Cotton Crop Development in Central Punjab (Faisalabad, 2024)

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Abstract

This study has been carried out to investigate the impact of day to day changes in the meteorological parameters like rainfall, air and soil temperature, soil moisture, RH, sunshine duration and significant weather events on plant growth and development during each phenological stage and hence on final yield of cotton crop. For this purpose, both Meteorological and phenological observations along with soil moisture data have been monitored at each phenological stage of cotton crop, cultivated in the field of Ayub Agriculture Research Institute Faisalabad (Central Punjab) during the Kharif Seasons 2024. Beside this some other factors e.g., time of sowing, fertilizer intake, use of insecticides, weeds removing operations and supplied irrigated water have also been studied. The crop accumulated 3074 heat units in 134 days during its life cycle from emergence to maturity. Crop was sown slightly later than normal time of sowing. Water requirement was fulfilled through flood irrigation onwards from early growth up to maturity stage. Crop growth and production depends mainly on the time of sowing, irrigation, in time use of chemicals against weeds and pest/viral attacks, variation in rainfall and heavy rain spells from flowering to maturity stages, day time rise in temperature and other meteorological parameters. This study is based upon the data collected at the crop field and meteorological observatory located at the Ayub Agriculture research Institute, Faisalabad. The study will be much fruitful in future to narrow the gap between present yield obtained and potential yield of this cultivar, being cultivated in Faisalabad and other cotton growing areas of central Punjab.

Chapter 1

INTRODUCTION

This study is based upon field observations of cotton crop at Regional Agrometeorological Center Faisalabad, cultivated in the experimental field of Plant Physiological section of AARI Faisalabad during the Kharif season 2024. The cotton crop variety F.H-333 (Faisalabad hybrid) was cultivated in the experimental field. It is a BT (Bacillus Thuringiensis) variety.BT variety are resistant against bollworm. The study will provide a base to estimate the optimum ranges of various meteorological parameters for getting highest yield of the particular crop variety grown under varying weather conditions.

1.1 Geographical Description and Climate of Central Punjab (Study Area)

Pakistan has a variable climate, ranging from arid (33-254mm annual rainfall) in the south to humid (1016-2032mm annual rainfall), sub-humid (508-1016mm annual rainfall) and semi-arid (254-508mm annual rainfall) in the north. The Indus River that originates from the north along with its tributaries irrigates the great plains of the country including Central Punjab. Chaudhry and Rasul found that about 2/3 of the total agriculture area lies in the arid climate. [1]

The study has been conducted for "Faisalabad District" in Central Punjab with longitude 73.06^{o}E, latitude 31.26^{o}N and elevation of 184.5m from mean sea level. The climate of central and southern Punjab possesses the dry semi-arid agro-climatic characteristics (Figure– 1.1) but well managed canal irrigation system has placed it among the highly productive agriculture zones. Mainly summer monsoon produces more rainfall and winter has a little contribution. Day time temperature reaches above 40°C during summer from April to September except some occasional relief from monsoon rains and decreases the evaporation demand of the atmosphere. The winter season starts from November and continues till March. December, January and February are the coldest months. In winter, night time temperature occasionally drops below 0°C [2]. More detail about the climate of Faisalabad during Kharif season is shown in the figures (1.2& 1.3). The highest amount of rainfall occurs during Kharif season in the month of July followed by September and August. Day time mean maximum and night time mean minimum temperature gradually decreases from November up to January and then increase gradually [3].

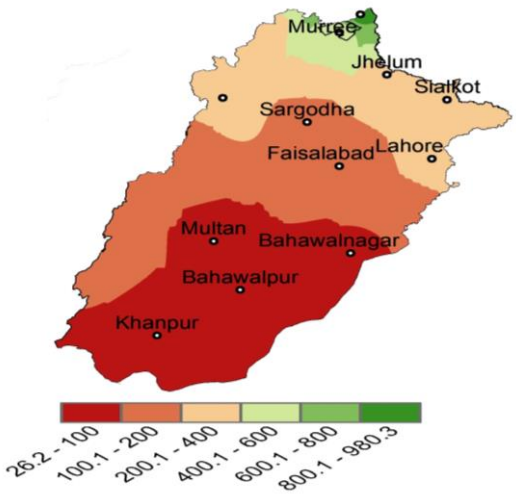


Figure 1.1:Mean Annual Rainfall (mm) of Punjab [Normal (1981-2010)]

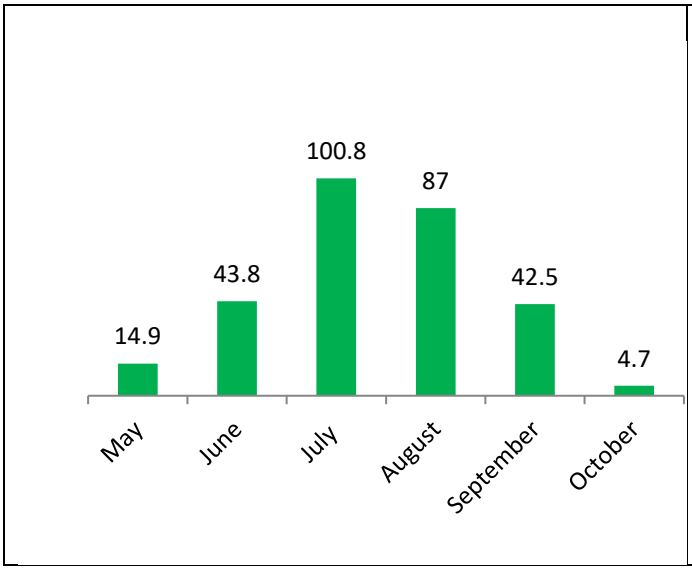


Figure 1.2: Monthly Mean Rainfall (mm) of Faisalabad during Kharif Season

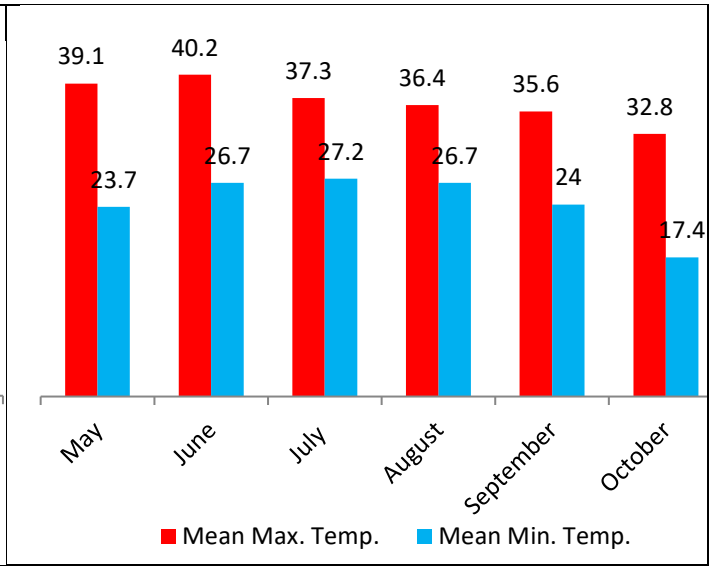


Figure 1.3: Mean daily Maximum and Minimum Temperature (ºC) of Faisalabad during Kharif Season

1.2 Scope of the Study

Cotton is grown mostly in the irrigated agricultural plains of Punjab and Sindh, on the two sides of Indus canal network. Every year cotton production in Pakistan varies due to the unpredictable climate of Pakistan beside other important factors. Therefore, year to year variation in the spatial and temporal distribution of precipitation causes changes in the amount of available water for irrigated agricultural regions, which consequently brings up and down in the annual cotton production. Sometime heavy rains along with persistent cloudy/humid conditions during monsoon season trigger to viral/pest attacks on cotton crop and also cause rapid growth of weeds in the

fields, which significantly affect crop growth and yield. Rain, just after sowing, causes decrease in the number of germinated cotton seeds. Heavy rains in particular, damage and cause shedding of flowers/bolls from flowers to maturity stages. Abnormal rise in day time temperature due to climatic variability may also raise crop water requirement at a particular phase and also may cause early completion of a phase. Therefore, in this study the impacts of variations in all-weather parameters along with variations in soil temperature and moisture is analyzed to understand crop growth and development throughout the crop life and their impact on final yield of the crop.

1.3 Objective of the Study

- To analyze and study the impact of various meteorological parameters on crop growth and development.
- To investigate the water satisfaction sensitivity of crop in Faisalabad region.
- To develop the relationship between weather parameters, crops life cycle and yield obtained.
- To determine the onset of pests and diseases related to weather elements.
- To get a step forward for formulation of yield estimation.

1.4 Review of Agriculture Production in Pakistan

The agriculture sector continues to be an essential component of Pakistan's economy. It currently contributes 21 percent of GDP. Agriculture generates productive employment opportunities for 45 percent of the country's labor force and 60 percent of the rural population depends upon this sector for its livelihood. It has a vital role in ensuring food security, generating overall economic growth, reducing poverty and the transforming towards industrialization.

Within the agricultural sector, the contribution of crop production is about 42 % while livestock contributes 55 %. Therefore, any change in agricultural productivity sends a ripple effect throughout the rural population of Pakistan. Thus, rapid agricultural growth can stimulate and sustain the pace of industrial growth, setting into motion a mutually reinforcing process of sustained economic growth in the country [5].

The Economic development of Punjab largely depends on the progress and growth of Agriculture Sector. The province dominates in overall national agriculture production in major crops: it contributes up to 55% in National Rice Production, 65% in National Sugarcane Production, 75% in National wheat Production and 70% in National Cotton Production [6].

1.5 Cotton Production in Pakistan

Cotton is an important cash crop for Pakistan known as "white gold". It accounts for 8.2 percent of the value-added share in agriculture and about 3.2 percent to GDP. Around two thirds of the country's export earnings are from the cotton by-products which add over $2.5 billion to the national economy. Hundreds of ginning factories and textile mills in the country mainly depend on cotton. Life of millions of farmers is dependent on this crop, in addition to millions of people employed along the entire cotton value chain, from weaving to textile and garment exports. Well-

researched cotton seed, proper crop-related information to growers for usage of fertilizer and pesticides and appropriate water availability in major crop-growing areas in Punjab and Sindh increased the production beside torrential rains and flash flooding in cotton belt of Punjab and Sindh in 2010 and 2011 [7].

In Punjab cotton is cultivated on both sides of Indus River. The crop is mainly grown in agricultural plains of central and southern Punjab. The crop is planted in April/May and picking starts in August/September. The crop is harvested in October/November. Total contribution of Punjab is about 70% in total cotton production of Pakistan. The fertile land of Sindh dominates in per acre yield across the cotton belt followed by Punjab. Whereas Punjab dominates in area cultivated and total annual production in the country.

Chapter 2

MATERIALS AND METHOD

The cotton crop F.H-333 was cultivated at Regional Agrometeorological Center, Faisalabad in central Punjab during Kharif season 2024. Both the meteorological and crop phenological data were recorded during the crop season. In order to compile the data of each development stage careful, precise and timely recording of the following parameters (table 2.1) were undertaken at 0300, 0900 and 1200 (UTC) as routine practice.

Table 2.1: Observed Meteorological Parameters

1.	Air Temperature (˚C)
2.	Maximum & Minimum Temperature (˚C)
3.	Soil Temperature (˚C)
4.	Relative Humidity (%)
5.	Precipitation (mm)
6.	Pan Evaporation at 0300 & 1200UTC
7.	Bright Sunshine Hours
8.	Wind Speed (km/hour)
9.	Wind Direction
10.	Soil Moisture (%)

Crop data including Phenological data and soil moisture observation was collected according to World Meteorological Organization (WMO) and Food & Agriculture Organization (FAO) standards.

2.1 Phenology

For a sound understanding of plant growth and development, observation and recording of phenological stages of plant is an essential element (table 2.2). The impact of precipitation, heat, drought, diseases, insects, and weeds can be more accurately predicted with a clear picture of the relationship between growth stage and plant response to stress. The optimum timing of fertilizer, irrigation, herbicide, insecticide, and fungicide applications are also best determined by crop growth or phenological stage rather than calendar date. [8]

Table 2.2: Phenological Stages of Cotton Crop 2024

	Phenological stage	Date
1.	Sowing	23-04-2024
2.	Emergence	29-04-2024 To 05-05-2024
3.	Third Leaf	06-05-2024 To 19-05-2024
4.	Budding	20-05-2024 To 14-06-2024
5.	Flowering	15-06-2024 To 30-07-2024
6.	Boll Opening	31-07-2024 To 23-08-2024
7.	Maturity	24-08-2024 To 09-09-2024
8.	Picking	24-09-2024

2.1.1 Phenological Observations

Generally, the field selected for phenological observations should be of one hector in size but in this case area of field selected for observation was half acre and it was divided into 4 replications. Over all 10 plants were selected from each replication. These plants were tagged in a row in each replication. Thus, phenological observations were recorded on 40 plants and continued throughout the period on the same plants.

Total number of plants in a particular phenological phase at the same time was observed from each replication on every Monday, Wednesday and Saturday and these observations were recorded on the prescribed Performa. When 10% of the selected plants were in certain phase, that particular phase was considered to be started. If 50% of the selected plants displayed a certain phase, that phase was considered to be in full swing. Similarly, 75% occurrence of certain phase displayed by the selected plants was considered as completion of that particular phase and next Phenological phase observations were started at their proper time. Thus, next phenological stage is not bound to appear after the completion of first one. It has been observed that at a time two phenological phases or no phase can exist.

2.2 Methodology

In this study the impact of different meteorological/non-meteorological parameters in comparison with

the normal (1981-2010) values, including soil temperature and soil moisture, amount of seed per acre cultivated, time of sowing, fertilizer intake, number and timing of irrigation water added and pest attack/pesticide used over crop growth, development and final yield are discussed.

Chapter 3

RESULTS AND DISCUSSION

In this chapter, variations in meteorological and non-meteorological parameters and their impact on the cotton crop is analyzed along with a brief summary of whole cotton crop's life cycle. Normally the cotton crop takes 140-160 days to get fully mature. The crop is cultivated in the start of April up to the mid of May. In order to investigate the chief causes about variation in the crop's growth, development and yield related to varying weather conditions and some other factors during each phenological stages of cotton crop, different meteorological parameters are studied as well.

Table 3.1: Brief Summary of the Cotton Crop

1	Field size	4 kanal
2	Crop variety	F.H-333
3	Date of Sowing	23-04-2024
4	Information about any disease/pest attack,	Boll worms Whitefly,Jassid
5	Pesticides And weedicides Details	Big Hit 300gm/Acre for Jassid Gramoxone 1lit/Acre for weeds removal Red Gold 250ml/Acre for Pest control Chlorphrofos 1lit/Acre for sucking worms Proaxis 100ml/Acre for Pink Boll Worm Dual Gold 800ml/Acre for grass removal
6	Quantity of seed per acre	08 Kg
7	Row spacing	75cm
8	Schedule and quantity of supplied dose of fertilizer	At sowing 40kg DAP/Acre +SOP 30kg/Acre. At later stages 2 bags of Urea+Zinc/Acre
9	Irrigation Type	Flood irrigation
10	Irrigation schedule	23-04-2024 (First irrigation) 07-05-2024 (Second irrigation) 15-05-2024 (Third irrigation) 25-05-2024(Fourth irrigation) 02-06-2024(Fifth irrigation) 12-06-2024(Sixth irrigation) 19-06-2024(Seventh irrigation) 09-09-2024(Eight irrigation)

11	Heat units consumed from sowing to full maturity	3074
12	Total days taken by the crop from sowing to full maturity	134
13	Date of Picking	24-09-2024
14	Actual/ Potential yield	1200/1600 kg /acre

3.1 Rainfall and Cotton Crop Growth

Rainfall is one of the most important factors that affect annual cotton production in Pakistan. Faisalabad and its surrounding areas of central Punjab get most of its annual rainfall during Kharif season, particularly during monsoon season from July to September. But this amount is not sufficient to fulfill cotton crop water requirement in hot Kharif season. Therefore, cotton crop is mainly grown under flood irrigation from Indus canal network. But monsoon rains during hot summer some time damage standing crops. Humid atmosphere during monsoon may also trigger pest attack on the crop. In addition, rainfall also provides clean environmental conditions to support optimum photoperiodic activity for better biomass and grain yield [10].

During the crop season 2024, below normal precipitation was recorded in the months of May, June and October while July, August and September received above normal rainfall. July was the wettest month of the season with precipitation amount to 180.8 mm which also include a heavy spell of 46.0 mm in a single day on 6th of July. July received 79.3% above normal precipitation. The heaviest spell of the season was 59.2mm in a single day on 4th of August 2024.Overall the precipitation remained 45.3% above normal during the kharif season 2024 at RAMC, Faisalabad. Rainfall distribution differs much over the months from well below normal to extremely high above normal.

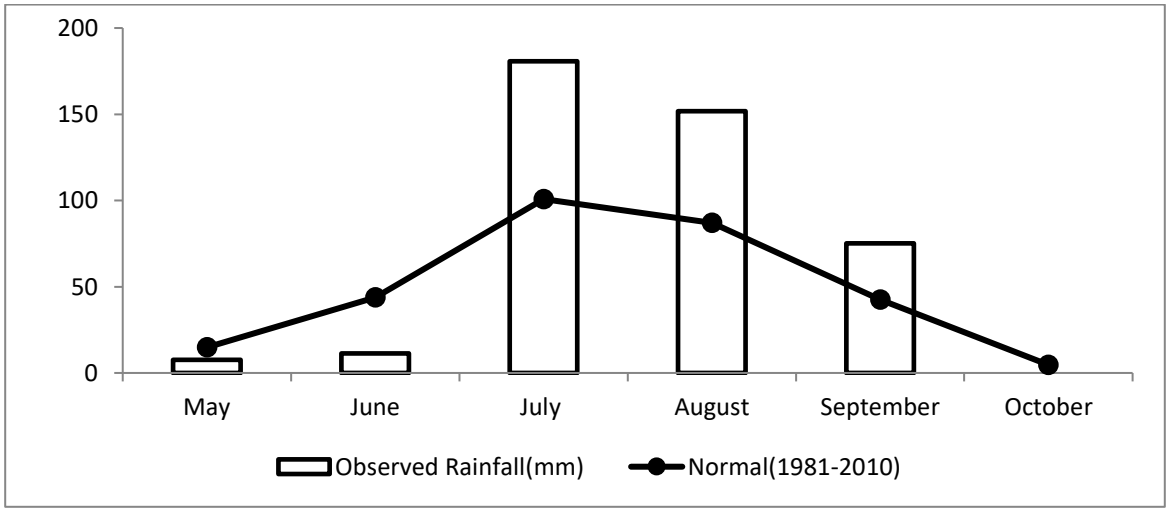


Figure 3.1: Comparison of Monthly observed rainfall with Normal (1981-2010) at Faisalabad during

Kharif season 2024.

Table 3.2: Daily Rainfall History of the Crop Life 2024

Year	Phenological stage	Month	Day	Daily Precipitation (mm)	Total Precipitation During Stage (mm)	Monthly Total (mm)
2024	Sowing	April	25	0.0		
2024	Germination	April	26	Tr	Tr	
2024	Emergence	April	30	7.0	7.0	14.7
2024	Third Leaf	May	10	6.0		
2024	Third Leaf	May	11	Tr	6.0	
2024	Budding	May	24	1.6		7.6
2024	Budding	June	05	1.6	3.2	
2024	Flowering	June	18	Tr		
2024	Flowering	June	20	9.8		11.4
2024	Flowering	July	04	35.6		
2024	Flowering	July	05	0.6		
2024	Flowering	July	06	46.0		
2024	Flowering	July	12	43.6		
2024	Flowering	July	21	Tr		
2024	Flowering	July	23	16.0		
2024	Flowering	July	29	15.6	190.6	180.8
2024	Boll Opening	August	02	1.4		
2024	Boll Opening	August	04	59.2		
2024	Boll Opening	August	09	2.2		

2024	Boll Opening	August	16	35.0		
2024	Boll Opening	August	17	4.0		
2024	Boll Opening	August	22	Tr		
2024	Boll Opening	August	23	6.4	108.2	
2024	Maturity	August	27	2.8		
2024	Maturity	August	28	1.4		
2024	Maturity	August	29	30.4		
2024	Maturity	August	30	8.4		151.8
2024	Maturity	September	02	16.4		
2024	Maturity	September	06	Tr		
2024	Maturity	September	19	0.4	16.8	
2024	First Picking	September	-	--	--	
2024	Second Picking	September	27	58.4		
2024	Second Picking	September	28	Tr	58.4	75.2

3.2 Irrigation during Crop Growth

During kharif season 2024, irrigated water was added to the field 08 times; first irrigation was done at sowing while 2nd irrigation was done 14 days after sowing during emergence stage. Remaining irrigations were done during other phenological stages at the time of need. Significantly above normal rainfall during the month of July, August and September fulfills most of the water requirements.

3.3 Air Temperature and Cotton Crop Growth

Air temperature is also one of the most important climatic variables that affect plant life. Plants growth is restricted to certain limits of air temperature. The main dry matter process i.e., photosynthesis is also temperature dependent. Hence three temperature values for a plant growth are of particular importance.

They are;

- Biological Zero: is the minimum temperature below which plant growth stops. For cotton crop its value is 12°C.

- Optimum Temperature: at which maximum plant growth occurs. For cotton crop its value is 30°C.
- Maximum Temperature: above which the plant growth stops. For cotton crop its value is above 40°C. [10]

Detail of Mean Monthly Air Temperature, Monthly Mean Maximum and Minimum Temperature and Absolute Maximum and Minimum temperature are presented in Table – 3.3 along with Normal (1981-2010) values and is also shown in following figures (3.2 – 3.4).

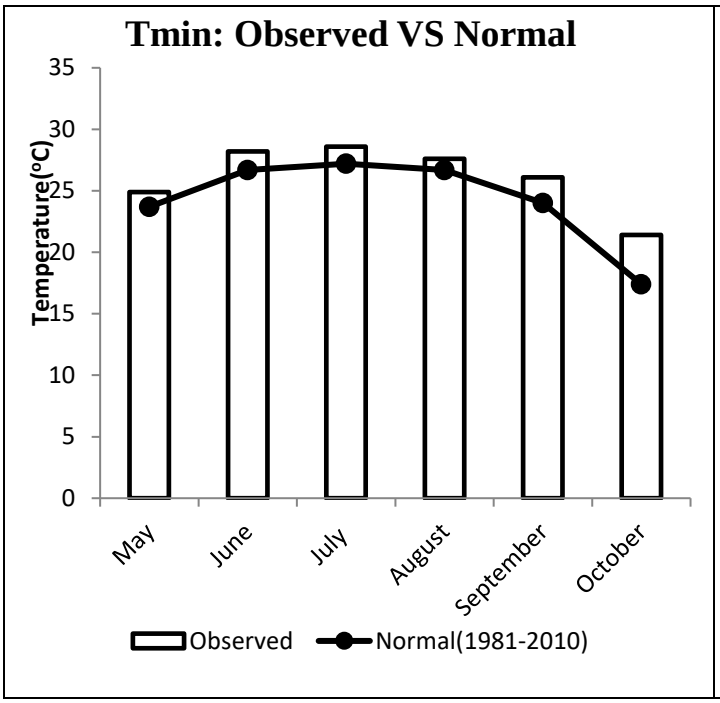


Figure3.2: Mean daily Minimum Temperature (ºC) of Faisalabad during the Kharif Season

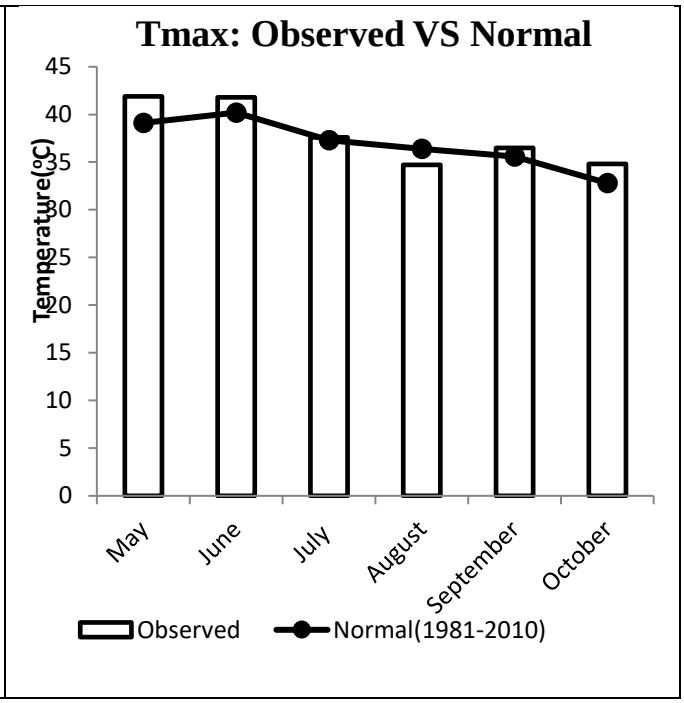


Figure3.3: Mean daily Maximum Temperature (ºC) of Faisalabad during the Kharif Season

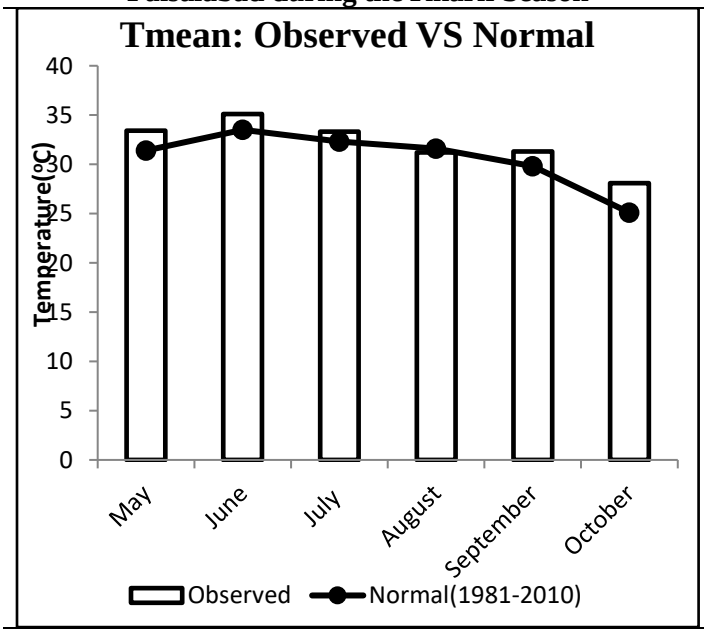


Figure 3.4: Mean Monthly Temperature during Kharif Season

During the crop season of 2024 mean night time minimum temperature remained above normal during the whole crop season. Mean day time maximum temperature remained above normal to normal during the season expect the month of August when it dropped to below normal values. Mean daily temperature recorded above normal to normal values during the crop season.

Table3.3: Mean Monthly Temperature during Kharif Season 2024

Month	Mean Monthly (°C)	Monthly Mean Max.(°C)	Monthly Mean Min(°C)	Absolute Max. (°C)	Absolute Min. (°C)
May-2024	33.4 (30.6)	41.9 (38.4)	24.9 (22.7)	46.8 (48.0)	14.5 (13.0)
Jun-2024	35.1 (33.7)	41.8 (40.5)	28.2 (26.9)	45.2 (48.0)	22.5 (17.0)
Jul-2024	33.3 (32.3)	37.6 (37.1)	28.6 (27.1)	42.2 (47.0)	22.0 (19.0)
Aug-2024	31.2 (32.3)	34.7 (36.1)	27.6 (26.6)	38.0 (42.0)	24.5 (18.6)
Sept-2024	31.3 (29.7)	36.5 (35.7)	26.1 (23.7)	40.0 (43.0)	22.0 (16.0)
Oct-2024	28.1 (25.0)	34.8 (33.0)	21.4 (17.0)	37.0 (40.0)	19.0 (8.0)

( ) in Table 3.3 shows Normal values (1981-2010)

3.4 Soil Moisture Observations during Crop Growth

Soil moisture plays a vital role during crop's life. Soil moisture content is proportional to rainfall and intake of irrigated water and is inversely proportional to evapotranspiration from the plant and its surroundings. Variation in soil moisture during crop's life play important role in plant growth and development. Water or soil moisture requirement of cotton crop varies during different growth or Phenological stages. Highest amount is needed during flowering stage followed by grain formation stages and then vegetative stages [11].

To calculate soil moisture, soil samples are taken on 7^{th}, $17^{th}$and 27^{th} of each month in four replications at 5, 10, 20, 30, 40, 50, 70 and 90 cm depths with the help of auger. However, in case of any anomalous event on the specific date, the sample can also be taken on the next day. Soil sample is then weighed and dried in the oven for about 8 hours. The dried sample is weighed again and moisture present in the soil is then calculated by the difference of weight between wet and dry samples as illustrated below:

$$Moisture(\%) = \frac{(\text{Weight of the cane containing soil before drying} - \text{Weight of the cane containing dry soil})}{(\text{Weight of cane containing dry soil} - \text{weight of cane})} \times 100$$

Moisture contents of the soil varied due to dry and wet spells throughout the season. After each effective

irrigation or rain the moisture level increased in the shallow layers as compared to deep layers of the soil.

During the crop season 2024, from the observed soil moisture data, figures (3.5 – 3.7) depicts that soil moisture remained highest at all depths for the soil sample collected on 07-06-2024. This is due to the rainfall spell few days earlier. Some other observation shows the comparatively low values of moisture content especially at shallow depths. This is due to the fact that high temperatures cause more evaporation.

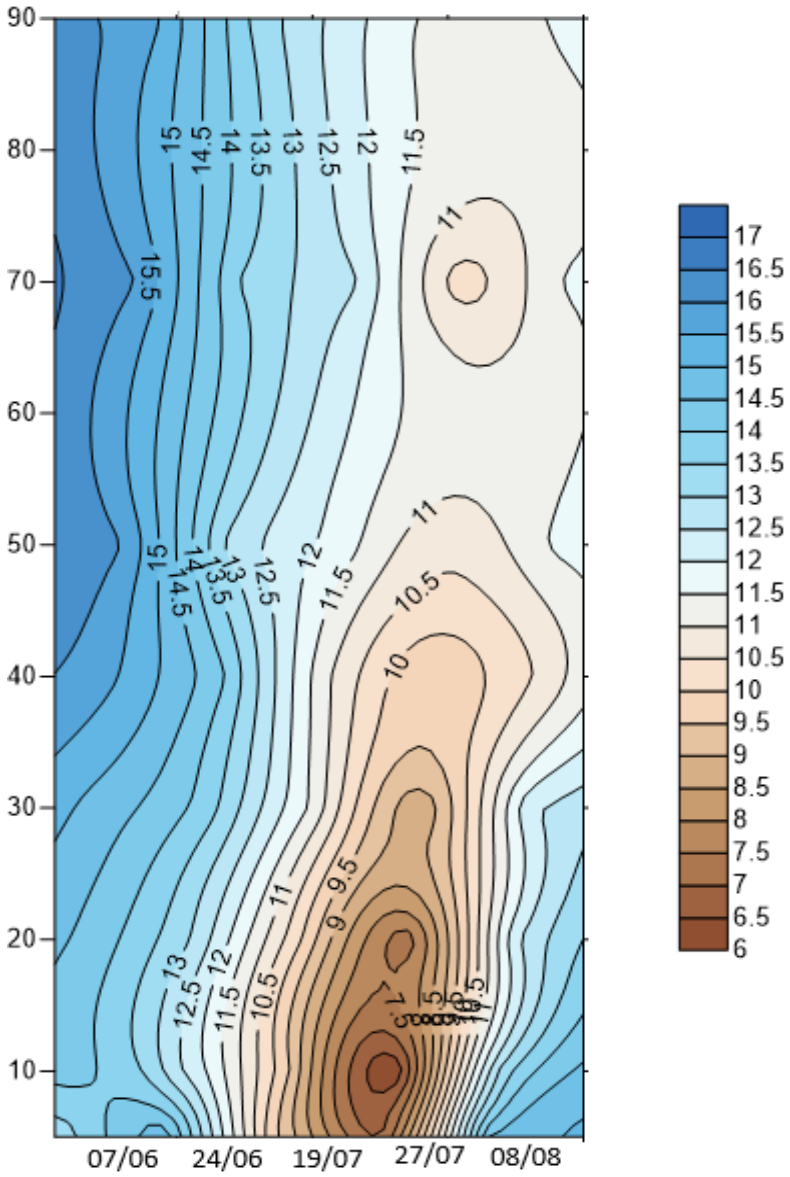


Figure 3.5: Soil moisture chrono Isopleths for Kharif Crop at Faisalabad for the year 2024.

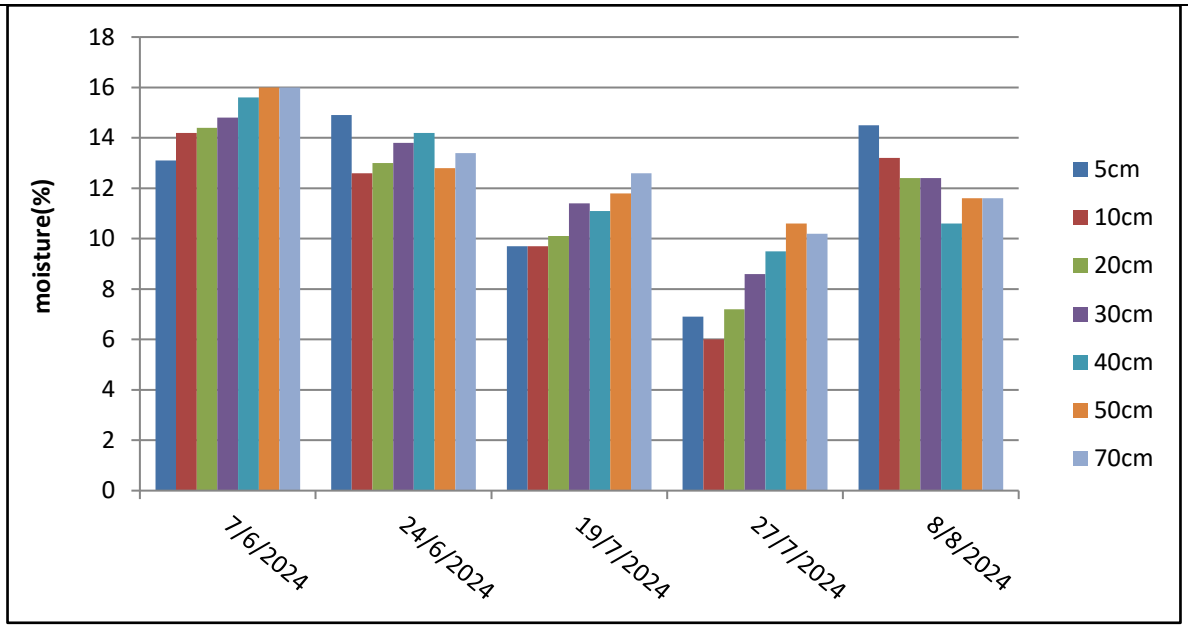


Figure3.6: Soil moisture at different depths during Cotton crop 2024.

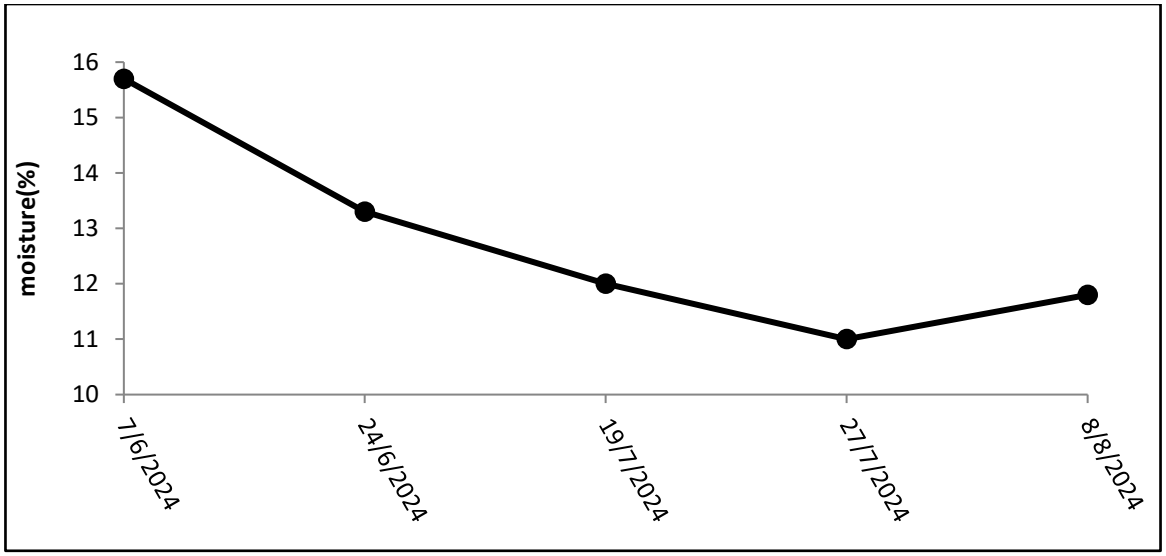


Figure 3.7: Soil moisture at deep soils (90cm) during Cotton crop 2024.

3.5 Soil Temperature and Crop Growth

Soil temperature is the most important parameter affecting growth of the crop. Plants roots are very sensitive to the soil temperature. In comparison to air temperature, the amplitude of variation in soil temperature is much more pronounced because of the varying characteristics, texture, composition, and organic material of soil. Soil temperature influences the germination of seeds, the functional activity of the root system, the incidence of plant diseases and the rate of plant growth. The daytime soil temperature is more important than the nighttime temperature, because it is necessary to maintain the internal crop water status to match the evaporation rate. Optimal soil temperature for the germination of cotton plant is 15.5°C. [10]

Soil temperature is also an easy tool to predict the status of soil moisture content during varying conditions of air and soil throughout crop's life. Generally, above normal condition of soil temperature at a particular depth indicates deficiency of soil moisture content and below normal soil temperature indicates satisfactory condition of soil moisture content.

From the observed data, it is evident that generally, soil temperature increases gradually with increasing depths. Soil temperature varies as soil moisture varies from depth to depth and time to time. To measure soil temperature, the soil thermometers were installed at different depths to monitor the thermal regime of the soil. The soil temperatures in degree Celsius (℃) were observed and then recorded three times a day at 0300, 0900 and 1200 UTC. The depth at which the soil temperatures were observed on daily basis includes 5, 10, 20, 30, 50 and 100 cm depths. It was observed that major root concentration centered between 30cm to 40 cm.

Note: This soil temperature data is collected from the soil observations taken at Agromet observatory of RAMC Faisalabad situated near the experimental field of cotton crop. Therefore, this data tells us a general status of soil moisture of the soils of the area (which is not irrigated) and not of the crop's field particularly, which is irrigated as per requirement. It is thus important to note that any deficiency in soil moisture indicated by soil temperature data may or may not be actually experienced by the crop's soil, which was irrigated in accordance with water requirement of the crop several times during its life time.

During the crop season 2024, soil temperature remained highest during June at all depths. This is due to the reason that June received well below normal rainfall. The deep layer of 100 cm remained warmest in June while coolest in October. The break in the graph indicates the unavailability of 50cm depth data.

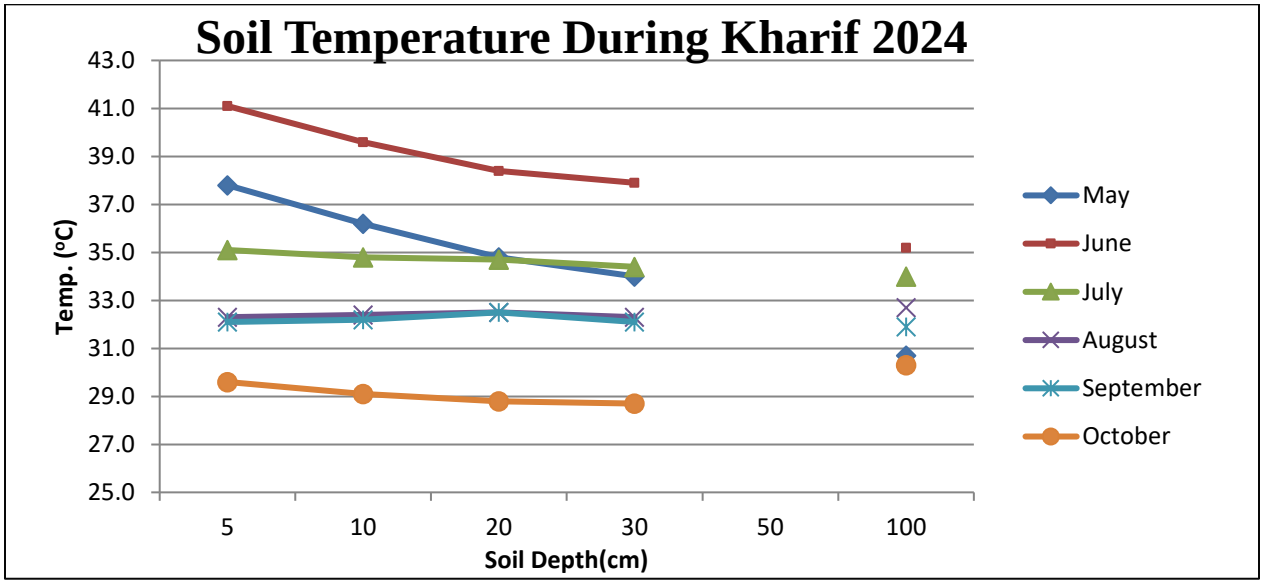


Figure 3.8: Soil temperature during Cotton crop 2024.

3.6 Heat Units Consumption during Crop Cycle

Heat units, Growing Degree Days, effective heat units or growth units are a simple means of relating plant growth, development, and maturity to air temperature. Heat units are often used in agronomy, essentially to estimate or predict the length of the different phases of development in crop plants.

The heat unit concept assumes a direct and linear relationship between plant growth and temperature. It starts with the assumption that total plant growth is dependent on the total amount of heat to which it is subjected during its life time. The heat units for a particular crop on any day are the difference between the daily mean temperature (T) and the base temperature (Tb) of the crop. Base temperature or Biological zero is the minimum temperature below which no growth occurs. The base temperature or threshold varies with different plants, and for the majority it ranges from 4.5 to 12. 5°C.Here for cotton crop base temperature is 12°C. This concept assumes that a given cultivar requires the same summation (k) of the daily mean temperature for going one phenological stage to next stage, regardless of temperature distribution. Generally, only positive values above the biological zero (Tb) are considered. The period of negative value is termed as "dormant" because crop does not grow under such conditions.

In this study the effective method has been used for determining heat units which is represented by the following equation.

$$GDD = \sum(T - Tb) = k \quad if\ T > Tb \text{ And } GDD = 0 = k \quad if\ T < Tb$$

Where ***T***= Mean daily temperature, ***Tb*** = Biological Zero (5°C), ***k***= Heat Unit [10].

Interphase period for cotton crop during 2024 and corresponding heat units at RAMC Faisalabad observed at different phenological stages varies from phase to phase. Heat unit requirements of different phases and cumulative heat units for the crop have been worked out, are shown in figure 3.9 and Table–3.4. Total heat units consumed by the cotton crop were 3047, accumulated from germination to full maturity in 134 days. On average 22.7 heat units were consumed by the crop per day. Normally these heat units are consumed in 150 days at the rate of 18.5 heat units per day, which shows that the crop reached to full maturity earlier normal thermal time. From figure 3.9 it is clear that crop consumed less than normal heat units during the emergence, third leaf and boll opening stage while above normal amount of heat units consumed during budding and maturity stages. Crop consumed almost normal heat units during third leaf and flowering stages. Below normal heat units consumed indicates the completion of a stage earlier than normal thermal time.

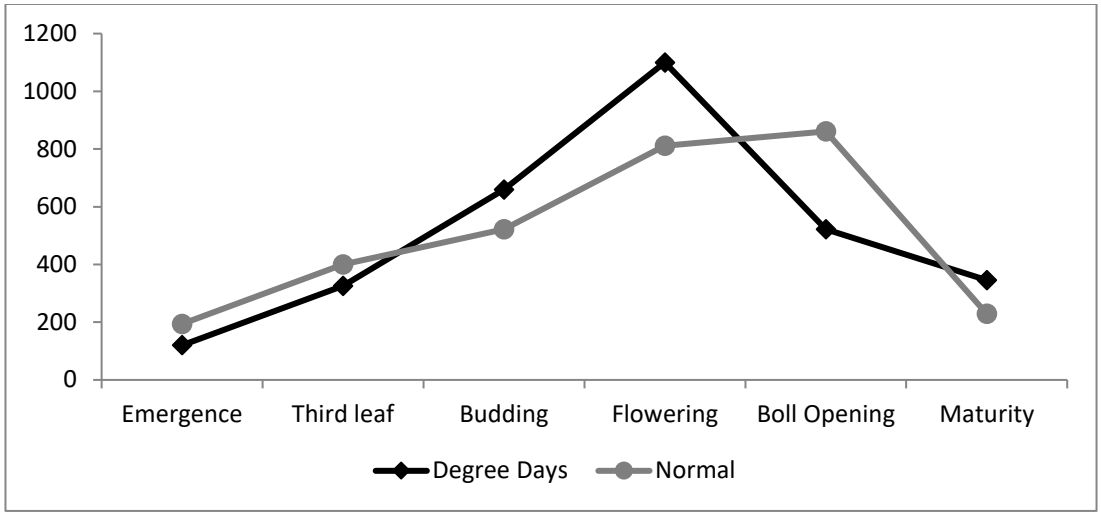


Figure 3.9: Heat units during crop life 2024.

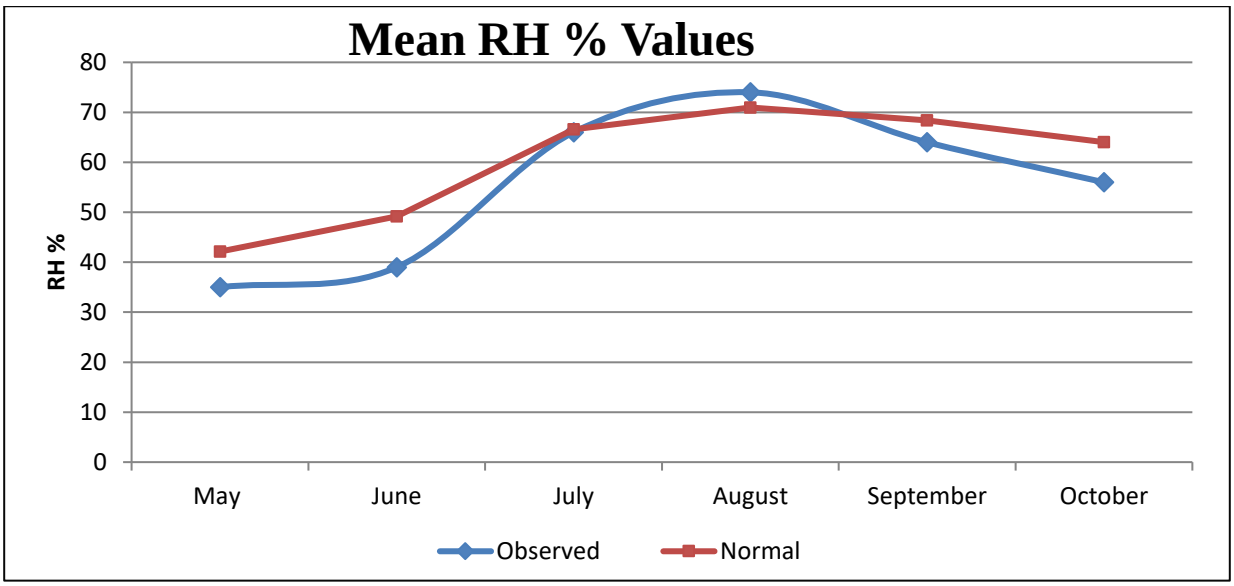
Table 3.4: Heat Units Consumed by the Crop during Different Phenological Phases

S. No.	Inter Phase	Period	No. of Days Taken	Degree Days (T-10℃)	Normal Degree Days
1	**Date of Sowing**	23-04-2024	--	--	--
2.	**Emergence**	29-04-2024 To 05-05-2024	7	120	194
3.	**Third leaf**	06-05-2024 To 19-05-2024	14	326	400
4.	**Budding**	20-05-2024 To 14-06-2024	26	660	522
5.	**Flowering**	15-06-2024 To 30-07-2024	46	1100	811
6.	**Boll Opening**	31-07-2024 To 23-08-2024	24	522	861
7.	**Maturity**	24-08-2024 To 09-09-2024	17	346	229
8.	**Picking**	24-09-2024	--	--	--
9.	**Emergence to Maturity**	23-04-2024 To 24-09-2024	134	3074	3017

3.7 Relative Humidity (%)

Relative humidity (RH) is simply defined as the ratio of the actual amount of water vapor (grams) in the unit mass of air at a given temperature to the mass of water vapor in the same sample of air when it is

saturated at the same temperature. RH tells us about how much a sample of air around the observing station is saturated. It is expressed in percentage. For example, if relative humidity of the atmosphere is 60%. It means that 60% of the atmosphere is saturated with water vapor or moisture and 40% of the present moisture may be added more to saturate (100% RH) the atmosphere. RH is temperature and moisture dependent and may vary if moisture content or temperature of the atmosphere is changed. It is always inversely proportional to temperature and ETo. RH is calculated with the help of dry bulb and wet bulb temperatures fitted in the Stevenson screen. RH remained below normal values during most of the crop season. It remained higher than normal value during the month of August 2024.



3.8 Reference Crop Evapotranspiration, ETo (mm/day)

Reference Crop Evapotranspiration or ETo is defined as the rate of Evapotranspiration from an extended surface of 8– 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground, free from disease and not short of water. The standard method of calculating ETo is revised Penman-Monteith equation. Using this method, ETo is calculated using data of temperature (maximum and minimum), wind speed, relative humidity and solar radiation. Solar radiations are calculated with the help of total bright sunshine hour data at a particular station. Sunshine duration recorders with sunshine cards are used for sunshine hours recording [11].

During the crop season 2024, relative humidity remained below normal during the month of May June and September. During the month of August RH was above Normal range whereas, ETo remained almost normal during the month of July.

3.9 Wind and Crop Growth

Wind also play significant role in plant growth besides its role in variation of ETo. Normal/gentle wind is necessary for the movement of carbon dioxide to plant canopy so that normal rate of photosynthesis continue in day time. Strong cyclonic or stormy wind accompanied by any severe weather event like hail storm, heavy shower may badly affect/damage the crop. During the Kharif crop period 2024, wind speed was observed generally below normal below normal values during the whole crop season. No significant damage was done by the wind storm to the crop.

Table 3.5: Summary of some Meteorological Parameters during Kharif Season 2024

Month	Wind speed (km/hr)	RH (%)	Days with mean RH ≥80%	ETo (mm/day)
May-24	2.5(4.6)	35(42.0)	00	4.3
Jun-24	4.3 (6.4)	39 (49.0)	00	6.1
Jul-24	3.8 (6.0)	66(67.0)	12	4.6
Aug-24	3.0 (4.0)	74 (71.0)	04	2.8
Sep-24	2.2 (2.5)	64(68.0)	03	1.6

3.10 Crop Water Requirement (CWR)

The crop water requirement (ET crop) is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally.

The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favorable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

The crop water need mainly depends on:

Water Requirement is mainly dependent on climatic factors such as air temperature, solar radiation, relative humidity, wind velocity etc. and agronomic factors like stage of the crop development as well.

The climate: in a sunny and hot climate crops need more water per day than in a cloudy and cool climate.

The crop type: crops like maize or sugarcane need more water than crops like millet or sorghum.

The growth stage of the crop; fully grown crops need more water than crops that have just been planted [12].

3.10 Calculation of Crop Water Requirement (CWR)

After determining ETo, the ET crop/crop water requirement (CWR) can be predicted using the appropriate crop-coefficient (Kc)

ETcrop = Kc. ETo or CWR = Kc. ETo

Crop coefficient (Kc) is actually the ratio of maximum crop evapotranspiration to reference crop evapotranspiration. For cotton, this ratio becomes 1 during the boll opening otherwise it remains less than 1 bearing minimum values during the early age of the crop and at maturity. The crop water requirement was calculated for the period from emergence to wax maturity. A schematic variation of the crop coefficient related to different crop development stages under normal conditions is given in figure 3.10.

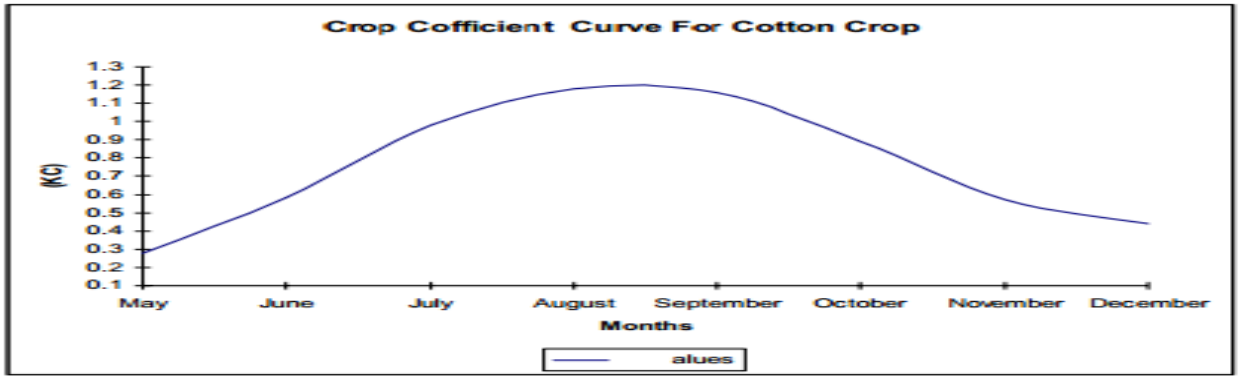


Figure 3.10: March of Crop Coefficient (Kc) for normal duration of Cotton growing season (Emergence to Wax- Maturity).

The water requirements can be calculated in millimeters and they can be converted into cubic meter per hectare by following equation:

10 mm = 1 cubic meter per hectare

Along with the loss of water through evaporation and transpiration, the compensation of this loss by precipitation may also be considered. Normally most of the plants grow successfully and utilize water for the soil at 50% and above available soil moisture. The maximum demand (daily or seasonal) may be equal to the reference crop evapotranspiration (ETo) which is utilized through soil moisture. It is

observed that crop water requirement has quantitatively increased due to increasing temperature trend [13].

During the Kharif Season 2024 in Faisalabad, crop water requirement of cotton crop was observed to be above normal during budding and flowering stages while it was below normal during third leaf, boll opening and maturity stages (Fig 3.11& Table 3.6). It means that crop growth suffered due to sharp rise in crop water demand mostly during flowering and budding. Thus, the available irrigated and rain water was utilized to fulfill the moisture requirement of the crop.

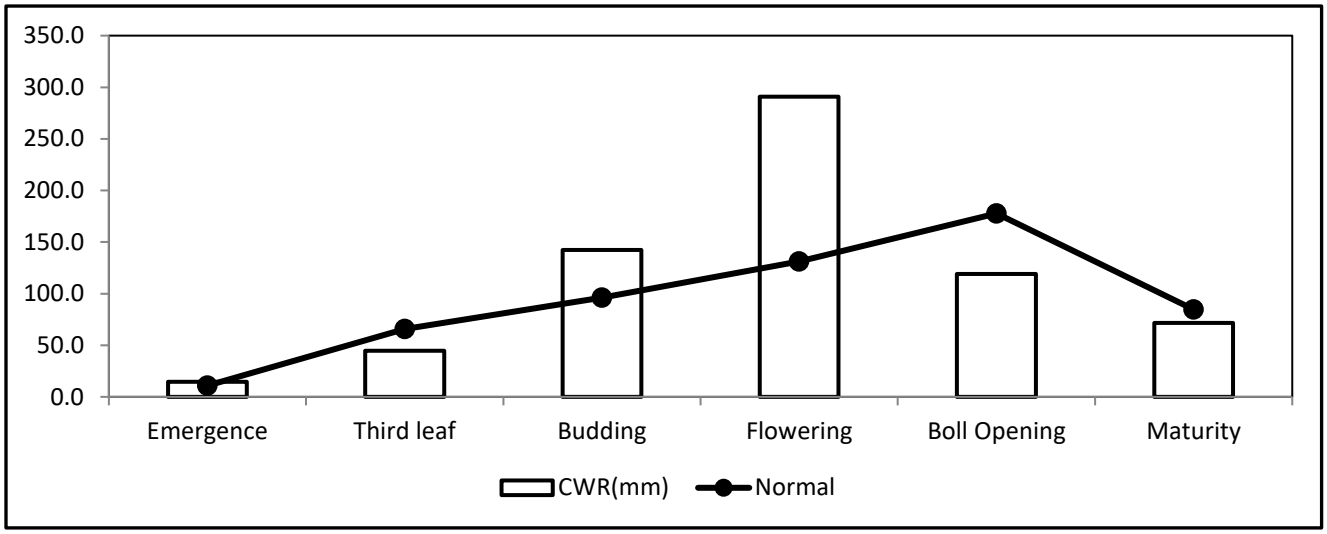


Figure3.11: Crop Water Requirement (CWR) During Crop Life.

Table 3.6: Crop water requirement during different phenological phases

S. No.	Inter Phase	Period	No. of Days Taken	ETo (mm)	*ETo (mm)	CWR=Kc ETO	CWR=Kc *ETO
1.	**Emergence**	29-04-2024 To 05-05-2025	07	32.9	39	14.5	10.9
2.	**Third leaf**	06-05-2024 To 19-05-2024	14	77.0	135.2	44.6	65.9
3.	**Budding**	20-05-2024 To 14-06-2024	26	171.6	139.6	142.4	96.2
4.	**Flowering**	15-06-2024 To 30-07-2024	46	266.8	134.1	290.9	131.2
5.	**Boll Opening**	31-07-2024 To 23-08-2024	24	110.4	148.1	119.2	177.7
6.	**Maturity**	24-08-2024 To 09-09-2024	17	73.1	70.5	71.6	84.6

7.	**Emergence to Maturity**	29-04-2024 To 09-09-2024	134	731.8	666.5	683.2	566.5

*Normals based upon 1981-2010 data.

3.11 Agro Meteorological Summary of Crop Cycle

A number of meteorological parameters were recorded during all the phenological phases for cotton crop season 2024. The impact of these parameters at different phenological stages of cotton crop is discussed as under.

3.11.1 Sowing

Cotton crop was sown during the last decade of April which is proper time for sowing. The mean day temperature was around normal values and there was no rain at the time sowing. Night temperatures were also around normal values.

3.11.2 Emergence

Emergence phase is distinguished by the appearance of spike above the ground. When plant emergence stage was completed; the field was divided into four replications. The mean relative humidity during this phase was 42%. Mean air temperature during emergence was in the range 23.7°C to 31.3°C. Rainfall of 7.0 mm was reported during this phase.

3.11.3 Third Leaf

This phase took 04 days to complete. The mean relative humidity was 38%; mean air temperature range was from 29.9°C to 36.5°C. A precipitation amount of 6.0mm was recorded during this phase. Good crop growth was reported during this stage.

3.11.4 Budding

The bud is in the shape of three walled pyramid and lighter in colour than the plant leaves. This phase is considered established when the bud is 3-5 mm in size. The mean air temperature during this phenological stage was 30.7°C to 37.1°C and mean relative humidity was 32%. This phase experienced 3.2 mm of precipitation.

3.11.5 Flowering

The mean air temperature during this stage was recorded in the range from 26.0°C to 37.4°C and mean relative humidity was 58%. This phase experienced much frequent rain with a significant total amount of 190.6 mm. It includes a spells of 35.6 mm on 04th of July, 46.0mm on 06th of July and 43.0mm on 12th of July. The increase in humidity also triggered the pest and disease attack on the crop.

3.11.6 Boll Opening

This phase is established when the opening of the top of the boll is one centimeter long and the cotton fibers are visible through the opening. The mean air temperature was from 27.0°C to 34.0°C during this phase. The relative humidity was 73%. Precipitation of 108.2 mm was reported during this phase. Due to relatively higher temperatures during this phase boll took less days to open. Higher temperatures not only reduce the production of new boll but also cause shedding of boll.

3.11.7 Maturity

This phase is established when the lint hairs have dried and turned into fez and can be easily detached from the boll. The mean air temperature was recorded as from 26.5°C to 32.7°C whereas mean relative humidity during this phase was 71%. This stage experienced 16.8mm of rain. This rain at the maturity resulted in the decline of the quality of the fiber.

3.11.8 Picking of Cotton

First Picking of the cotton crop was started on 24-09-2024. The maturity was completed on 09-09-2024. The large amount of rainfall after maturity and before the completion of picking resulted in the loss both in quantity and quality.

Chapter 4

CONCLUSION AND RECOMMENDATIONS

The crop variety F.H-333 was cultivated in the experimental field of Ayub Agriculture Research Institute Faisalabad. The sowing time is a very important factor. The time of sowing is directly related to yield of the crop.

According to Table – 3.1 and Chapter-3 (Results and Discussion), the crop was sown later than the proper time. Amount of seed cultivated per acre was 08 kg which is sufficient for the crop cultivated at the end of April. Fertilizer intake was also enough. Very high above normal Rainfall was reported during July, August and September while May and June received below normal rainfall. Irrigation was made 08 times during the season which mostly fulfilled the water requirement of the crop. Day and night time temperatures fluctuate slightly from below normal to above normal range. RH was also observed to be slightly above normal during the reproductive growth period of the crop while it was below normal during the vegetative stage of the crop. ETo remained below normal during most of the growing period. Normal moisture content of soil in major root zone was observed during most of the crop life thus contributing to normal crop's growth, development. Air temperature regime remained about normal values for most of the crop's period. Total heat units consumed by the cotton crop were 3074 accumulated from germination to full maturity in 134 days. On average 22.7 heat units were consumed by the crop per day. Normally these heat units are consumed in 150 days at the rate of 18.5 heat units per day, which shows that the crop reached to full maturity earlier than normal thermal time. From figure 3.9 it is clear that crop consumed well above normal heat units during the reproductive stages while below normal values were observed during third leaf and boll opening stages.

Excess of weeds also play important role in yield's reduction as weeds consume considerable amount of moisture and other soil nutrients and negatively affect crop's growth at the same time. But this issue can be resolved by proper and timely use of recommended varieties of weedicides. During 2024 recommended weedicides operations were performed in time, which also reinforced crop's growth and production. Due to favorable temperature and humidity values pest attack was observed on the crop during its life cycle. Pesticides were used for the control of whitefly, Jassid, sucking and bollworms.

4.1 Conclusions

During the kharif season 2024, crop was sown at normal time. Both day and night time temperatures remained in normal range during most of crop life. High value of humidity during reproductive growth

period was favorable for disease attack. Crop was treated with normal fertilizer doze and weeds removing spray at suitable intervals. Pesticides were also used to control the pest attacks. Overall the weather conditions variations during different stages of crop life effects differently. High humidity at reproductive stages favor pest and disease attack while high rainfall during maturity negatively affect the cotton fiber quality and quantity.

4.2 Recommendations

Keeping above results and conclusions, following recommendations/suggestions are given to farmers and other related personals to enhance cotton crop yield in central Punjab as well as all over Pakistan.

1 – Farmers generally plant cotton late due to late harvesting of Rabi crop which results in drastic low yields because the crop is exposed to heat stress at early stages leading to the formation of reduced boll size. Late-planted crop has central germination, smaller heads, shriveled boll and central biomass than the timely planted crop. Any delay in planting would reduce yield drastically. To achieve good yield, cotton sowing should be carried out well in time. Keeping the results of this study, it is suggested that the most suitable time of sowing under existing climate and available water in central Punjab is month of May.

2 – Cotton plant water requirement is maximum during flowering and boll opening and maturity stages followed by vegetative stages. Therefore, farmers and other decision makers should make possible the availability of irrigation water to cotton crop keeping this order in mind to get maximum crop yield.

3- Farmers should take in time precautionary measures against any pest/fungus/viral etc. attack on crop, especially during hot/humid period of monsoon.

4 – The frequency of extreme weather events like heat waves, flash flooding, and heavy spells with stormy winds has increased globally including Pakistan in the last decade due to climate change. Pakistan has also been o facing water shortages and drought conditions for the last several years due to lesser rains and high temperatures due to global warming which resulted in hampering of cotton production. In order to minimize the negative effects of climate change and accompanied global warming, drought and heat tolerant varieties need to be evolved in addition to the judicial use of available irrigation water. Keeping in mind the available water resources, it is also indeed necessary to decide suitable verities to be cultivated in a particular region.

5 – Farmers may be advised to be in contact with local and Federal Agricultural Departments and Pakistan Meteorological Department throughout crop's life, especially at the time of sowing, adding fertilizers to crop and before irrigation. It will help the farmers to get in time weather advices to deal in better way with any present or coming water stress condition and to be aware of any weather-related pest attack, especially during monsoon season and to get best results of fertilizer and irrigated water used.

6 – Frequent rains/irrigation some time sharply increases plant growth and elongates plant height above normal and speeds up weed's growth. Due to which crop stages take more time for completion and number of branches emerge on each plant decrease, which ultimately affect final yield and lengthens crop life span. As a result, sowing of coming Rabi crop on the same field becomes late. Therefore, farmers should carefully add irrigated water in rainy conditions.

7 – Weeds being the main robbers of plant food from soil; space and even light required for cotton plants, be controlled by cultural practices and in case of heavy infestation, may be eliminated by application of recommended herbicides and weedicides. This technique will definitely increase the yield.

8 – Seed of high yielding cotton varieties resistant to rusts, smuts, etc. approved by Agricultural Department for a particular region in a particular amount must be used. Seed should be treated with a suitable insecticide carefully before sowing.

9 – Timely application of nitrogen-phosphoric fertilizers should be done.

10 – Care must be taken to check the pre and post-harvest losses of cotton.

11 – Crop rotation is an important factor that enriches the fertility of the land, which should not be ignored.

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