

A Study into the Agro-Climatic Conditions in the Central and Eastern Regions of Saudi Arabia

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ABSTRACT. A study into the climatic conditions of Central and Eastern regions in the Kingdom of Saudi Arabia over a period of 236 years indicated both drought and without drought periods. The duration of drought varied from 1 to 7 years whereas that of without drought varied from 8 to 44 years. Study of the agro-climatic conditions usually gives a good approximation of the existing crop growth conditions. In general, it also shows promising areas of research in plant breeding for drought resistance, water management for better moisture conservation and future project planning.

The agro-climatic conditions in the Central and the Eastern Regions of the Kingdom of Saudi Arabia fall under the arid and semi-arid zones (Thornwaite 1943, 1948 and Koppen 1900). The rainfall variability is extremely high as is the case in all desert regions. The annual precipitation at one station shows great differences from year to year. Dhahran, for example, registered 186.9 mm in 1974 and 5.3 mm only in 1946 (Aramco 1935-74). The temperature ranges from 27.5 to 36.8°C in summer, from 4.5 to 20°C in winter, from 13.2 to 32.2°C in spring and from 13.1 to 34.7°C in fall. However, a yearly average of 51.1 percent relative humidity was obtained for 1970 with a minimum and maximum monthly average of 28.4 and 73.5 percent, respectively.

A review of some historical books of Arabia for the past three centuries revealed that the Arabia had undergone periods of severe droughts (Bin Bisher 1974 and Abo Aliah 1974). Recently, a positive correlation between the effects of weather in one place and those in another has been observed (U.S. Dept of Agriculture 1975). Unfavourable weather conditions played a dominant role in caus-

ing major declines in food production in 1964-66, and 1972-74. Similarly, effect of rainfall on wheat yield in India and that of drought on groundnut production in Nigeria were reported (Chowdhry and Rao 1976, and Julius and Richard 1979).

There is a close relationship between temperature, relative humidity and evaporation rate (Kettani 1973). He also observed a maximum and minimum monthly evaporation of 691 mm (22.3 mm/day) in July and 144 mm (4.7 mm per day) in January, 1971, respectively, for Dhahran Station. The effect of climate parameters on the evapotranspiration of different crops has been reported by many authors (Hagan *et al.* 1967, Jensen and Haise 1963, Pruitt *et al.* 1972, Isrealsin and Hansen 1973, Hofuf Agr. Res. Center 1973a, b, and FAO/UNESCO 1973, 1977, Asseed *et al.* 1982).

As such, there is a great possibility that the adverse climate conditions may occur during a part of the year in the Central and Eastern regions of the Kingdom which would limit the agricultural expansion. Consequently, this is likely to affect the future groundwater development program in the country.

The present study is an effort to collect the agro-climatic data related to rainfall, temperature, relative humidity and evapotranspiration/evaporation rates in the Central and Eastern regions of the Kingdom of Saudi Arabia. The main objectives of this study are (1) to collect and compile data for some climatic factors, namely, rainfall, temperature and relative humidity and, (2) to findout, if any, the adverse effect of extreme climatic conditions on agriculture development in the region.

Material and Methods

The data for the different climatic factors, namely, rainfall, temperature, relative humidity and evaporation rate, were collected from the statistics published by the Central Department of Statistics, Ministry of Finance and National Economy, Kingdom of Saudi Arabia (1965-81), FAO/UNESCO Publications, World Meteorological Organization (WMO) publications, Hofuf Agr. Res. Center Reports, SANCST Reports, a book on Quaternary period in Saudi Arabia, ARAMCO sources, and the related journals etc. (Sources utilized listed as references).

It is pointed that more emphasis has been placed on rainfall amount and distribution pattern, temperature and relative humidity. Mean monthly values for temperature and relative humidity are reported as given in the source. The data is presented for the period from 1959-81 for four stations in the form of tables and graphs. These include Dhahran, Riyadh, Hail and Al-Qašim. Also additional data collected for the drought period has been incorporated for information and utilization by the research workers.

Results and Discussion

1. Drought conditions

Drought is a general term meaning a sustained period of significantly subnormal water or soil moisture supply. It has different meanings to agriculturists, meteorologists, and hydrologists as discussed by Hoffman and Rantz (1968). Frank Veits Jr. (1972) defined drought as any period when water deficiency, either acute or chronic, affects plant growth and the decision on what to plant and how to grow it. Drought may mean short periods without rain in humid regions or by the prevailing conditions in the desert. Saarinen (1966) discusses three types of droughts; meteorologic, from lack of precipitation; hydrologic, from stream and groundwater sources diminishing; and agricultural, where, due to timing, volume or both, the crops do not develop properly.

The data given in Table 1 indicate the drought duration over a period of 236 years starting from 1673 to 1909. The drought period varies from 1 to 7 years with an average values of 2.56 years, whereas the period of without drought conditions range from 8 to 44 years. It also shows that the drought conditions prevailed for a short period compared to without droughty conditions. Because the ultimate effect of drought depends on its intensity and the time of the year when it occurs. For example, in Nigeria, droughts accompanied by famine occurred in the 1890 and in 1913-14, 1927, 1934-35, and 1942-48. Rainfall records for Nigeria show that the 1972-73 drought excelled all previous droughts in area and in severity. In 1973, rainfall deficits ranged from 10% of the average to over 50%. Many crops were destroyed and there was considerable loss of livestock as herds moved northward

Table 1. Drought periods with different intervals for 236 years (1673-1909).

S. No.	First year	Last year	Duration of drought	Duration without drought
1	1673	1674	2	—
2	1715	1715	1	41
3	1723	1724	2	8
4	1766	1766	1	44
5	1782	1782	1	16
6	1804	1910	7	22
7	1834	1837	4	24
8	1870	1872	3	33
9	1908	1909	2	36
Average			2.56	28.00

to seek shelter. Groundnut production was badly affected and exports were stopped. Food prices rose by more than 200%. The drought caused major damage to the Nigerian economy. An example is provided in Fig. 1 of groundnut output, based on figures issued by the Federal Office of the Statistics, Lagos. Other evidences of the severity of drought and its impact on land use has been reported by Khalil (1974). He found losses in livestock amounted to about 400,000 and losses in food crops exceeded 1.1 million tons, about 50% of the average annual production.

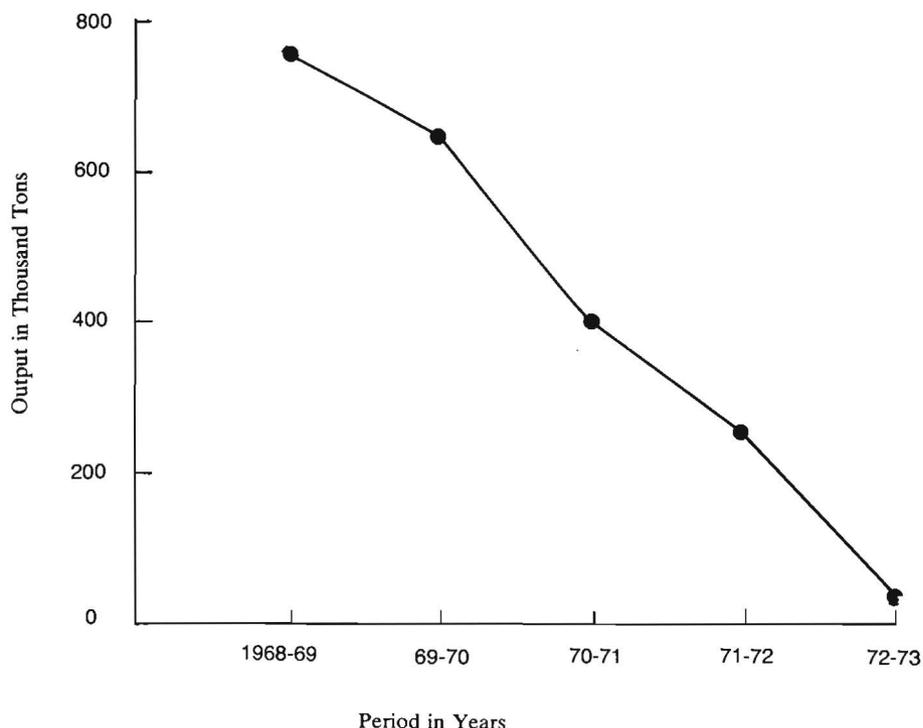


Fig. 1. Effect of drought on ground nut production in Nigeria (adapted from World Climate Conference WMO-FAO. Geneva, Feb, 1979).

A comparison has been made between the average rainfall received over a year and the actual and potential evapotranspiration determined under Al-Hassa conditions (Fig. 2). The data indicate a significant difference between the amount of rainfall received and the water demand for Alfalfa crop. This also shows an extreme dry conditions because the rainfall is hardly enough to meet less than 5% of the crop water needs. Furthermore, the data given in Table 2 give a good approximation about the weather conditions and its impact on socio-economic

conditions of the area. Hence, there were periods of prosperity and the time when there were problems of acute food shortage, animal losses, and migratory periods enforcing the people to move towards more healthy areas.

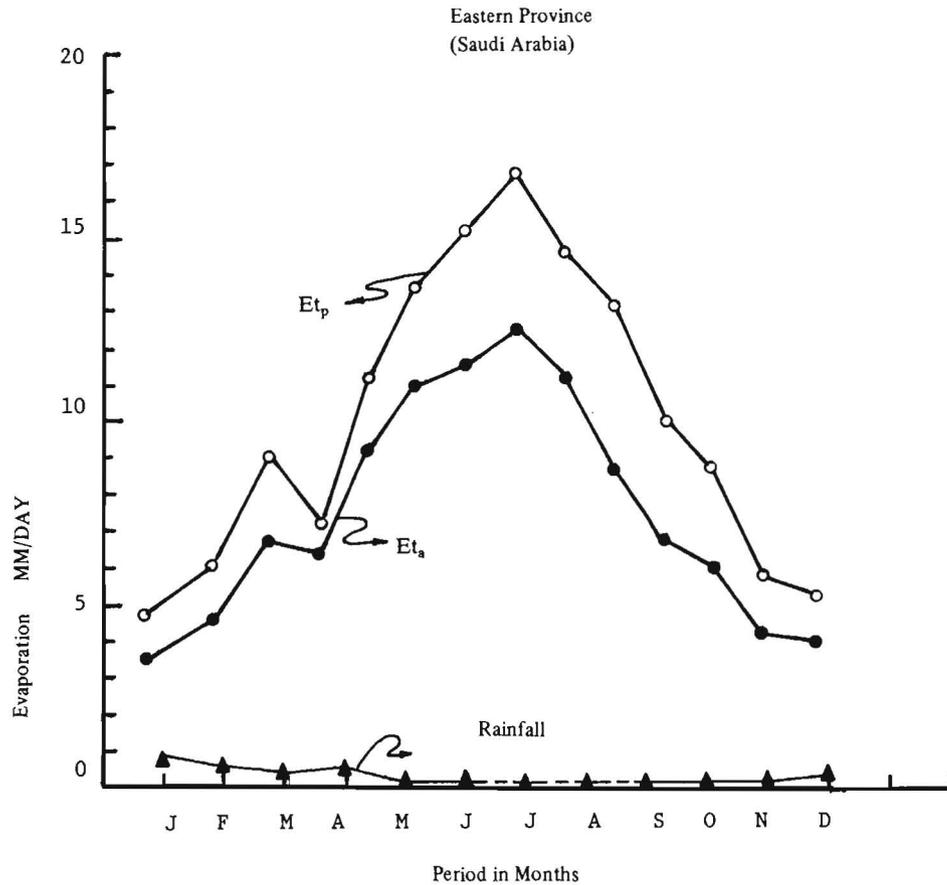


Fig. 2. Comparison between rainfall and E_{t_a} and E_{t_p} under Al-Hassa conditions for Alfalfa crop (source — Hofuf Agr. Res. Cent. Publ. no. 8: 1970-71).

2. Rainfall

The rainfall variation is extremely high as is the case in all desert climate. The rainfall distribution pattern is presented in Fig. 3 and 4 on monthly as well as yearly basis for the central and eastern regions of the Kingdom. The total amount of rainfall is highly variable from one year to another and among different stations. (For example, take the case of Dhahran station). The total amount of rainfall in Dhahran varies from a minimum of 4.4 mm in the year 1970 to a maximum of 235

Table 2. Explanation of weather conditions in respect to drought in the Central and Eastern Region of Saudi Arabia from 1673 to 1909 (Bin Bisher 1974).

Sr. No.	Year	Observations
1	1673 to 1674	Drought of extreme nature prevailed in the regions creating problems of food shortage and other necessities of life.
2	1685	A low price situation – an indication of prosperity which means that agro-climatic conditions were more favourable.
3	1709	Weather was good. An improvement of the community.
4	1715	Area affected and water-table lowered. This is a good approximation of extreme drought conditions in Area.
5	1720	The situation was same as in the year 1685 – a kind of low-commodity-price period.
6	1723 to 1724	Severe drought conditions prevailed all over the Kingdom. This caused heavy crop damage resulting in low production. Later on, this was followed by rains.
7	1764	Cold weather was observed which restricted the crops growth.
8	1766	The drought was severe in nature. This resulted in heavy crop losses, especially to the Date-Trees ultimately created food shortage in the region.
9	1772	Plegue caused heavy losses of man-power. This was followed by acute labour shortage in the area, thus affecting the agrarian community very badly because in the early days of development more dependence was on human-labour than on machines being almost negligible in supply.
10	1779	Al-Qasim was flooded causing heavy life and crop losses.
11	1782	The drought was extremely severe in nature – a kind of famine-situation. This might have caused heavy life losses due to the non-availability of essentials of life.
12	1785	Normal conditions prevailed bringing prosperity and development in the region in all spheres of life.
13	1789	A cloud-burnt type hail-storm engulfed the area causing heavy losses to plants and buildings; which had serious socio-economic repercussions.
14	1793	Rainfall occurred all over the Kingdom bringing in more prosperity and happy situation.
15	1804 to 1808	Extremely drought conditions prevailed. This restricted not only the development of work in the area but created a bad food situation.

Sr. No.	Year	Observations
16	1809	Weather conditions were normal; hence the situation was much better and improved compared to that found in abnormal years.
17	1820	A wide-spread 'Cholera' in Al-Hassa creating unhealthy conditions and more problems of its control.
18	1826	Migration of birds to this region – as indicator of normal conditions; good weather.
19	1828	Normal agroclimate conditions – a sign of prosperity.
20	1830 to 1831	Again cold weather prevailed, causing lot of crop damage, especially to the date trees.
21	1833	Cold weather prevailed in the area. This damaged the date palm trees heavily resulting in yield decrement upto 50% in some cases.
22	1834 to 1837	Severe type of drought was observed in the region. This affected greatly crop yields, especially in case of date palms. This also created acute food shortage problems – a kind of deteriorated socio-economic conditions.
23	1841	A period of normal weather conditions – means prosperity and a healthy situation.
24	1845	Excellent agroclimatic conditions were noticed more suitable and appropriate for the development of nomadic-situation.
25	1852 to 1855	A period of prosperity – rain covered all Najd.
26	1870 to 1872	Severe drought conditions prevailed in the region.
27	1882	A period of prosperity prevailed in the region.
28	1908 to 1909	Severe drought conditions occurred in the region.

mm in the year 1976. Similarly on monthly basis, the rainfall varies from a minimum of 3.66 mm in the month of June to a maximum of 24.93 mm in the month of January. Furthermore, the rainfall variability ranges observed for other stations are from 13.5 to 257.7 mm for Riyadh, from 33.4 to 324.9 mm for Hail and from 49.6 to 215 mm for Al-Qaṣīm on yearly basis. However, the monthly rainfall variability ranges from 2.2 to 32 mm for Riyadh, from 2 to 36.16 for Hail and from 6.27 to 27.19 mm for Al-Qaṣīm meteorological station.

The study of Fig. 3 and 4 shows that the rainy season normally occurs between October to June except in Riyadh Region where some rainfall has also been observed in the months of July and August. The graphic lines in Fig. 4 indicate a cyclic distribution pattern for the annual rainfall among different years at a given station. For example, in Dhahran, a low rainfall period is normally followed by a

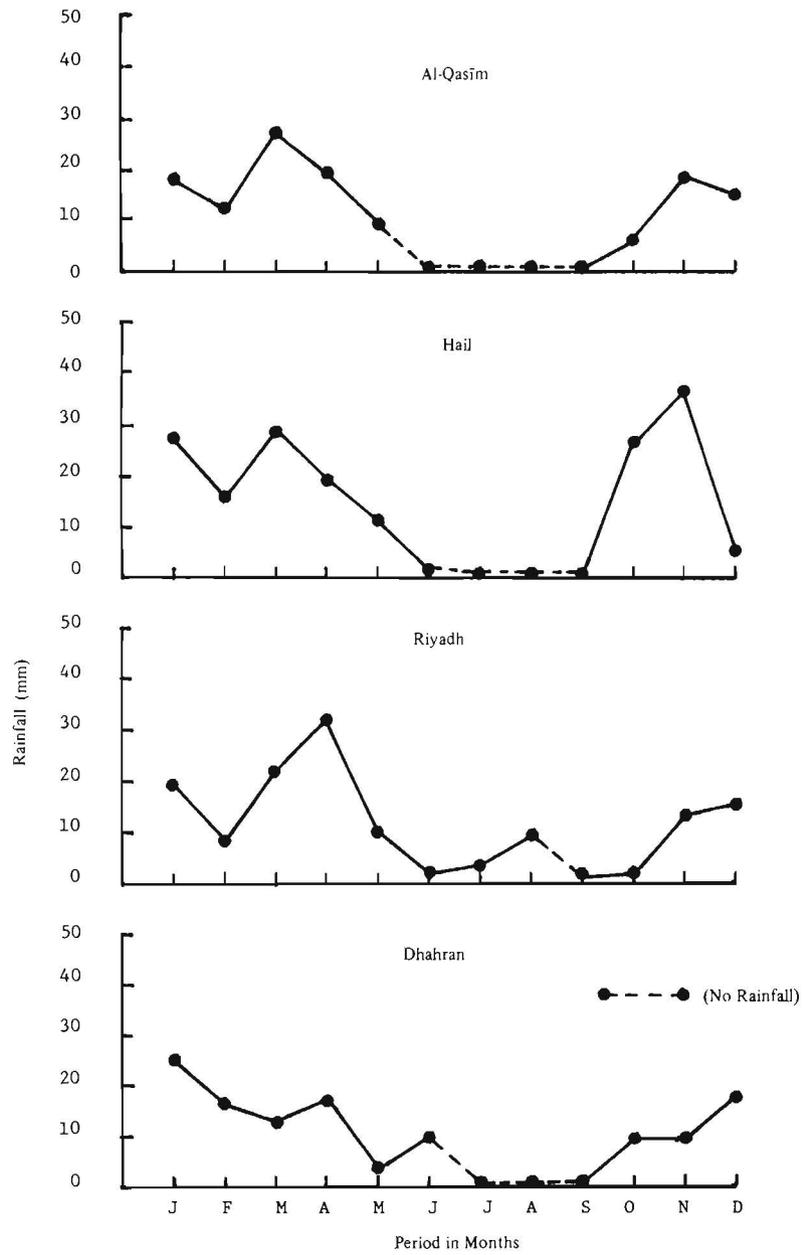


Fig. 3. Average monthly rainfall pattern for four stations from 1959-81.

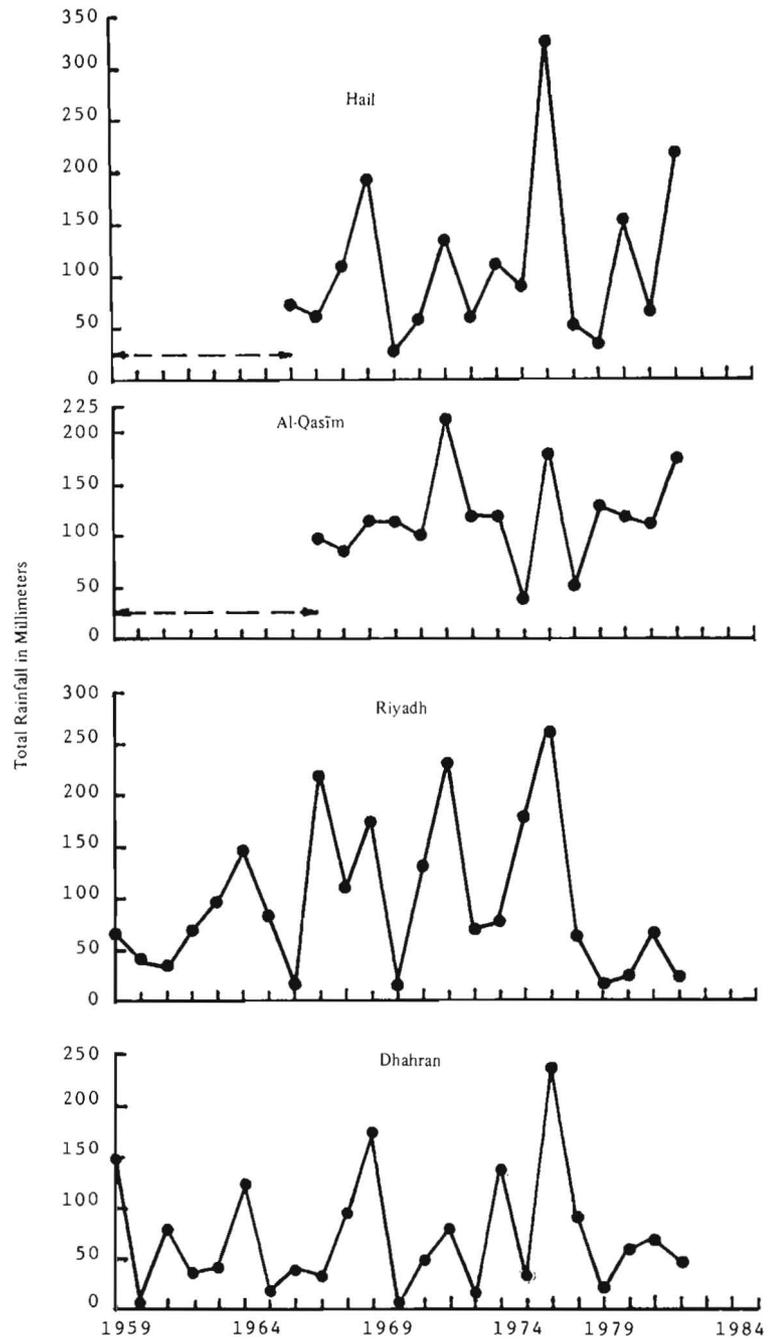


Fig. 4. Annual rainfall pattern for four stations (1959-81).

high rainfall year (wet year). This cycle period has a range of 1 to 4 years. In the period presented, the years 1959, 1964, 1969, 1974 and 1976 received more than 100 mm rainfall at Dhahran station. Although there is a great difference in the total amount of rainfall received at different stations, but the distribution pattern is almost the same over the whole period. The data for annual rainfall was not available from 1959-1967 for Al-Qaṣīm and from 1959 to 1966 for Hail meteorological stations.

Overall, the total amount of rainfall and its distribution pattern suggests that hardly less than 5% crop water needs can be met and the rest has to be managed through irrigation. For example, the stabilizing influence of irrigation was brought about by Chowdhry and Rao (1976), who studied the effect of climate change on wheat yield in the States of Punjab and Haryana of India over a 50-year period (1911 to 1960). Rainfall and mean daily temperature from December to February were examined in relation to the mean yield of wheat. There was a striking correspondence between rainfall and yield till about 1940. After 1940, the rainfall showed a falling trend but the wheat yield went up. This was attributed to the increase in the area under irrigation (Fig. 5).

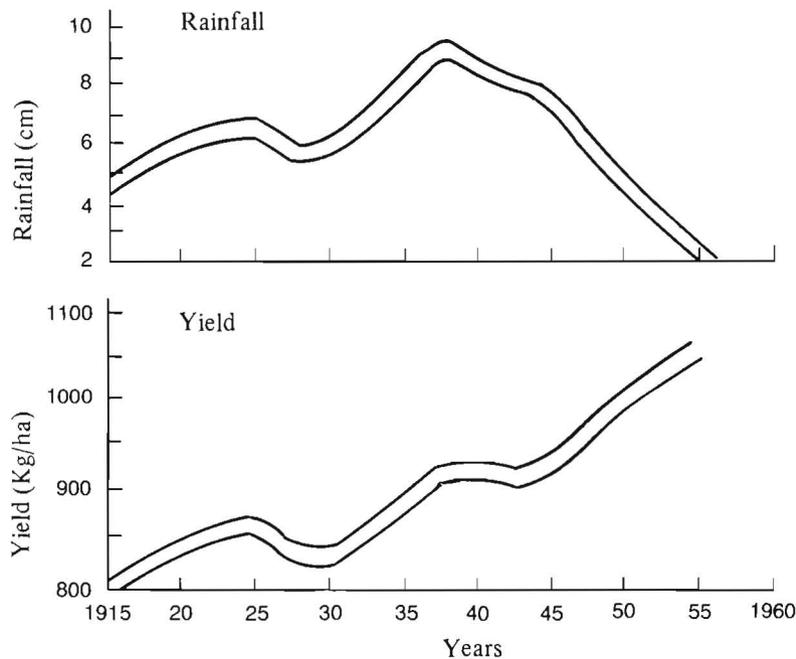


Fig. 5. Relationship between rainfall and wheat yield in northwest India showing the impact of irrigation on enhancing and stabilizing yield (Chowdhry & Rao 1976).

Generally, this much amount of rainfall is considered as arid because the threshold value for arid climate rainfall is 250 mm or less rainfall a year.

3. Temperature

The temperature is one of the most important climate factors as it determines the crop water needs. There are four major periods in a year, namely the Summer (June, July and August) and Winter (December, January, February), Spring (March, April, May) and Fall (September, October, November).

a. Summer (June, July, August)

During the summer period, the mean maximum temperature normally exceeds 40°C under shade except in Hail where it remains below 40. The mean maximum temperature varies from 41.23 to 42.08°C in Dhahran, from 40.94 to 42.49°C in Riyadh, from 36.89 to 37.63°C in Hail and from 40.03 to 41.46°C in Al-Qaṣīm. The mean minimum temperature varies from 27.19 to 28.54°C in Dhahran, from 25.67 to 27.39°C in Riyadh, from 20.08 to 22.53°C in Hail and from 32.90 to 33.98°C in Al-Qaṣīm. The average temperature ranges from 33.91 to 35.59°C in Dhahran, from 33.94 to 34.98°C in Riyadh, from 30.58 to 31.53°C in Hail and from 23.78 to 26.57°C in Al-Qaṣīm (Fig. 6).

b. Winter (December, January, February)

During the winter months, the temperature hardly drops below freezing point. The mean minimum and maximum monthly temperatures during the winter in four stations range from 3.59°C (Hail, January) to 22.74°C (Riyadh, February) respectively. These values represent the two extremes in the central and eastern parts of the Kingdom.

c. Spring (March, April, May)

During spring, the temperatures in the Central and Eastern parts are usually pleasant with sunny days and cool nights. The mean minimum and mean maximum temperatures range from 9.18°C (Hail, March) to 39.87°C (Dhahran, May), respectively. The increase in temperature from winter to spring is considerable.

d. Fall (September, October, November)

During the fall, the weather is characterized by sunny days and pleasant cool nights. The mean minimum and mean maximum temperatures range from 9.48°C (Hail, November) to 39.79°C (Riyadh, September), respectively. The decrease of the mean monthly temperatures from September to November is quite considerable as compared to the summer temperatures.

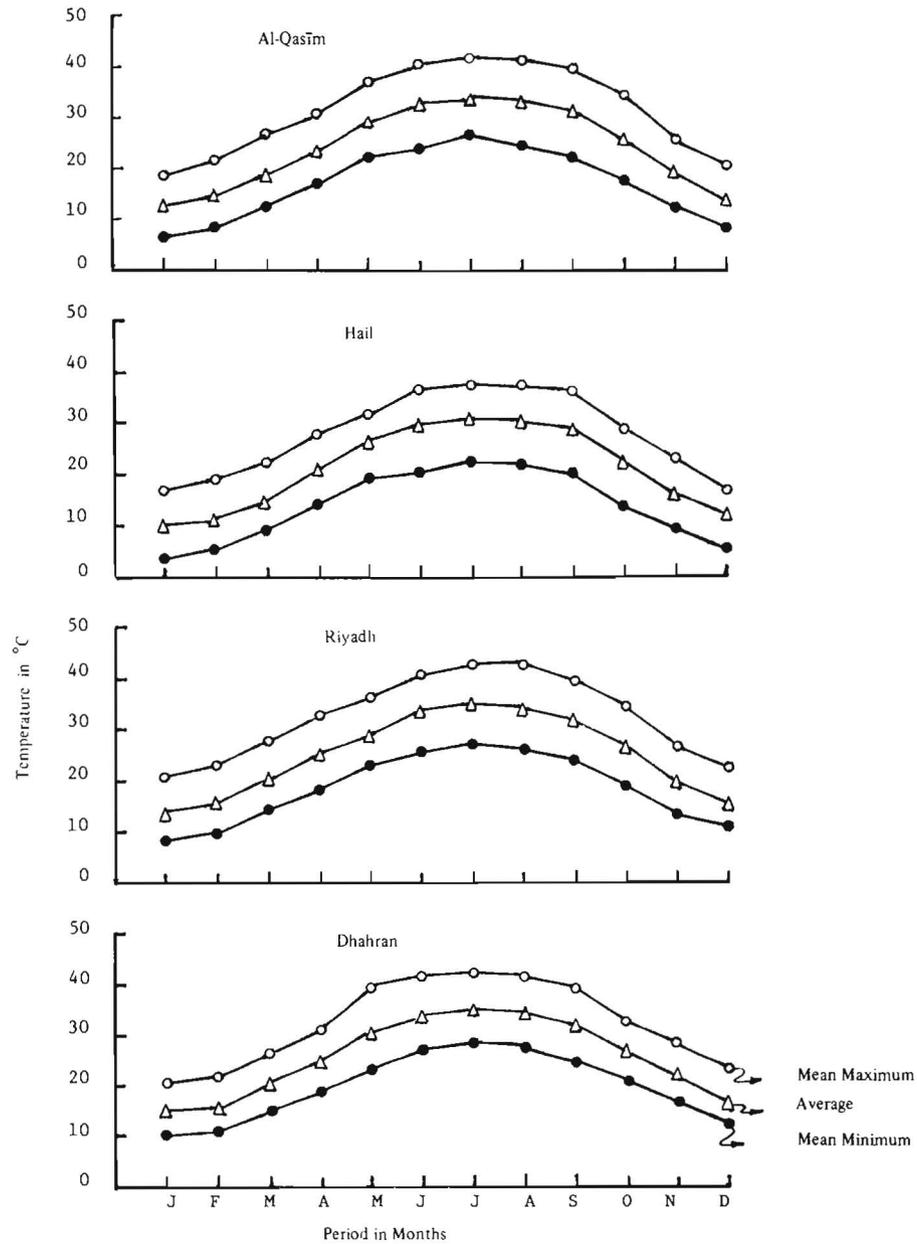


Fig. 6. Average of minimum, maximum and average temperature for four stations (1959-81).

The effect of temperature on the evaporation rate is given in Fig. 7 that has been measured under local conditions (Hofuf Agr. Res. Cent., Publ. No. 8).

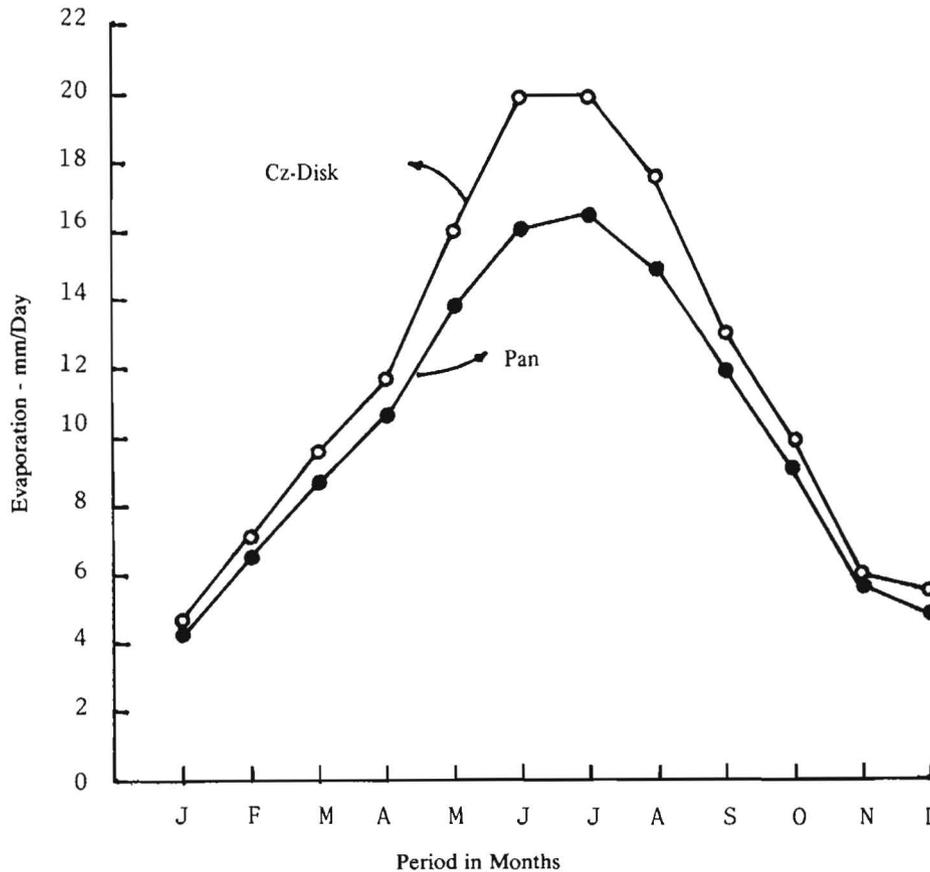


Fig. 7. Open-pan and Cz-disk evaporation rates in eastern province (source-Hofuf Agr. Res. Cent. Publ. No. 8, 1970-71).

4. Relative Humidity

Relative humidity is one of the most important climate factors because it determines the plant evapotranspiration and the temperature gradient. There is, of course, a close relationship between relative humidity and evaporation rate (Ketani 1973). The data on relative humidity for four stations is presented in Fig. 8. The range of mean minimum relative humidity is 7 percent (Riyadh, June) to 46.53 percent (Dhahran, January). The range of average relative humidity is 13.78 per-

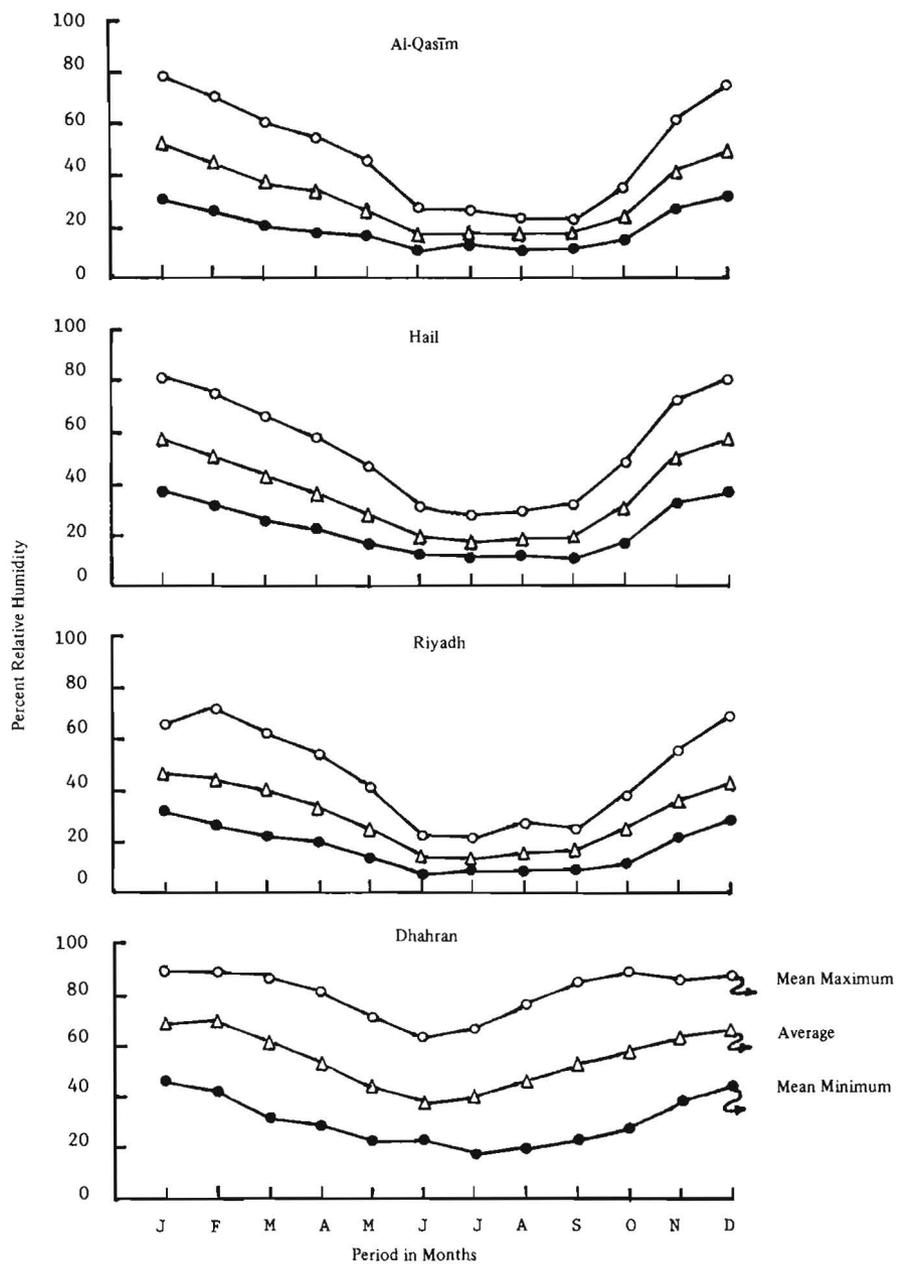


Fig. 8. Average, minimum and maximum relative humidity in percent for four stations (1959-81).

cent (Riyadh, July) to 69.33 percent (Dhahran, February). This slight variation in the computed values of average, minimum and maximum relative humidity is due to the difference in total period. For example, the relative humidity data for the month of January in an average of 18 years, compared to February (19 years, average) and March (20 year, average).

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(Received 18/08/1982;
in revised form 04/05/1983)

دراسة في الظروف الزراعية المناخية للمنطقة الشرقية والوسطى من المملكة العربية السعودية

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المملكة العربية السعودية

تشير دراسة الظروف المناخية للمنطقة الوسطى والشرقية من المملكة العربية السعودية خلال فترة من الزمن قدرها ١٣٦ سنة إلى وجود فترات متعاقبة من الجفاف وعدم الجفاف ، حيث تراوحت فترات الجفاف من سنة إلى سبع سنوات بينما تراوحت فترات عدم الجفاف من ٨ سنوات إلى ٤٤ سنة .

إن دراسة الظروف الزراعية المناخية عادة ما تعطي تقديراً جيداً للظروف الحالية لنمو المحاصيل ، وبصورة عامة ، فإنها تظهر مجالات أوسع للبحث في تربية النبات من أجل مقاومة الجفاف وإدارة الري للحفاظ الجيد للرطوبة ، ولتخطيط المشاريع المستقبلية .