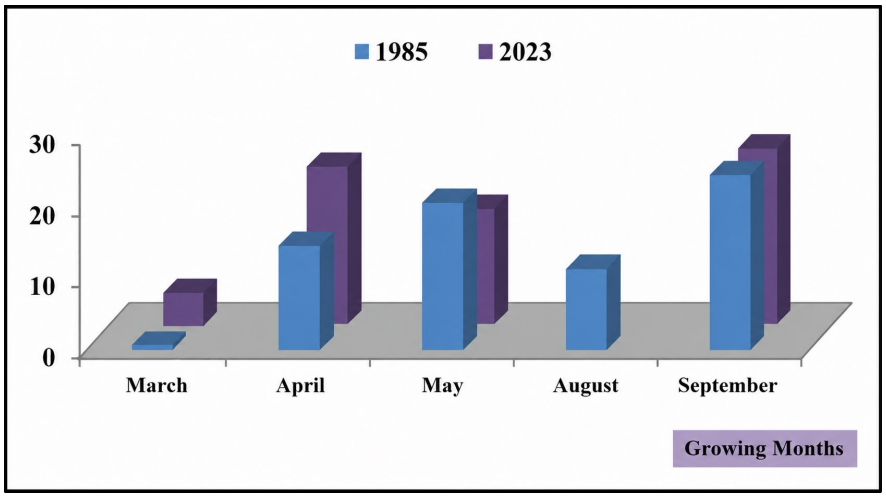


Figure 7: Number of days with maximum temperatures suitable for growing aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period 1985–2023

Daily maximum temperature for May over the period 1985–2023

It is evident from Table (9) and Figure (7) that May is one of the most suitable months for the growth of aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period (1985–2023). The data in the table indicate an increase in the number of days suitable for growth during the early years of the study, namely 1985, 1986, 1991, 1992, 1994, 1998 and 2022, with the number of

suitable days being 22, 24, 26, 26, 20, 22 and 22 days respectively. However, the number of days has begun to decline gradually in recent years, falling in 2023 to 17 days. This decline is attributed to maximum temperatures exceeding the upper limit suitable for the growth of these crops, which is approximately 38°C, with some days recording maximum temperatures exceeding 40°C. The year 2023 is a clear example of the decline in thermal suitability during the month of May, as maximum temperatures exceeded the upper limit suitable for growth. This led to a reduction in the number of days suitable for growth and had a negative impact on the month's efficiency within the growing season, given the direct influence of temperatures on crop growth and development. These temperatures are as follows (42.0, 42.4, 44.5, 43.6, 42.5, 43.0 °C) on days 12, 13, 23, 24, 27 and 28, which are unsuitable for growth .

Daily maximum temperature for September over the period 1985–2023

Table (9) and Figure (7) show the number of days with maximum temperatures suitable for growing okra, aubergines, eggplants and watermelons. It is evident that September is characterised by unstable thermal suitability for the growth of these crops; this is attributed to maximum temperatures in most years exceeding the upper limit suitable for growth, which is approximately (38°C). This rise has contributed to a reduction in, or the absence of, days suitable for growth during the month, particularly in the later years of the study, namely 1986, 2001, 2002, 2011, 2015, 2017, 2018, 2019 and 2023. When comparing the years 1985 and 2023, it is noted that 1985 recorded 11 days suitable for growth, whereas no days suitable for growth were recorded in 2023. The year 2023 is a clear example of thermal unsuitability, as values ranged between (44.0, 45.4, 45.2, 47.0, 48.2, 48.8, 46.2, 45.0 °C) on days 1, 2, 3, 4, 5, 6, 22 and 23 respectively. Consequently, the clear decline in the number of suitable days during September in Dhi Qar Governorate reflects the impact of climate change associated with rising maximum temperatures and increased heat stress, which has limited suitability for this month. In contrast, suitability for this month in Mosul Governorate remains relatively higher due to lower maximum temperatures and more stable suitable days.

Daily maximum temperature for October over the period 1985–2023

Table 9 and Figure 7 show that October is one of the most favourable months for the growth of aubergines, okra, eggplant and watermelons in Dhi Qar Governorate for the period (1985–2023), as the month recorded a high number of days suitable for growth compared to previous months due to a gradual decrease in maximum temperatures with the onset of autumn, creating suitable conditions for the physiological activity of these crops. The data indicate variation in the number of days suitable for growth, with most years recording a higher number of such days, as follows: 1985, 1986 and 1998 recorded 25 days each, whilst 1992, 2002, 2017 and 2020 recorded 29 days, 1994 (26 days), 1995 and 2009 (27 days), 2001 (30 days), 2007 (28 days) and 2023 (24 days) were suitable for growth. The years

with the fewest days suitable for growth were 1990 (10 days), 2012 (15 days), 2013 (14 days) and 2018 (11 days) respectively. The year 2006 is a clear example of thermal suitability, having recorded maximum temperatures as follows, respectively (36.4, 36.0, 36.8, 37.8, 35.5, 38.5, 37.0 °C) on days 5, 6, 7, 8, 11, 14 and 24) respectively. It is therefore clear that October represents a suitable period for the growth of these crops in Dhi Qar Governorate, although annual fluctuations may occur due to variations in maximum temperatures between years, a factor that must be considered when planning planting dates and crop management .

Climatic requirements for winter vegetable crops

The climatic requirements and planting dates for the crops listed are set out in Tables 10 and 11.

Winter vegetable crops

Green onion crop: The onion belongs to the Alliaceae family (Alliaceae) and the genus Allium. It is a biennial herbaceous plant; during the first growing season, the vegetative growth and the cultivated edible part (the bulb) develop, whilst during the second growing season, the plant completes its reproductive growth, producing flowers, then fruits and seeds (Hassan Ahmad Abdul-Moneim, 1984, 183) Onions are cultivated as both green and dry varieties across various provinces of Iraq. There are numerous varieties, though the most common are the red onion, known as the Mosul onion after the city of Mosul, and the local white onion. In the early stages of growth, the onion crop requires a cool, temperate climate to aid vegetative growth, whilst in the final stage, a hot, dry climate is required to ensure the bulbs develop fully and improve their quality (Al-Ani, Khattab and Sakkar, 1976, 317).

Carrot crop: The carrot crop is one of the most important root crops belonging to the Umbelliferae family, also known as the Parsley Family. The carrot is known in English as 'carrot', and its scientific name is Daucus carota subsp. It is an annual or biennial herbaceous plant, depending on the variety and temperature (Hassan Ahmed Abdel Moneim, 1991, 446).

Table (10): Minimum, optimum and maximum temperatures, and accumulated heat requirements for winter vegetable crops.

Crop	Minimum Temperature (°C)	Optimum Temperature (°C)	Maximum Temperature (°C)	Harmful Minimum Temperature (°C)	Harmful Maximum Temperature (°C)	Accumulated Heat (°C)
Green onion	8	12–20	26	6–	35	1200–1400
Carrot	11	18–25	30	6–	35	900–1000
Faba	6	18–20	25	2	32	1300

bean						
Lettuce	4	16–18	27	7–	32	400–500

Source: Compiled by the researcher based on

1- Ahmed Abdel-Moneim Hassan, Fundamentals of Vegetable Production and Technology of Open-Field and Protected Cultivation, 1st ed., Al-Dar Al-Arabiya for Publishing and Distribution, Cairo, 1984, p. 113.
2- Zhalal Jawad Kazim, Dalal Hassan Kazim, 'A Geographical Analysis of Winter Vegetable Cultivation in Najaf Governorate', Journal of Tikrit University for Humanities, Vol. 28, No. 3, 2021, pp. 222–223.
3- Haifa Nouri Isa Al-Ankoushi, The Relationship Between Climatic Characteristics and the Cultivation of Agricultural Crops in Najaf Governorate, Master's thesis, Faculty of Education, University of Kufa, 2004, p. 71.
4- Kinkov, Mortazov, Ayl Minkov, Vegetable Production, Cultivation and Seed Production, trans. Najm Abdullah Adhib, Part II, Basra, 1984, pp. 112–155.

Faba bean crop: The faba bean (Vicia faba) is one of the oldest legume crops cultivated in the world and belongs to the Fabaceae family It is primarily grown for its dry or green seeds, which are consumed as food for humans or as animal feed. It is a plant of the Fabaceae family, subfamily Papillonoideae, and is widely cultivated throughout the world. The plant is characterised by a strong stem, pinnate compound leaves and white flowers tending towards purple, and a pod-shaped fruit containing several seeds that vary in size and number depending on the variety and environmental conditions (Al-Tawil, Mohamed Sobhi, 2019, 163)**.**

Lettuce crop: Lettuce is a crop belonging to the Asteraceae (Composite Family) and is believed to have originated from a wild species native to Europe and Asia. Lettuce is consumed fresh in local markets and is increasingly popular due to its high nutritional value as well as its medicinal benefits (Al-Samara'i, Omar Mazahim Habib, 2006, p. 50)**.**

Table (11) Planting dates for winter vegetable crops and length of the growing season.

Source: Compiled by the researcher based on

1. Republic of Iraq, Ministry of Agriculture, Agricultural Statistics Department, Baghdad, unpublished data, 2025.
2. Ahmad Kassad Adel Al-Juhayshi, The climatically optimal geographical location for growing winter vegetable crops in the Euphrates River Valley in Iraq, Master's thesis, Faculty of Arts, Al-Qadisiyah University, 2022, p. 48.

Fourth – Thermal requirements of selected winter crops and analysis of daily temperatures (minimum and maximum) at the Nasiriyah station for the period 1985–2023.

Green onion crop

A. Daily minimum temperature and its suitability for the thermal requirements of green onions in Dhi Qar Governorate .

Daily minimum temperature for October over the period 1985–2023

It is evident from Table (12) and Figure (8) that October is one of the months with climatic conditions suitable for the growth of green onions in Dhi Qar Governorate for the period 1985–2023 and for all years of the study. However, the number of days suitable for growth showed a clear variation between years, attributed to minimum temperatures deviating from the minimum threshold suitable for crop growth, which is approximately 8°C . It is also evident that the number of days suitable for growth has gradually decreased in the later years of the study compared to the earlier years, due to rising minimum temperatures approaching the upper limit suitable for growth. These years are as follows: 2006 recorded 2 days; 2008, 2009 and 2014 recorded 8 days each; 2015 and 2019 recorded 3 days each, 2018 recorded 6 days, 2021 and 2023 recorded 5 days each, and 2022 recorded 4 days. When comparing the years 1985 and 2023, it is noted that 1985 recorded 22 days suitable for growth, whilst the number in 2023 fell to 5 days, representing a decrease of 17 days. This is attributed to higher minimum temperatures; for example, in 1985, minimum temperatures fell within the range suitable for growth, as follows: (16.5, 16.6, 17.0, 16.0, 15.0, 12.5, 12.5, 14.5, 15.3 °C) on days 5, 11, 15, 21, 22, 23, 29, 30 and 31 respectively, whilst in 2023 higher temperatures were recorded, falling outside the suitable thermal range, as follows: (27.0, 27.0, 25.2, 27.8, 28.5, 27.6, 28.6, 25.6 °C) on days (2, 3, 4, 11, 12, 13, 14 and 16 days) respectively, which contributed to a decrease in the number of days suitable for growth. This change clearly reflects the impact of climate change in Dhi Qar Governorate and its direct effect on the suitability of thermal conditions for the growth of green onions.

Table (12) Number of days with minimum temperatures suitable for growing spring onions in Dhi Qar Governorate for the period 1985–2023

Year	Oct.	Nov.	Jan.	Feb.
1985	22	28	22	19
1986	10	20	15	25
1987	18	29	9	24
1990	18	30	10	18

1991	11	26	2	14
1992	27	26	6	11
1994	8	25	27	20
1995	23	21	24	27
1996	19	29	23	26
1997	11	27	17	11
1998	21	30	18	20
1999	9	22	20	26
2000	21	17	13	18
2001	12	18	15	22
2002	8	15	8	19
2003	—	—	18	—
2004	—	—	11	18
2005	12	13	14	20
2006	2	9	19	28
2007	10	21	8	27
2008	9	26	6	17
2009	8	18	8	28
2010	8	26	29	24
2011	12	23	12	20
2012	11	25	7	20
2013	22	29	22	28
2014	8	18	25	22
2015	3	21	12	26
2017	7	26	9	13
2018	6	29	16	25
2019	3	28	21	28
2020	17	24	21	23
2021	5	27	20	28
2022	4	27	17	27
2023	5	27	24	23

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

* **The minimum temperature suitable for growing spring onions (8 m)**.

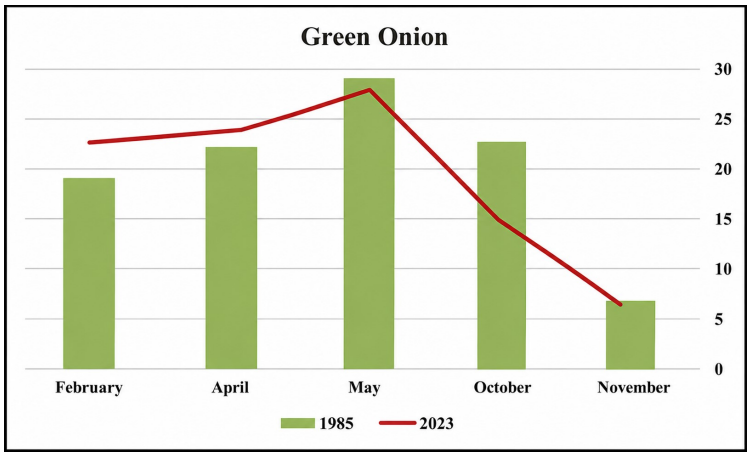


Figure 8: Number of days with minimum temperatures suitable for growing spring onions in Dhi Qar Governorate for the period 1985–2023

Daily minimum temperature for November over the period 1985–2023

It is evident from Table (12) and Figure (8) that November is one of the most suitable months for the growth of green onions in Dhi Qar Governorate for the period 1985–2023 This is attributed to the gradual decrease in minimum temperatures starting from October, which meant that most days in November fell within the temperature range suitable for crop growth. This temperature gradient contributed to an increase in the number of days suitable for growth, indicating stable climatic conditions favourable to the plant during this month. It is noted that the increase in the number of suitable days continued in most of the years under study, with the exception of those years which recorded a relative decrease in the number of suitable days, namely 2002 (15 days), 2005 (13 days) and 2006 (9 days) respectively. The year 2013 can be cited as an example, as November recorded 29 days suitable for growth, indicating that minimum temperatures were in line with the thermal requirements of spring onions. These values are as follows: 15.0, 15.0, 14.2, 14.4, 16.0, 14.6, 14.2, 15.2, 13.8, 12.5, 12.6, 11.6, 15.8 on days 3, 4, 5, 6, 14, 15, 16, 17, 21, 23, 24, 27 and 29 respectively, and this pattern applies to the remaining years.

Daily minimum temperature for January over the period 1985–2023

It is evident from Table (12) and Figure (8) that January is considered a suitable month for the growth of green onions in Dhi Qar Governorate for the period 1985–2023 , as this month recorded

days suitable for growth in all years of the study, with variations in the number of days from one year to the next depending on changes in minimum temperature values. The data indicate that some years recorded a small number of suitable days, such as 1987 and 2017, which recorded 9 days each, 1991 (2 days), 1992 and 2008 (6 days), and 2002, 2007 and 2009 (8 days each), and 2012 (7 days). Meanwhile, the remaining years recorded a clear increase in the number of days suitable for growth. This can be inferred from certain examples: 2005 recorded approximately 14 days suitable for growth, with values ranging from 7.0, 12.2, 8.8, 10.5, 7.0, 9.9, 11.0, 8.5 and 7.0 m during (2, 3, 5, 6, 7, 10, 18, 25, 30 days) respectively, whilst in 2015 there were approximately 12 days suitable for growth, with minimum temperatures ranging as follows: (6.0, 7.0, 8.5, 11.0, 9.0, 6.6, 11.5°C) on days (1, 2, 3, 7, 8, 25, 28) respectively. When comparing the years 1985 and 2023, an increase in the number of suitable days is observed, particularly in the later years of the study period, as 2023 recorded (24 days) suitable for growth, an increase of (2 days) compared to 1985, which recorded (22 days). This is attributed to the relative rise in minimum temperatures experienced by the region over recent decades .

Daily minimum temperature for February over the period 1985–2023

It is evident from Table (12) and Figure (8) that February is one of the most suitable months for the growth of green onions in Dhi Qar Governorate for the period (1985–2023), as minimum temperatures exceeded the minimum threshold suitable for crop growth, which is approximately (8°C). This gradual rise in minimum temperatures results in stable thermal conditions that effectively support plant growth during this month, as all years recorded an increase in the number of days suitable for growth. These years are as follows: 1986 and 2018 recorded (25 days), 1987 and 2010 (24 days) each year; 1994, 1998, 2005, 2011 and 2012 recorded (20 days) each year; 1995, 2007 and 2022 recorded (27 days) suitable; 1999 and 2015 recorded (26 days); and 2006, 2009, 2013, 2019, 2021 recorded (28 days) per year. With the exception of some years which recorded a lower number of suitable days; for example, 1985 recorded approximately (19 days) suitable for growth, whilst 2023 recorded approximately (23 days), an increase of nearly 4 days, reflecting a gradual improvement in suitable thermal conditions. The values for the year 2023 ranged as follows: (10.5, 7.5, 9.2, 13.8, 11.0, 10.0, 9.0, 13.5, 14.8 °C) on days 1, 2, 5, 6, 12, 13, 21, 25 and 28 respectively.

b) Daily maximum temperature and its suitability for the thermal requirements of green onions in Dhi Qar Governorate.

Daily maximum temperature for October over the period 1985–2023

Table 13 and Figure 9 show the number of days with maximum temperatures suitable for growing spring onions in Dhi Qar Governorate for the period 1985–2023 It is evident that October is

characterised by limited thermal suitability for crop growth; although minimum temperatures fall within the thermal limits suitable for growth during most of the study years, maximum temperatures often reach high values exceeding the upper limit suitable for crop growth, which is approximately 26°C, leading to a reduction or absence of suitable growing days during this month. The data in the table indicate that in the majority of the study years, no days suitable for growth were recorded due to high maximum temperatures exceeding the upper limit suitable for growth. This can be illustrated by some examples: in 1999, maximum temperatures were recorded as follows (41.0, 43.0, 42.0, 41.5, 40.8, 34.0, 34.6, 37.0, 35.5, 36.7 °C) on days 1, 2, 3, 6, 11, 13, 20, 25, 28 and 30 respectively. Whereas in 2017, they were approximately (40.0, 39.5, 39.0, 38.8, 40.2, 13, 17, 26, 40.3 °C) on days 1, 2, 3, 8, 10, 37.6, 35.7 and 40.0 respectively. These values exceed the upper limit suitable for the growth of green onions, resulting in no suitable days being recorded .

Table (13) Number of days with maximum temperatures suitable for growing spring onions in Dhi Qar Governorate for the period 1985–2023

Year	October	November	January	February
1985	9	30	10	12
1986	4	29	15	15
1987	11	29	14	27
1990	2	26	6	12
1991	2	28	2	12
1992	—	26	3	7
1994	2	28	18	19
1995	—	21	12	20
1996	4	28	12	22
1997	6	29	13	12
1998	1	22	17	17
1999	—	25	22	18
2000	7	28	12	16
2001	—	20	12	26
2002	5	28	4	24
2003	—	—	16	—
2004	—	—	10	18
2005	7	28	11	15
2006	6	28	9	14

2007	—	28	6	23
2008	7	29	6	19
2009	4	27	12	28
2010	—	30	27	22
2011	5	26	15	15
2012	6	16	18	13
2013	14	28	16	26
2014	13	26	8	17
2015	5	28	18	22
2017	—	23	18	13
2018	4	29	27	27
2019	7	28	11	18
2020	—	22	21	21
2021	—	27	27	26
2022	—	27	17	26
2023	5	27	12	22

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025.

*The optimum maximum temperature for growing spring onions (26°C).

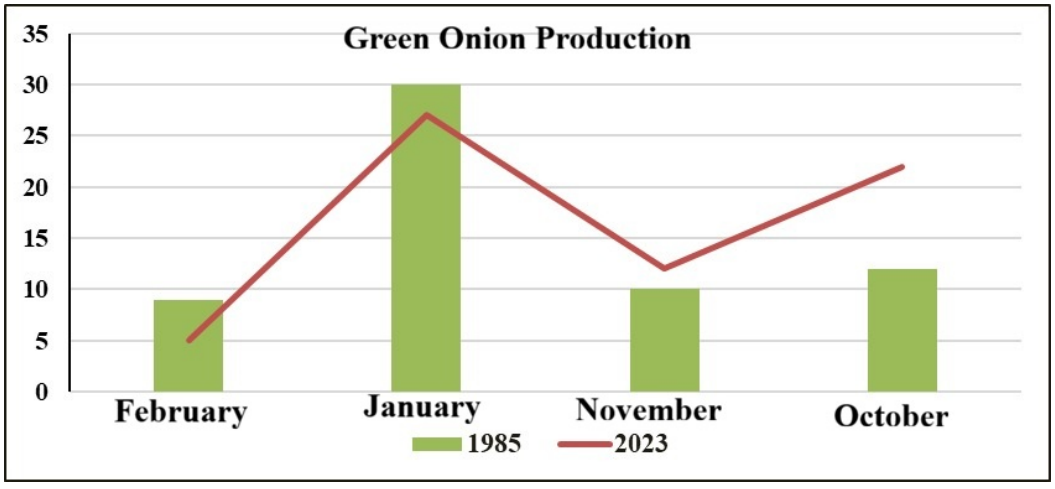


Figure 9: Number of days with maximum temperatures suitable for growing spring onions in Dhi Qar Governorate for the period 1985–2023

Daily maximum temperature for November over the period 1985–2023

It is evident from Table (13) and Figure (9) that November is one of the months with a climate suitable for the growth of green onions in Dhi Qar Governorate for the period 1985–2023 This is attributed to the fact that maximum temperatures begin to decline gradually during this month compared to October, with most values falling within the upper limit suitable for growth, which is approximately 26°C, thereby contributing to an increase in the number of days suitable for crop growth. It was observed that the number of suitable days ranged between 25 and 30 days in most of the years studied, reflecting near-perfect suitability for November, with the exception of 2012, which recorded around 16 days suitable for growth due to high temperatures that year. The temporal variation between the start and end of the study period can also be inferred: 1985 recorded around 30 days suitable for growth. Meanwhile, the figure fell to around 27 days in 2023, a decrease of approximately three days, reflecting the effects of climate change and the gradual rise in maximum temperatures. These values are as follows: (23.3, 24.3, 24.3, 22.4, 24.7, 27.0 °C) on days (15, 18, 19, 25, 26, 27) respectively. This pattern suggests that climate change may affect the number of days suitable for growth in the future if temperatures continue to rise, whilst the month remains, as it has so far, among the months climatically suitable for the growth of green onions in Dhi Qar Governorate, making it ideal for studying the relationship between thermal variables and growing seasons in the region .

Daily maximum temperature for January over the period 1985–2023

It is evident from Table (13) and Figure (9) that January is considered one of the most suitable months for the growth of green onions in Dhi Qar Governorate for the period 1985–2023, as maximum temperatures were recorded within the upper limit suitable for crop growth, which is approximately 26°C, during the years under study. A clear variation was observed in the number of days suitable for growth between the years under study, with most years recording a higher number of such days, as follows: 1994, 2012, 2015 and 2017 recorded 18 days each year; 1999 recorded 22 days, and 2010, 2018 and 2021 recorded 27 days each, whilst 2021 recorded 21 days. In contrast, other years recorded fewer days suitable for growth, as follows: 1991 recorded 2 days, 2002 recorded 4 days, and 2007 and 2008 recorded 6 days each. The years 2000 and 2017 can be cited as illustrative examples of suitability; in 2000, maximum temperatures ranged as follows (22.8, 20.8, 25.0, 22.0, 22.4, 24.5, 22.7, 20.7 °C) over 6, 12, 16, 17, 20, 22, 28 and 29) respectively. In 2017, the values ranged as follows (20.4, 20.4, 23.5, 20.6 and 22.5 °C) on days 6, 7, 8, 19 and 27 respectively.

Daily maximum temperature for February over the period 1985–2023

It is evident from Table (13) and Figure (9) that February is one of the most suitable months for the growth of green onions in Dhi Qar Governorate for the period 1985–2023 as maximum temperatures suitable for growth were present throughout the study period. This month recorded a high number of

days suitable for growth in most of the study years, particularly in recent years, leading to a clear improvement in suitable thermal conditions during this month. A comparison between the beginning and end of the study period shows that the number of days suitable for growth rose from 12 days in 1985 to 22 days in 2023, an increase of approximately 10 days, which is a clear indication of the impact of climate change in the study area. The year 2023 can be cited as a clear example of thermal suitability, as the maximum temperatures recorded during that year were as follows (20.2, 20.0, 22.2, 20.4, 20.4, 20.4, 23.5, 26.6 °C) on days 3, 4, 5, 7, 12, 19, 20 and 23 respectively, indicating that climatic conditions in Dhi Qar Governorate have become more suitable for growing green onions during this month.

2. Lettuce crop

A. Daily minimum temperature and its suitability for the thermal requirements of lettuce in Dhi Qar Governorate.

Daily minimum temperature for October over the period 1985–2023

It is evident from Table (14) and Figure (10) that October is one of the most suitable months for lettuce growth in Dhi Qar Governorate for the period 1985–2023 The early years of the study period recorded several suitable days, as minimum temperatures approached the minimum threshold suitable for lettuce growth, which is approximately 4°C; however, this pattern

Table (14) Number of days with minimum temperatures suitable for lettuce cultivation in Dhi Qar Governorate for the period 1985–2023

Year	October	November	January	February
1985	16	27	31	25
1986	7	25	25	28
1987	13	29	28	28
1990	8	29	22	28
1991	3	27	30	26
1992	26	28	30	26
1994	6	22	31	28
1995	14	24	31	28
1996	12	30	31	28
1997	5	30	29	21
1998	17	30	30	26
1999	5	27	29	27
2000	16	30	31	28

2001	3	27	28	28
2002	3	26	20	24
2003	—	—	31	—
2004	—	—	30	28
2005	11	28	27	27
2006	—	30	18	28
2007	4	30	24	28
2008	5	28	21	23
2009	—	28	30	26
2010	2	28	30	27
2011	7	25	27	27
2012	2	27	31	25
2013	14	24	31	28
2014	2	30	31	27
2015	—	30	28	28
2017	—	22	29	27
2018	4	29	30	28
2019	—	30	30	28
2020	7	29	31	28
2021	—	23	28	28
2022	—	24	27	28
2023	—	21	30	28

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025 .

*Minimum temperature suitable for lettuce growth (4 m).

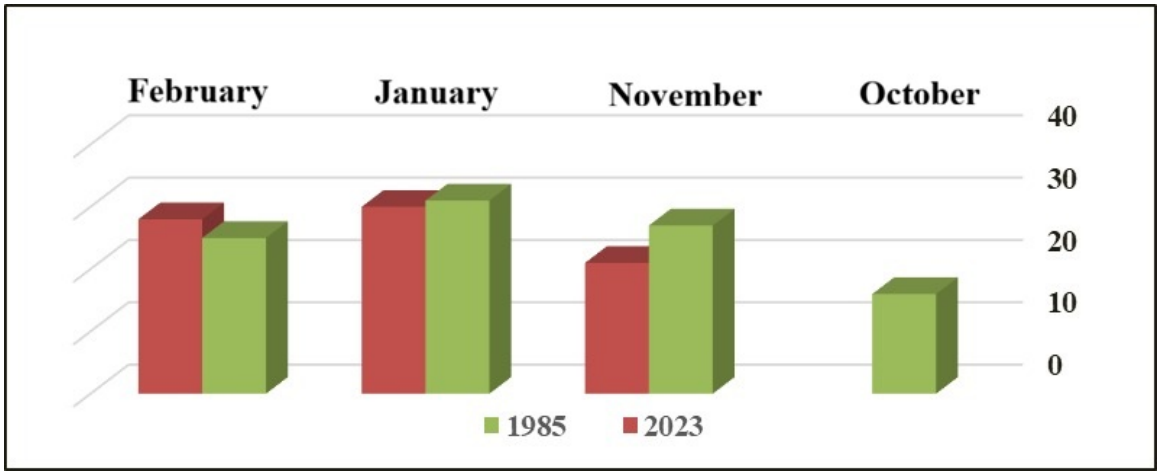


Figure (10) Number of days with minimum temperatures suitable for lettuce cultivation in Dhi Qar Governorate for the period 1985–2023

This trend did not continue, however, as recent years have seen an upward trend in minimum temperatures and a shift away from this threshold, resulting in a lack of days suitable for growth. When comparing the years 1985 and 2023, it is noted that 1985 recorded 16 days, whereas 2023 recorded no days suitable for growth. This is attributed to the marked rise in minimum temperatures, which exceeded the suitable thermal limits, rendering conditions unsuitable for crop growth. The year 2023 is a prime example of thermal unsuitability, as the maximum temperatures recorded were as follows (27.0, 27.0, 25.5, 24.3, 27.9, 28.6, 25.6 °C) on days 2, 3, 4, 8, 11, 14 and 16 respectively .

Daily minimum temperature for November over the period 1985–2023

Table (14) and Figure (10) show that November is one of the most suitable months for the growth of lettuce in Dhi Qar Governorate over the period 1985–2023. The results indicate that this month recorded a clear increase in the number of days suitable for growth, ranging from 21 and 30 days across all years of the study. This reflects the moderate minimum temperatures during this month, with values falling within the thermal limits suitable for crop growth, thereby contributing to the availability of suitable climatic conditions for lettuce cultivation. The years 1985 and 2019 can be cited as examples of thermal suitability, as 1985 recorded 27 days suitable for growth, indicating that minimum temperatures were in line with the crop's thermal requirements. These values are as follows (15.0, 15.0, 14.4, 11.8, 12.0, 11.5, 10.4, 10.7, 11.5, 12.5 °C) on days 1, 2, 6, 8, 15, 16, 17, 21, 28 and 29 respectively. As for 2019, it recorded (30 days), with minimum temperatures ranging between (15.2, 14.5, 14.6, 14.2, 14.0, 14.8, 8.0, 9.0, 13.8, 15.0 °C) on days (1, 2, 6, 9, 10, 18, 19, 23, 24 and 26) respectively, and this pattern applies to the other years as well. When comparing the years 1985 and 2023, it is noted that 1985 recorded 27 days, whilst the number fell to 21 days in 2023, representing a decrease of 6 days as a result of rising temperatures; this decline is directly linked to climate change in the study area.

Daily minimum temperature for January over the period 1985–2023

Table (14) and Figure (10) show the number of days on which minimum temperatures suitable for lettuce growth were recorded in Dhi Qar Governorate for the period 1985–2023. It is evident that January is one of the most suitable months for crop growth, with the minimum number of suitable days for growth amounting to approximately 4°C. Most years in the study showed an increase in the number of days suitable for growth, ranging from 20 to 31 days respectively, with the exception of 2006, which recorded 18 days suitable for growth. The years 1994 and 2014 are considered typical examples of thermal suitability, with 1994 recording 31 days suitable for growth and minimum temperatures as follows: (11.5, 8.6, 7.0, 7.4, 9.4, 8.5, 10.2, 10.5, 7.8, 10.0, 10.5 days) on days 1, 6, 7, 9, 13, 14, 19, 23, 27, 29, 30 days) respectively. In 2014, there were 31 days, with the following values (8.0, 6.0, 8.6, 10.0, 7.0, 7.5, 9.4, 11.4, 10.6, 10.6 °C) on days 1, 3, 5, 6, 11, 15, 22, 24, 26 and 30 respectively.

Daily minimum temperature for February over the period 1985–2023

It is evident from Table (14) and Figure (10) that February is considered a suitable month for lettuce growth in Dhi Qar Governorate for the period 1985–2023 In most of the years under study, 28 days were recorded as suitable, meaning that the month was entirely suitable for growth. This is attributed to the fact that minimum temperatures exceeded the minimum threshold suitable for crop growth, which is approximately 4°C, thereby providing suitable and stable thermal conditions for growth. A comparison over time also shows an increase in the number of days suitable for growth from 25 days in 1985 to 28 days in 2023, an increase of three days, reflecting the impact of climate change and rising temperatures .

b) Daily maximum temperature and its suitability for the thermal requirements of lettuce cultivation in Dhi Qar Governorate.

Daily maximum temperature for October over the period 1985–2023

It is evident from Table (14) and Figure (10) that October is considered an unsuitable month for growing lettuce in Dhi Qar Governorate for the period 1985–2023, as maximum temperatures were recorded that exceeded the upper limit suitable for crop growth, which is

Table (14) Number of days with maximum temperatures suitable for lettuce cultivation in Dhi Qar Governorate for the period 1985–2023

Year	October	November	January	February
1985	4	24	20	17

1986	—	26	20	23
1987	9	29	19	24
1990	—	17	7	21
1991	—	19	12	18
1992	—	19	9	14
1994	2	20	26	19
1995	—	24	19	23
1996	4	27	20	15
1997	5	28	19	23
1998	—	24	8	18
1999	—	23	28	22
2000	3	28	13	20
2001	—	18	16	28
2002	—	25	9	27
2003	—	—	21	—
2004	—	—	30	25
2005	—	9	20	19
2006	—	25	28	20
2007	—	12	10	28
2008	5	28	13	21
2009	—	18	25	28
2010	—	25	30	21
2011	3	22	18	20
2012	—	18	30	25
2013	4	24	28	28
2014	—	27	11	23
2015	—	30	26	27
2017	—	21	21	23
2018	3	28	26	27
2019	—	15	15	28
2020	—	22	25	23
2021	—	22	27	25
2022	—	11	20	28

2023	—	14	15	18

Source: Compiled by the researcher based on data from the Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological and Seismological Authority, Climate Division, Baghdad, unpublished data, 2025 .

* Optimum maximum temperature for lettuce growth (27°C).

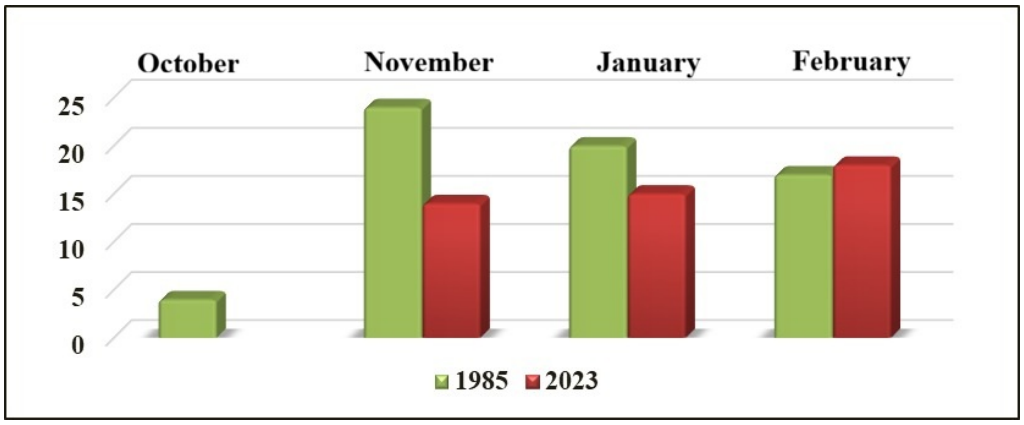


Figure (10) Number of days with maximum temperatures suitable for lettuce cultivation in Dhi Qar Governorate for the period 1985–2023

Around (27 days), which led to a decrease in the number of days suitable for growth, except a very limited number of years that recorded a small number of suitable days, as follows: 1985, 1996 and 2013 recorded (4 days) each year; 1994 recorded (2 days); 2000, 2011 and 2018 (3 days), 1997 and 2008 (5 days), and 1987 (9 days) respectively. For example, 1985 recorded 4 suitable days, whilst no suitable days were recorded in 2023; this is attributed to the high maximum temperatures during the month, and the values recorded in these two years serve as a clear example of thermal unsuitability for growth. The maximum temperatures in 2023 were as follows (40.1, 41.1, 40.9, 40.8, 41.5, 40.7, 40.9, 35.6, 36.1, 33.2, 34.0, 34.5 °C) on days 1, 2, 3, 4, 10, 14, 15, 20, 21, 27, 29 and 31 respectively. A comparison between the two governorates shows that October is more suitable in Nineveh Governorate than in Dhi Qar Governorate due to the moderate maximum temperatures in Nineveh, whereas the high temperatures in Dhi Qar make this month unsuitable for lettuce growth.

Daily maximum temperature for November over the period 1985–2023

It is evident from Table (14) and Figure (10) that November is one of the months with a climate suitable for lettuce growth in Dhi Qar Governorate for the period 1985–2023 This is attributed to the fact that maximum temperatures begin to decrease gradually during this month compared to October, with most values falling within the upper limit suitable for growth, which is approximately 27°C, thereby contributing to an increase in the number of days suitable for crop growth. It was observed

that the number of suitable days ranged in most of the study years between 18 and 30 days suitable for growth, respectively, except a few years that recorded fewer days, as follows: 1990 (17 days), 2005 (9 days), 2007 (12 days), 2019 (15 days), 2022 (11 days) and 2023 (14 days) respectively. The temporal change between the start and end of the study period can also be inferred: in 1985, approximately 24 days were suitable for growth. Meanwhile, the figure fell to around 14 days in 2023, a decrease of 10 days, reflecting the impact of climate change associated with a gradual rise in maximum temperatures, particularly in the later years of the study period. This pattern indicates future impacts on the agricultural sector, as the continued rise in maximum temperatures above the upper limit suitable for lettuce growth may lead to a reduction in the number of days suitable for its growth, which may adversely affect its yield and quality .

Daily maximum temperature for January over the period 1985–2023

Table 14 and Figure 10 show that, for the period (1985–2023) that January is one of the most suitable months for crop growth; however, there is a clear variation in the number of suitable days from year to year. The years with the highest number of suitable days were as follows: 1985, 1986, 1996, and 2002. The following years recorded (20 days) per year: 1994, 2015, 2018 (26 days), 1999, 2006, 2013 (28 days), 2003, 2017 (21 days), 2004, 2010, 2012 (30 days), 2020 (25 days), 2021 (27 days) respectively. The years with fewer days were 1990 (7 days), 1991 (12 days), 1992 and 2002 (9 days), 1998 (8 days), 2000, 2008 (13 days), 2014 (11 days), 2019 and 2023 recorded (15 days) each year. When comparing 1985 and 2023, it is noted that 1985 recorded (20 days), whilst the number in 2023 fell to (15 days), representing a decline of (5 days) conducive to growth. This discrepancy is attributed to changes in maximum temperatures, which lead to a reduction in the number of days suitable for lettuce growth, as it is a crop that prefers moderate climates. Consequently, the general trend indicates that the rise in temperatures has contributed to a reduction in the number of days suitable for cultivation, which negatively affects the growth and crop yield.

Daily maximum temperature for February over the period 1985–2023

It is evident from Table (14) and Figure (10) that February is one of the months with climatic conditions suitable for lettuce growth in Dhi Qar Governorate for the period 1985–2023 Most years in the study showed an increase in the number of days suitable for growth, ranging from 18 to 28 days, except years that recorded fewer suitable days, such as 1992 (14 days) and 1996 (15 days) suitable for growth. The results also indicate a gradual increase in the number of suitable days during the latter years of the study period. This is attributed to the fact that maximum temperatures during February begin to rise gradually, particularly in the second half of the month; however, they remain within the

suitable limits for lettuce crop growth in many years, contributing to an increase in the number of days suitable for crop growth, which is an indication of the climatic changes occurring in the study area.

Conclusions:

1- The results of the study indicate a general trend towards rising levels of solar radiation and minimum and maximum temperatures during the final years of the study period, suggesting clear effects of climate change and increased greenhouse gas emissions.

2- Relative humidity showed a downward trend during the study period as a result of the continuous rise in temperatures and the accompanying increase in evaporation rates and fluctuations in rainfall.

3- The study showed that March is characterised by conditions that are generally suitable for the growth of aubergines, eggplants, okra and watermelons, as minimum temperatures fall within relatively acceptable limits, whilst maximum temperatures are recorded at values below the optimum threshold required for the growth of these crops, leading to a poor growth response during this month, whilst suitable conditions begin to improve gradually during April as temperatures approach the optimum limits, making the month more suitable for growth.

4- As for September, it is an unsuitable month for the growth of the aforementioned crops, as whilst minimum temperatures are relatively suitable, maximum temperatures exceed the upper suitable limit, leading to heat stress that negatively affects the growth and productivity of these crops.

5- The results also showed that, for the winter vegetable crops lettuce and spring onions, October is unsuitable for growth, as maximum temperatures exceed the optimal thermal limits, whilst minimum temperatures are suitable only for limited and infrequent periods, failing to meet the for the growth of these crops; consequently, March is classified as an unsuitable month.

6- In conclusion, it is recommended that farmers monitor climatic conditions and the timing of the start of planting seasons in line with climate change to achieve better agricultural productivity.

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