An Analysis of Weather and Cotton Crop Development in Central Punjab (Faisalabad) (2007-2011)

by

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Summary

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; air and soil moisture on plant growth and development during each Phenological stage and on final yield of cotton crop. For this purpose both Meteorological and phenological observations along with soil data have been monitored at different phenological stages of cotton crop, cultivated in the field of Ayub Agriculture Research Institute Faisalabad (Central Punjab) during the Kharif Seasons 2007-2011. Beside this some other factors e.g., time of sowing, fertilizer intake, and weeds removing operations and supplied irrigated water have also been studied. The crop accumulated 4552 heat units in 147 days during its life cycle from emergence to maturity. Water requirement was fulfilled through flood irrigation onwards from early growth up to maturity stage. Crop growth and production varied during this period mainly due to 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 so on. This study is based upon limited data of 5 years span. 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

1. Introduction

This study is based upon field observations of cotton crop by Regional Agromet Center Faisalabad, cultivated in the experimental field of Plant Physiological section of AARI Faisalabad during the Kharif season2011. The study permits the cotton varietyMH-113recommended by Punjab Agriculture Department for centralPunjab. 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 Pakistan and CentralPunjab (Study Area)

Pakistan has a variable climate, ranging from arid (30-250mm annual rainfall) in the south to humid (1000-2000mm per year), sub-humid (500-1000mm per year) and semi-arid (250-500mm per year) in the north. The river Indus that originates in the north with its tributaries irrigates most of the agricultural plains of the country [1]. The agriculture in the major portion of upper half of the country which is mainly semi arid depends upon canal irrigation besides considerable intake of rain water also available due to monsoon weather systems in summer during kharif crops. Winter rains occur due to westerly waves that penetrate into Pakistan from the northwest and southwest. A narrow patch in the upper half of the country is sub-humid to humid, comprising of the mountainous to sub mountainous areas of Punjab and adjoining areas of Khyber Pakhtoonkhwa, where satisfactory precipitation occurs both in summer and winter and agriculture is carried out without canal irrigation [2].The climate of lower half including agricultural plains of southern Punjab, Sindh and Balochistanis mostly arid, where annual rainfall is much less than potential evapotranspiration and crop production is not possible without irrigation.

Regional Agromet Center (RAMC) Faisalabad is situated in the Agronomy Section of AyubAgricultural Research Institute Faisalabad in central Punjab. The latitude and longitude of RAMC Faisalabad are 31.43ºN and 73.1ºE respectively. Total annual rainfall in central Punjab ranges 300-660mm (375mm in Faisalabad), more than 60% of this is received during summer monsoon period (July-Sep) and remaining rain occurs due to westerly waves in winter and during pre-monsoon period in 2nd half of June. Temperature ranges cool to cold in winter and hot to very hot during summer. More detail about the climate of Faisalabad is located in the following Figures (1-1 to 1-3), which clearly indicates that highest amount of rainfall during Kharif seasonoccurs in the month ofJuly, followed byAugust. Day time mean maximum and night time mean minimum temperaturesgradually increase from May to June and then gradually decrease tillOctober during KharifSeason.

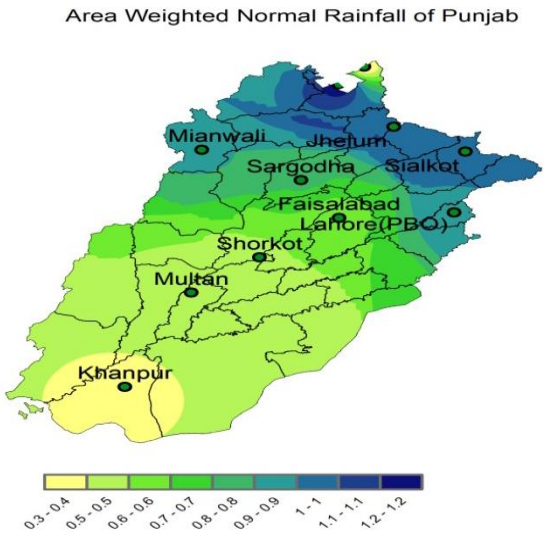


Figure 1-1: Area weighted Normal Annual Rainfall (mm) of Punjab

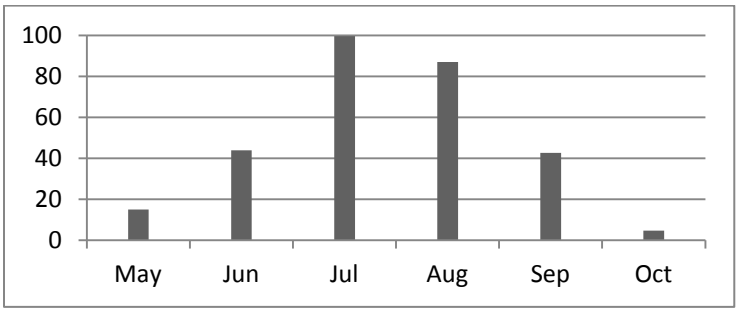


Figure 1-2: Monthly Mean Annual Rainfall (mm) of Faisalabad

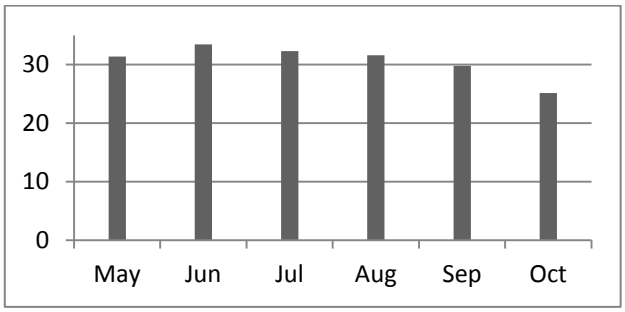


Figure 1-3: Mean daily Maximum and Minimum Temperature (ºC) of Faisalabad during Kharif Season

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 every year variation in the spatial and temporal distribution of precipitationcauses changes in the amount of available water for irrigated agricultural regions, which consequently brings up and down in the annual cotton production. Some time 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 beside rainfall and temperature along with variations in soil temperature and moisture will be analyzed to understand crop growth and development throughout the crop life and their impact on final yield of the crop obtained.

1.3. Objective of the Study

- To investigate the impact of various meteorological parameters on crop growth and development in Faisalabad area.
- To make an attempt for formulation of yield estimation mechanism, i.e. crop-weather model development.
- 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.

1.4. Review of Agriculture Production in Pakistan

The agriculture sector continues to be an essential component of Pakistan's economy. It currently contributes 21 percent to GDP. Agriculture generates productive employment opportunities for 45 percent of the country's labour 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 from 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 [4].

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 to55% in National Rice Production, 65% in National Sugarcane Production, 75% in National wheat Production and 70% in National Cotton Production [5].

1.5. Cotton Production in Pakistan and Punjab

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. The area under the cultivation has decreased from 3million hectares in 2007 to 2.8million hectares in 2007. Whereas yield per acre increased from 649kg in 2007 to 815kg in 2011-12. Well-researched BT 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 [4].

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. During the last ten years (2000-2009) period, cultivated area reduced from 2405200hectares to 2395600hectares but per acre yield increased from 8620200 balesto

6396600 bales in Punjab.The crop of 2010-11 was partially affected due to flood water but per hectare yield still increased from 597 to 607kg.

Chapter 2

2. Materials and Method

This study is based upon field observations of recommended varietiesof cotton crop planted in the experimental field of Plant Physiological section of AARI (Ayub Agricultural Research Institute)Faisalabad during the Kharif seasons 2007- 2011.

Weather parameters and crop data including Phenological and soil moisture/temperature observations at different depths, were observed and recorded according to World Meteorological Organization (WMO) and Food and Agriculture Organization (FAO) standards.

Table 2-1: Observed Meteorological Parameters

1	Precipitation or Rainfall (mm)
2	Air temperature (°C)
3	Maximum and Minimum Temperature (°C)
4	Soil Temperature (°C)
5	Relative Humidity (%)
6	Bright Sunshine Hours
7	Wind speed (Km/Hr) &Wind Direction
8	Soil Moisture (%)

2.1. Phenological Observations during Crop Growth

A sound understanding of plant growth and development is an essential element of efficient economic cotton management system. The impact of 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 [7].

2.1.1. Phenological Stages of Cotton Crop

Growth period of cotton crop consists of the followingphenological stages/phases.

Germination

This phase can be distinguished by the formation of radicals. The observation of this phase begins the fourth day after planting. In each plot soil is uncovered until two seeds are noted and the number of germinated seeds is recorded.

Emergence

Emergence is distinguished by the appearance of the cotyledons above the soil surface. The beginning of phase should be recorded in AR3-3 without giving numbers. Then enough plants have emerged so that crop rows are distinguished. One meter length of one row in each plot is selected for the observation of the next phase.

Third True Leaf

The terminal bud growth between the two cotyledons (seeds leaves) produces one true leaf and continues to grow and produce more true leaves. The first two true leaves are oval shaped while the third one is spear shape. The appearanceof this leaf is recorded. The number of plants in phase is given as noted in AR3-3 i.e. the number of plants in phase divided by the total number of plants in 5 meter length.

Budding

The first fruiting branch usually forms in the axil of 5th or 6th leaf (some time at the axil of third or 4th leaf). The fruit bud becomes visible to the eye, in most cases after the appearance of the 5th leaf. The bud is in the shape of a three walled pyramid. It is lighter in colour than plant leaves. This is due to the pubescence of bracket. The phase is considered established when the bud is 3-5cm in size.

Flowering

Cotton flowering starts from the base and progresses to the top of the plant. The fcentral lasts only one day. Therefore when counting the plants in flowering, it is necessary to include the bushes bearing the first open fcentrals and those with fcentrals already wilted.

The bud unfolded in the morning and the fcentral is already wilted by the evening. When the fcentrals open they are yellowish white in most cases. Towards the evening they turn pink, red or lilac and wilt afterward.

Boll opening

This phase is established when the opening of the top of the boll is 1cm long and the cotton lent fibers are visible through the opening. The phase is considered established even when only one boll is opened, abnormal bolls are obviously injured usually open earlier and sometimes sideways [8].

Table2-2 Date-wise occurrence of Phenological stages 2007 to 2011.

Stage	**Period of(10-75%) occurrence**				
	2011	**2010**	**2009**	**2008**	**2007**
Sowing	24-05-11	14-05-10	08-05-2009	29-05-2008	19-5-2007
Emergence	28-05-11to 4-06-2011	19-5-10 to 24-5-10	16-5-09to 31-5-09	04-06-08to 11-06-08	23-5-2007 3-6-2007
Third leaf	05-06-11to 20-06-11	26-5-10 to 5-6-10	01-06-09 to 14-06-09	12-06-08to 28-06-08	4-6-2007 22-6-2007
Budding	21-06-11to 26-07-11	16-6-10 to 3-7-10	15-06-09 to 0 3-07-09	29-06-08 to 03-08-08	23-6-2007 13-7-2007
Flowering	27-07-11to 07-09-11	7-7-10 to 22-8-10	04-7-09 to 16-08-09	04-8-8to 28-09-08	14-7-2007 19-8-2007
Boll opening	08-09-11to 12-10-11	23-8-10to 11-9-10	18-08-09 to 30-10-09	29-09-08 to 19-11-08	20-8-2007 23-10-2007
First picking	14-11-2011	25-10-10	31-10-09	13-11-08	24-10-2007

2.1.2. Field Selection and Phenological Observations

Generally the field selected for Phenological observations should be of one hector size but the field selected for observations of this crop was 4.5 acres 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. Phenological phases were particularly identified from the observed data. Total number of plants in a particular Phenological phase at the same time was observed from each replication on every Monday, Wednesday and Saturday. 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 a 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 may also exist.

2.2. Analysis of the Variation in Meteorological and Non-MeteorologicalParameters and Their Impact on the CropGrowth and Development

In order to analyze the major causes behind variations in the crop's growth, development and yield related varying weather and some other factors during each Phenological stage arestudied/analyzed in the following manner.

2.2.1. Rainfall and Cotton Crop Growth during Kharif Season in Faisalabad

Rainfall is one of the most important factors that affect annual cotton production in Pakistan. Faisalabad and its surrounding areas of centralPunjab get most of its total 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 additionrainfall also provides clean environmental conditions to support optimum photoperiodic activity for better biomass and grain yield [9].

During the crop season 2011, above normal rain amounting 36.4mm was reported for 4 days in May.In June below normal rain amounting 28mm was reported. Whereas during monsoon (July to Sep) above normal heavy rainfall was reported. Rainfall amounting160mm was reported during the month of September, badly affected the crop at boll formation stage.

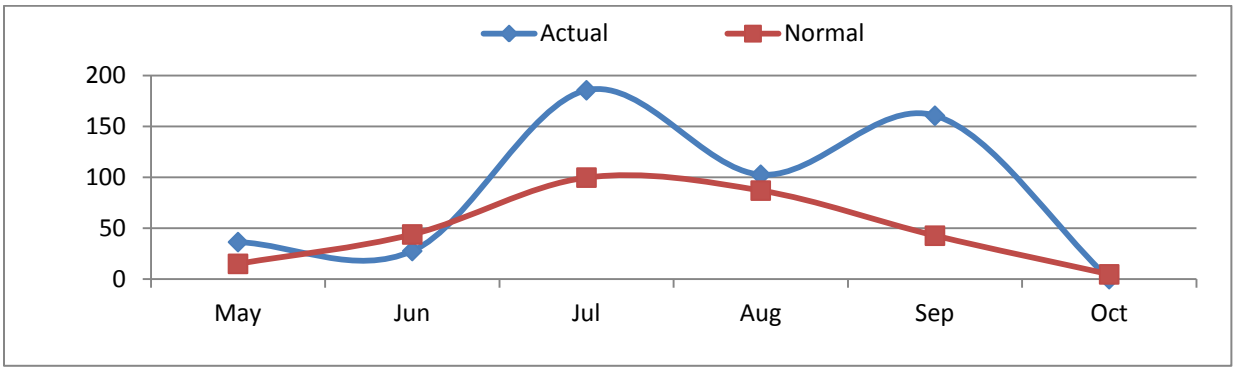


Figure 2-5: Rainfall duringKharif Season2011

During the crop season 2010, mostly hot and dry weather reported up to the end of June during emergence, third leaf and budding stages. However above normal rainfall, was reported in monsoon (July to September)during flowering, boll opening and picking stages. 300mm rain was reported for 9 days, 276mm rain was reported for 12 days in August and 71mm rain for 6 days was reported in September. These heavy rains resulted stagnant water in the field which negatively affected crop growth and production.

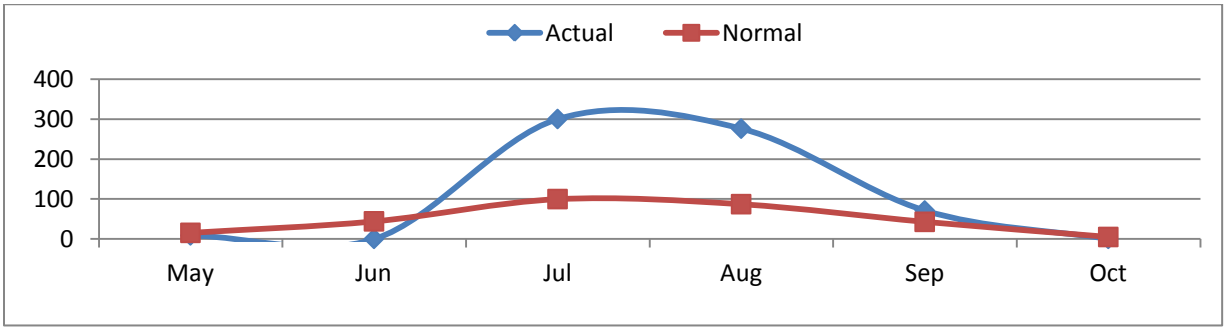


Figure 2-5: Rainfall duringKharif Season2010

During the crop season 2009, hot and dry weather/below normal rain was reported up to the end of July. However above normal rainfall amounting 129mm only for 3 days was reported in August and below normal rain of 30mm for 2 days was reported during September, El-Nino episode negatively affected rainfall throughout the country during 2009 monsoon.

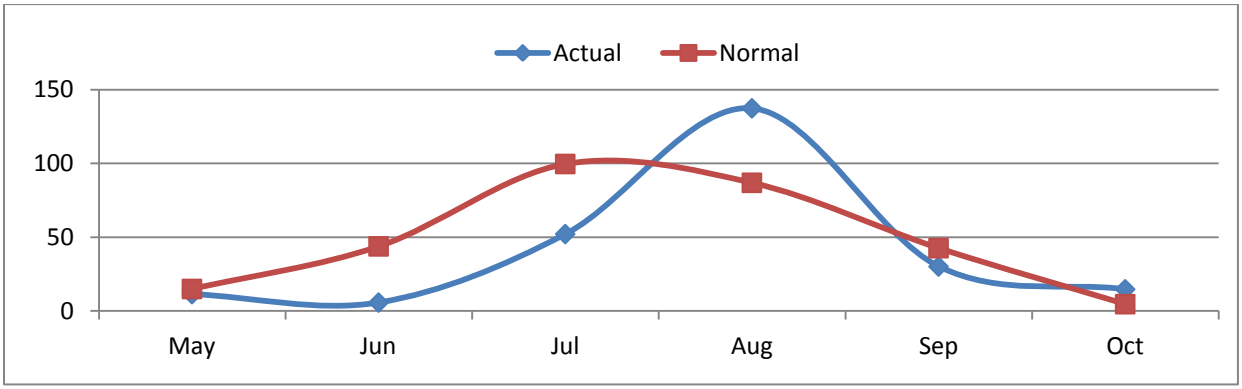


Figure 2-5: Rainfall duringKharif Season2009

During the crop season 2008, the crop was cultivated on 30th of May. Satisfactory rainfall was reported during early growing stages in May and June from sowing to end of third leaf stage. Rainfall reported below normal in the month of July during budding stage and observed above normal in August amounting 273mm for 6 days during flowering stage. Whereas whether mostly remained dry and below normal rain amounting 37mm for 3 days was reported during flowering stage and dry weather was reported during boll opening stage in October.

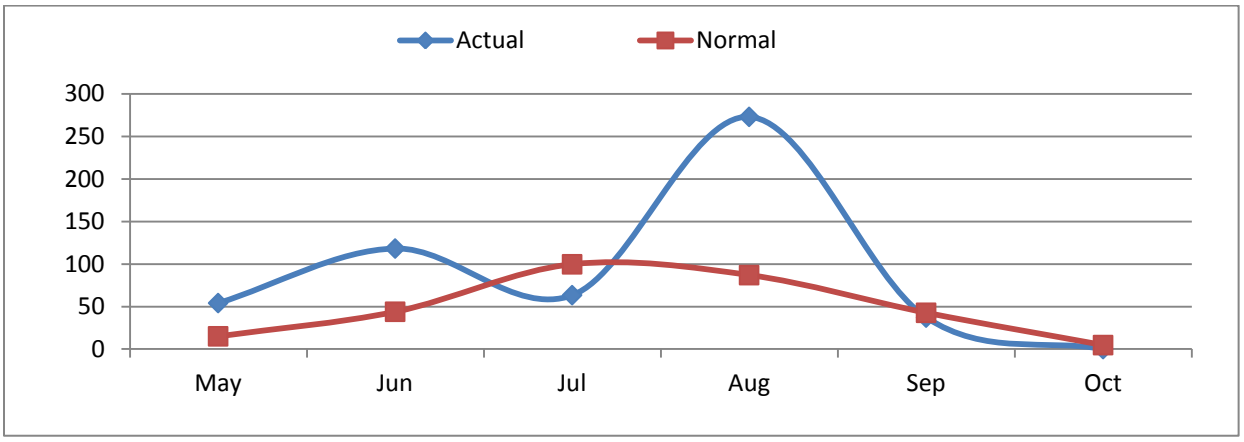
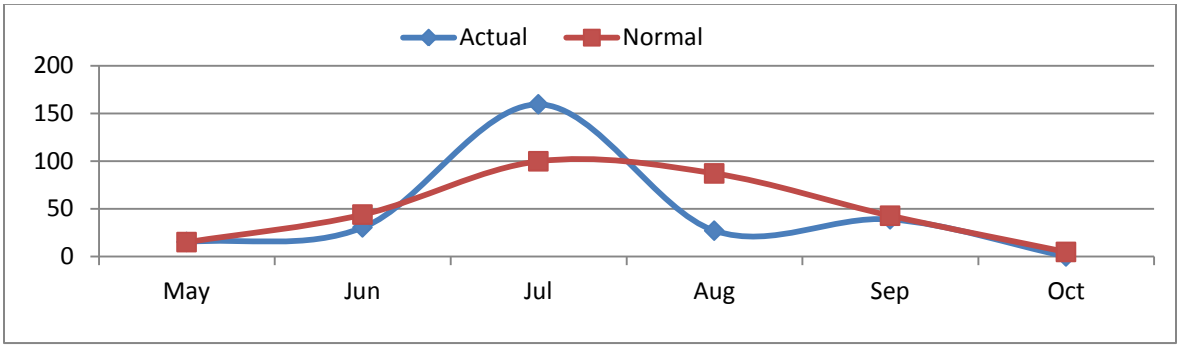


Figure 2-5: Rainfall duringKharif Season2008

During the crop season 2007, hot and dry weather/below normal rain reported during most of the crop life except in July during flowering stage. In July, above normal monsoon rain amounting 159mm for 6 days was reported.

Figure 2-5: Rainfall duringKharif Season2007



2.2.2. Irrigated Water during Crop Growth

During 2011,5 times irrigation water was given to the crop at the time of need.

During 2010, 4 times irrigated water was added to the field; first irrigation was given 18 days after sowing during third true leaf stage. Remaining 3 irrigations were given during budding and flowering stages at the time of need. Satisfactory rains at intervals during each Phenological stage helped in compensating crop water requirement.

During 2009, 4 times irrigated water was added to the field; first irrigation was given 20 days after sowing during third true leaf stage. Remaining three irrigations were given during budding, flowering and boll opening stages at the time of need.

During 2008, 4 times irrigated water was added to the field; first irrigation was given 22 days after sowing during third true leaf stage. Remaining three irrigations were given during budding, flowering and boll opening stages at the time of need.

During 2007, 4 times irrigated water was added to the field; first irrigation was given 23 days after sowing during early growing stage of third leaf. Remaining three irrigations were given during budding, flowering and boll opening stages at the time of need.

2.2.3. Air Temperature and Cotton Crop Growth during Crop Seasons 2007-2012

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 dependant [10].

The growth and maturity of cotton crop is disturbed at times byvariation in day time temperature during both plant vegetative and reproductive stage. Any rise in day temperature may rise crop water requirement and may also trigger pest attack on the plant during humid monsoon period.

During the crop season of 2011, mean daily temperature and day time maximum observed normal to below normal during most of the crop life, which promoted crop growth and development at most of the crop growing stages.

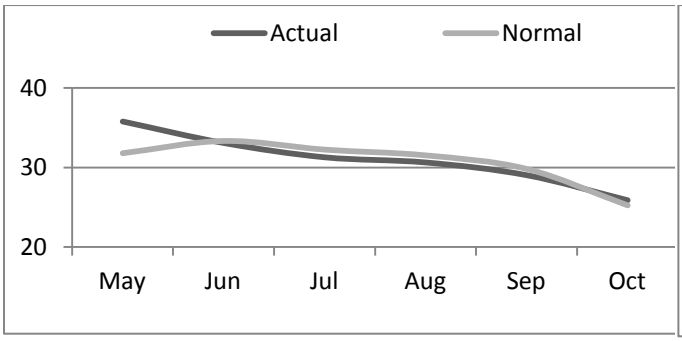


Figure 2-14: Mean Monthly Temperature during 2011

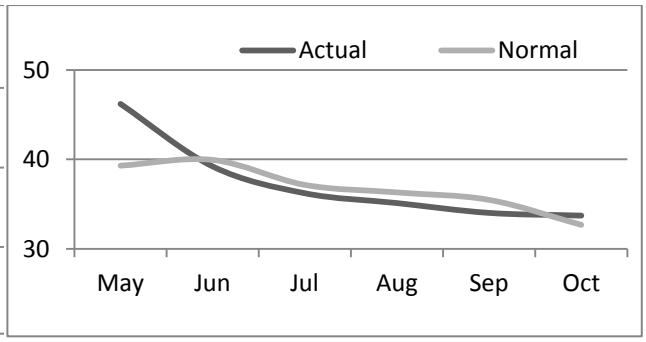


Figure2-15:Mean Maximum Temperature during 2011

During the crop season of 2010, mean daily temperature and day time maximum observed normal to below normal during most of the crop life, which promoted crop growth and development at most of the crop growing stages. Whereas these values remained normal to slightly above normal during early growing stages of germination from sowing to third leaf.

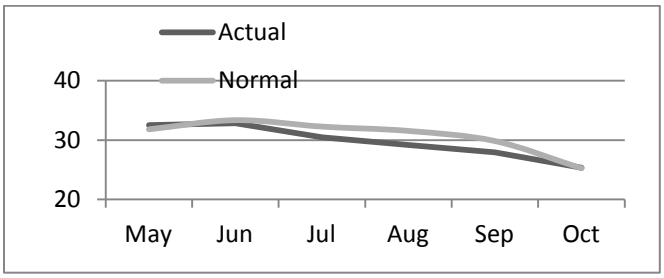


Figure 2-14: Mean Monthly Temperature during 2010

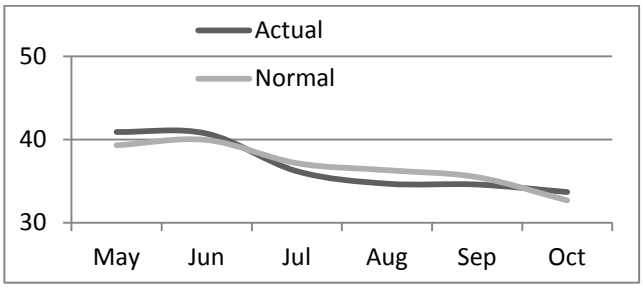


Figure2-15:Mean Maximum Temperature during 2010

During the crop season of 2009, mean daily temperature was observed normal during most of the crop life. Whereas day time maximum temperature remained above normal during early growing stages and observed almost normal during later stages in monsoon.

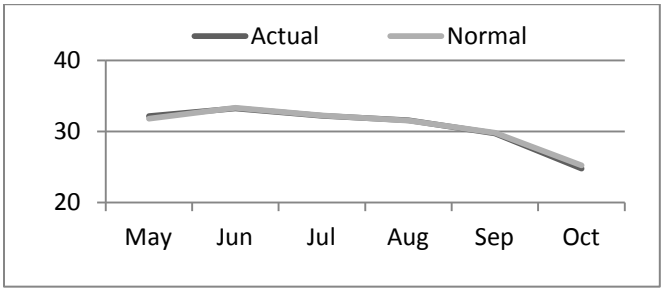


Figure 2-14: Mean Monthly Temperature during 2009

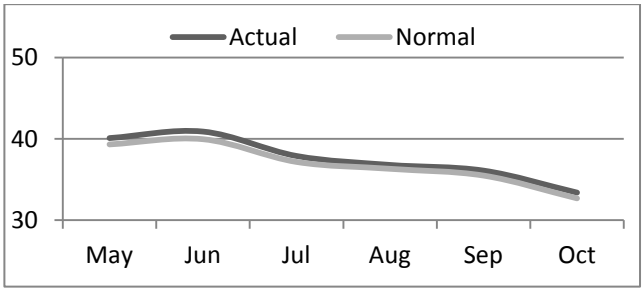


Figure2-15:Mean Maximum Temperature during 2009

During the crop season of 2008, mean daily temperature was observed normal to below normal during most of the crop life. Whereas day time maximum temperature remained slightlyabove normal during boll opening growing stage. This concludes that air temperature regime was mostly favorable for crop growth and development.

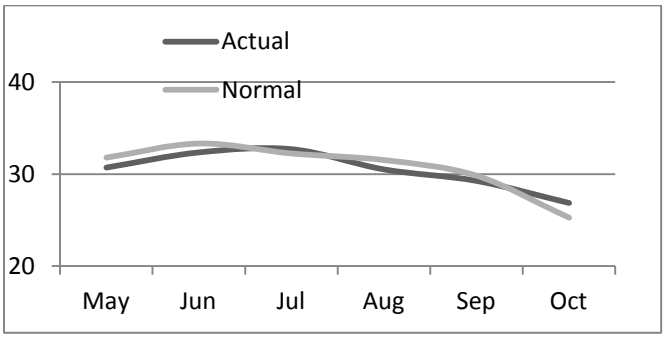


Figure 2-14: Mean Monthly Temperature during 2008

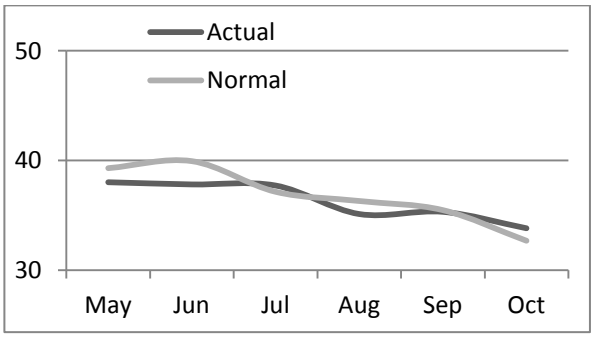


Figure2-15:Mean Maximum Temperature during 2008

During the crop season of 2007, mean daily temperature was observed normal to below normal during most of the crop life. Whereas day time maximum temperature remained normal to below normal during early growing stages from May to July and remained above normal during later reproductive stages in August, Figure (2-14 to 2-15).

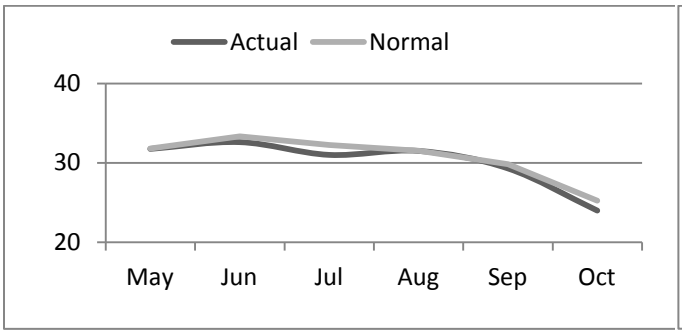


Figure 2-14: Mean Monthly Temperature during 2007

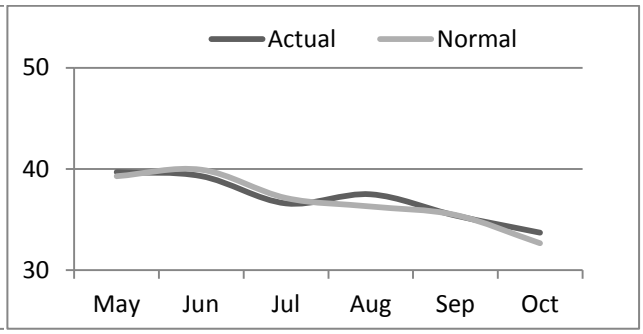


Figure2-15:Mean Maximum Temperature during 2007

2.2.4. 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. Water or soil moisture requirement of cotton crop varies during different growth or Phenological stages. Highest amount is needed during flowering/boll opening stage followed by maturity and early vegetative stages[11].

In order to measure the soil moisture at different Phenological stages, the most common and widely used, Gravimetric method was applied. To calculate soil moisture, soil samples are taken on 7th, 17th and 27th of each month from the four replications at 5, 10, 20, 30, 40, 50, 70, 90 and 110 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;

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

During the crop season 2011, from the observed soil moisture data, Figure 2-16depicts that soil moisture remained satisfactory during most of the crop stages due to in time irrigation and satisfactory rains during monsoon period. Slight moisture deficiency was observed late growing stages. Overall condition of soil moisture was satisfactory due to satisfactory availability of irrigated water during crucial stages.

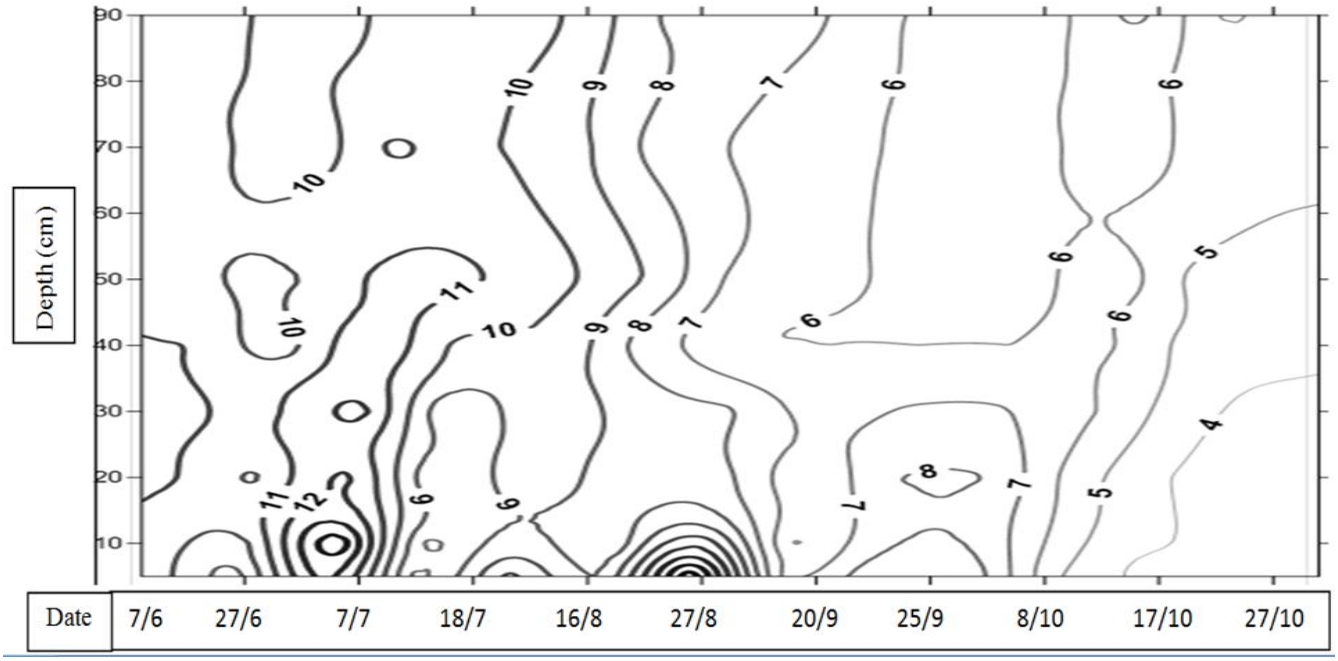
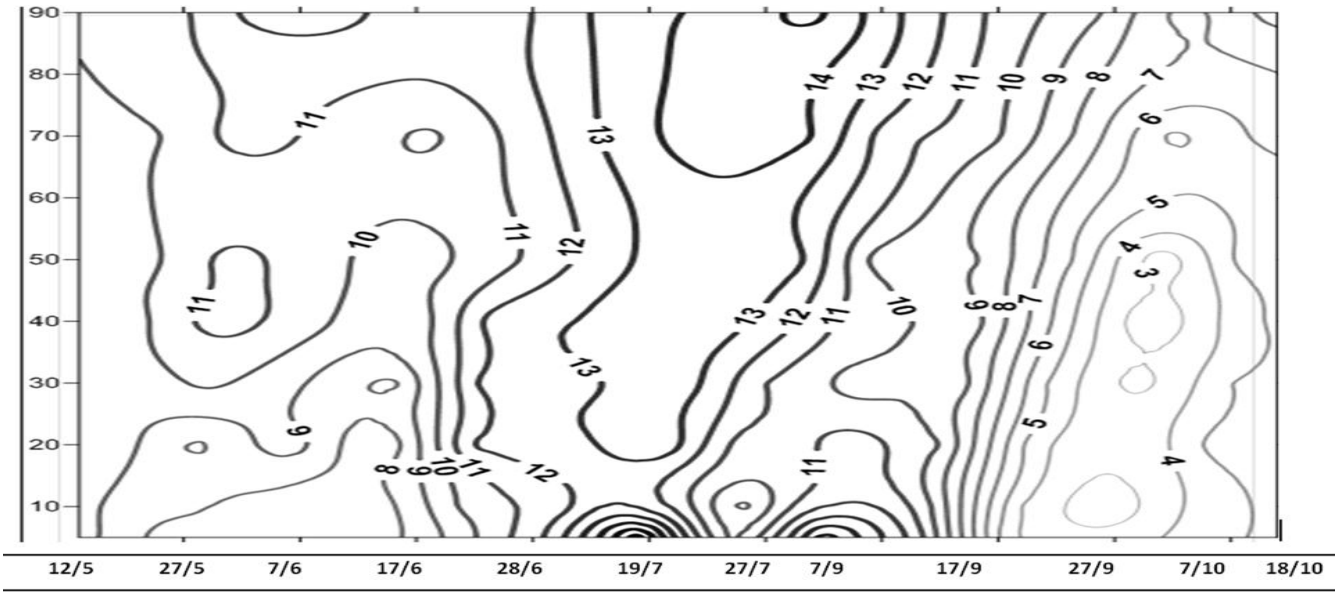


Figure 2-16: Soil moisture chrono-Isopleths for Kharif Crop at Faisalabad for the year 2011

During the crop season 2010, from the observed soil moisture data, Figure 2-16depicts that soil moisture remained satisfactory during most of the crop stages due to in time irrigation and satisfactory rains during monsoon period.



During the crop season 2009, from the observed soil moisture data, Figure 2-16depicts that soil moisture remained satisfactory during most of the crop stages due to in time irrigation and satisfactory rains during monsoon period. Slight moisture deficiency was observed during early growing stages in May.Overall condition of soil moisture was satisfactory due to satisfactory availability of irrigated water during crucial stages.

Figure 2-17: Soil moisture during May to June2010

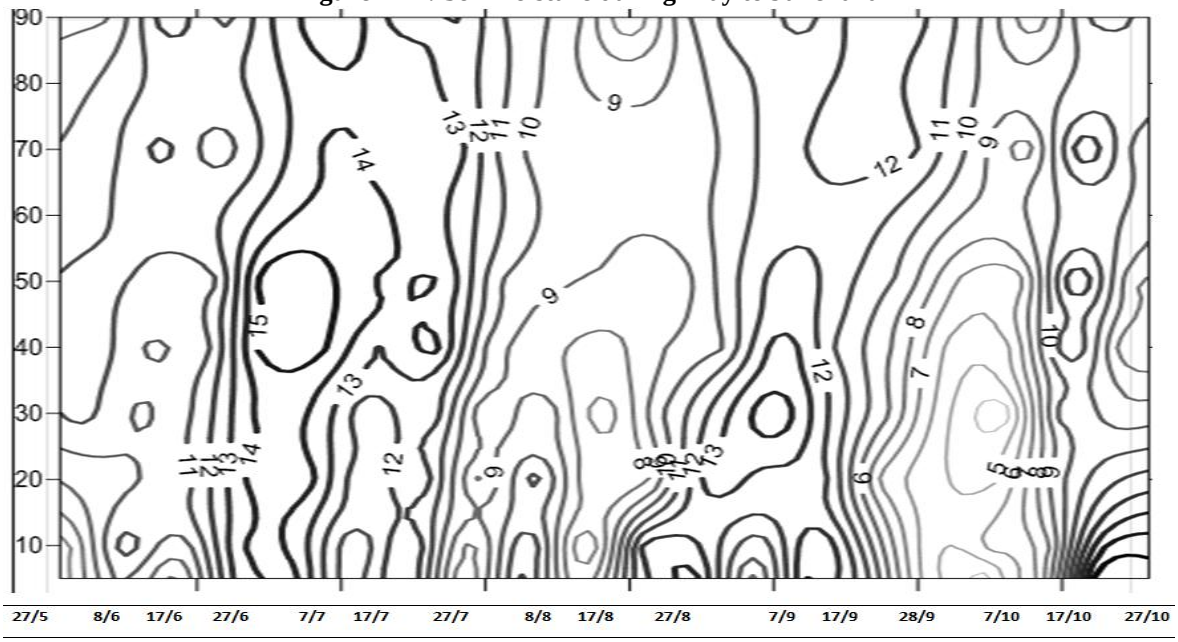


Figure 2-18: Soil moisture during July2009

During the crop season 2008, from the observed soil moisture data, Figure 2-16depicts that soil moisture remained satisfactory during vegetative stages. But soil moisture deficiency to some extent was observed from flowering and boll- formation/maturity stages.

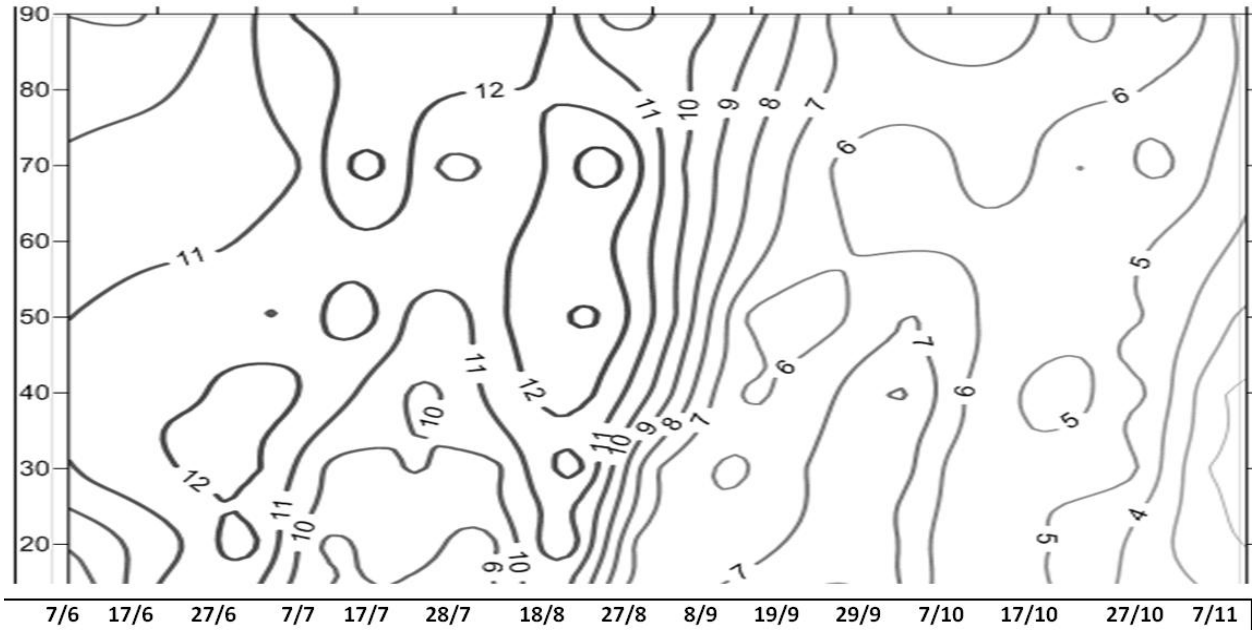


Figure 2-19: Soil moisture during Aug-Sep2008

2.2.5. Soil Temperature and Crop Growth

Soil temperature plays promising role in crop growing period, right from the germination to maturity. In comparison to air temperature, the amplitude of variation in soil temperature is much more pronounced because of the varying characteristics and composition 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 [10].

From the observed data, it is evident that generally, soil temperature increases gradually with increasing depths. Diurnal variations in soil temperature are more significant at shallow layers than deep soils. Soil temperature varies as soil moisture varies from depth to depth and time to time. Soil thermometers in °C were installed at depths of 5 cm, 10 cm, 20 cm, 30 cm, 50 cm and 100 cm to monitor thermal regime of the soil. The soil temperature was observed and then recorded three times a day i.e. 0300, 0900 and 1200 UTC.

Note: This soil temperature data is collected from the soil observations taken at Agromet observatory of RAMCFaisalabad 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 2011, soil temperature was observed normal tobelow normal at all depths. The drop was more significant at shallow layers than deep soils.It shows that soil favored normal crop growth and development at all stages.

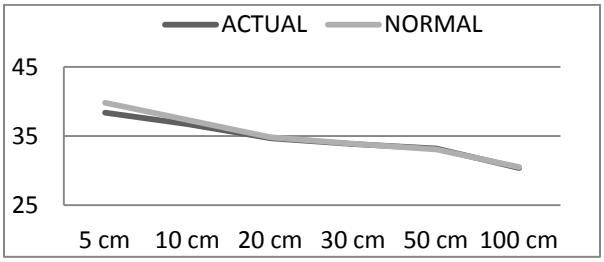


Figure 2-33: Soil temperature during May-2011

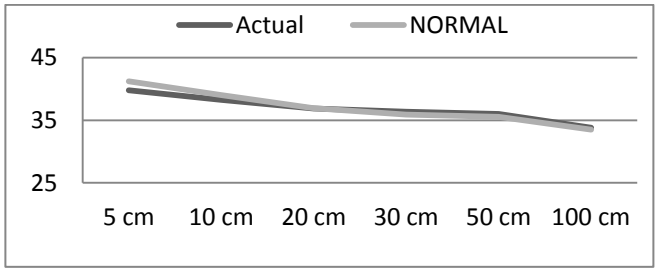


Figure 2-34: Soil temperature during June-2011

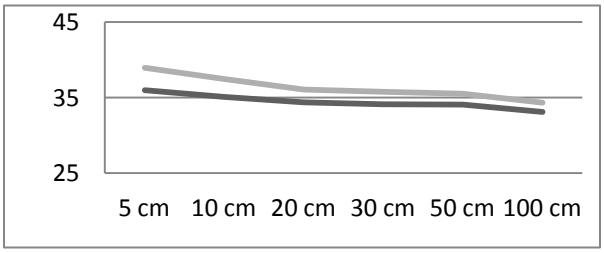


Figure2- 35: Soil temperature during July-2011

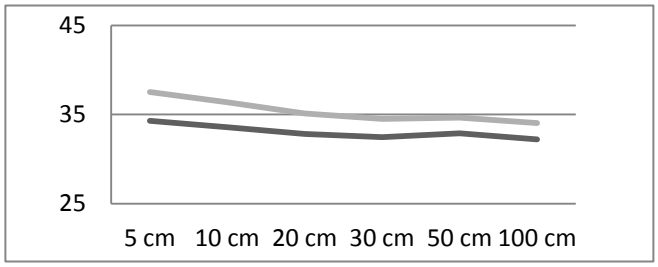


Figure 2-36: Soil temperature during August-2011

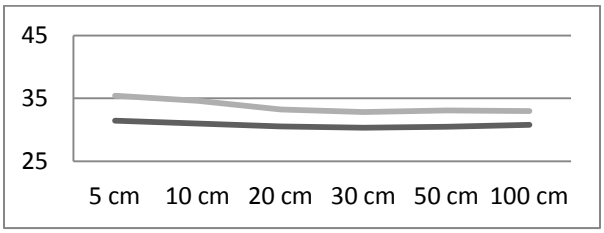


Figure2-42:Soil temperature during September-2011

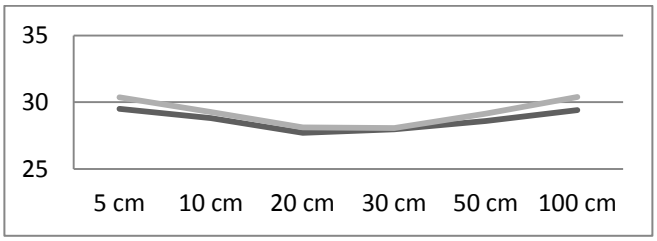


Figure 2-42 : Soil temperature during October-2011

During the crop season of 2010, soil temperature was observed above normal at all depths during early growing stages from emergence to budding.Whereas soil temperature was observed normal to below normal from flowering to maturity stages.

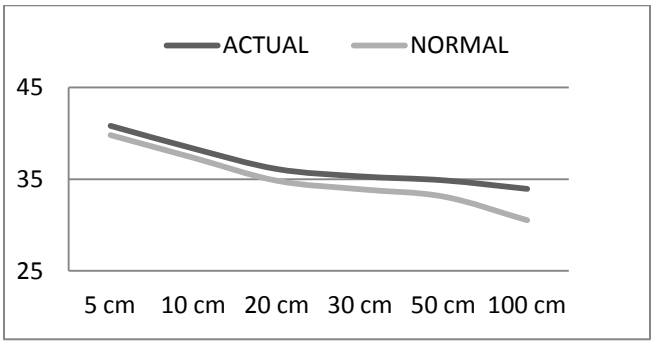


Figure 2-38: Soil temperature during May-2010

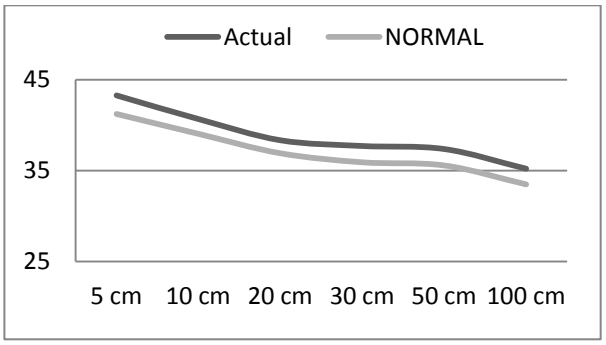


Figure 2-39: Soil temperature during June-2010

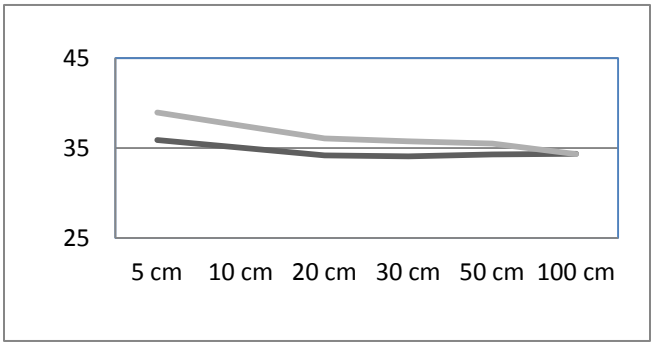


Figure 2-40: Soil temperature during July-2010

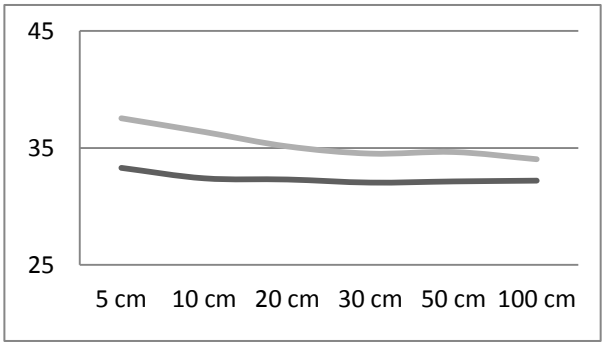


Figure 2-41: Soil temperature during August-2010

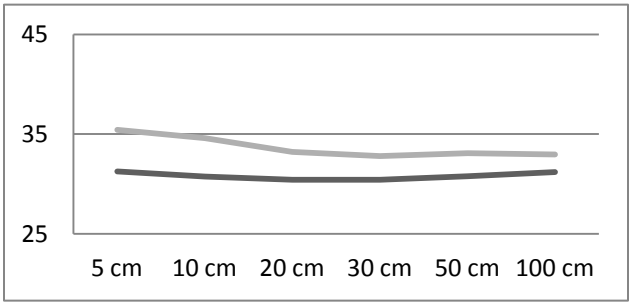


Figure 2-42:Soil temperature during September-2010

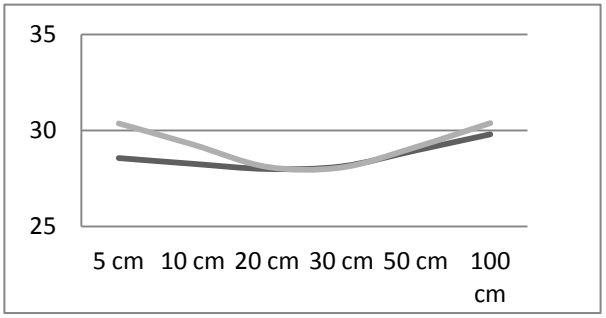


Figure 2-43: Soil temperature during October-2010

During the crop season 2009, soil temperature was observed mostly normal to slightlyabove normal up to boll opening stage and remained below normal at later maturity stages.

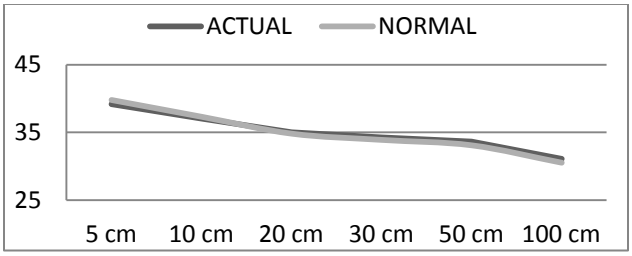


Figure 2-44: Soil temperature during May-2009

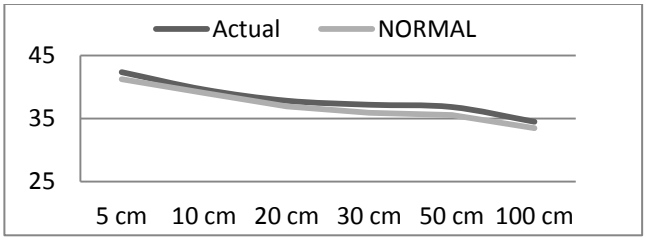


Figure 2-45: Soil temperature during Jun

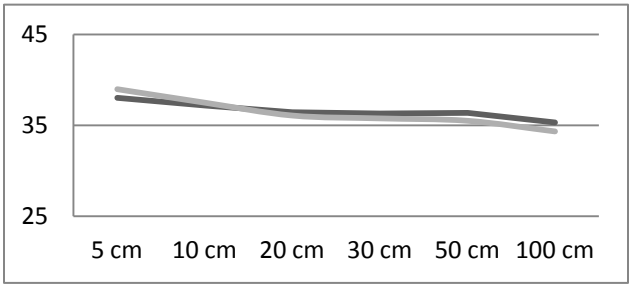


Figure 2-46: Soil temperature during July-2009

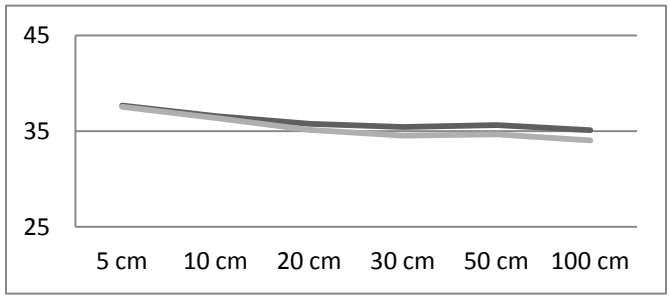


Figure 2-47: Soil temperature during August-2009

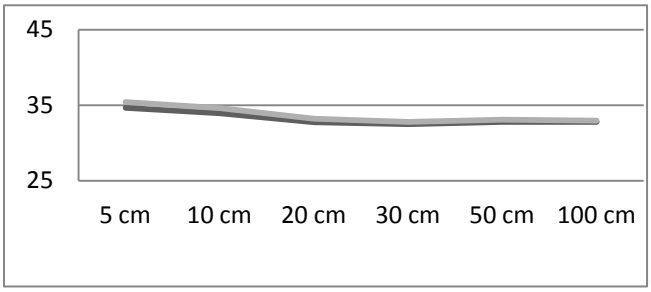


Figure 2-48:Soil temperature during September-2009

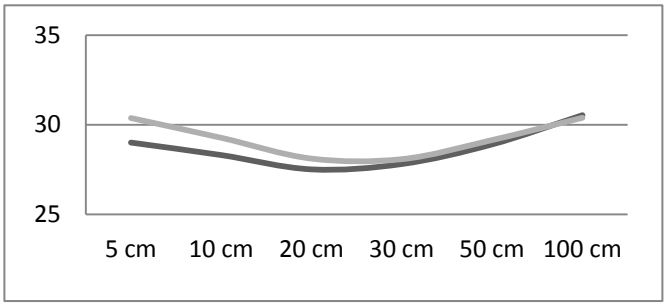


Figure 2-49: Soil temperature during October-2009

During the crop season 2008 in the month of April, soil temperature was observed mostly below normal at all depths. Whereas it was observed above normal at later boll formation stage.

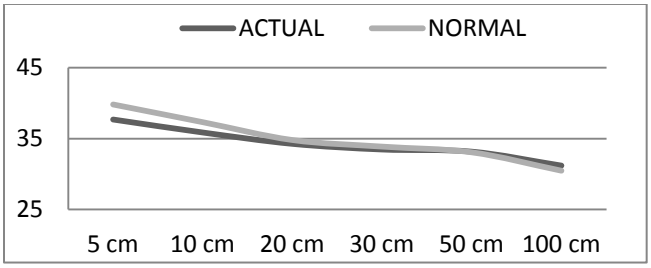


Figure 2-50: Soil temperature during May-2008

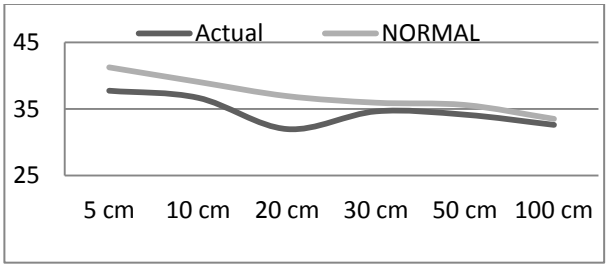


Figure 2-51: Soil temperature during June-2008

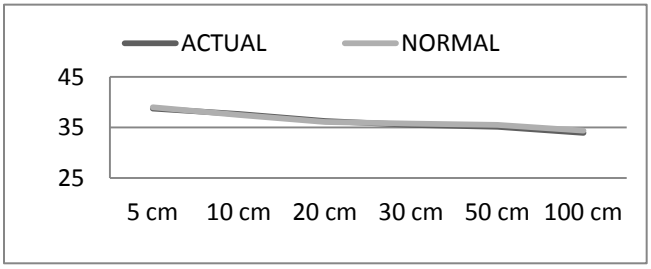


Figure 2-52: Soil temperature during July-2008

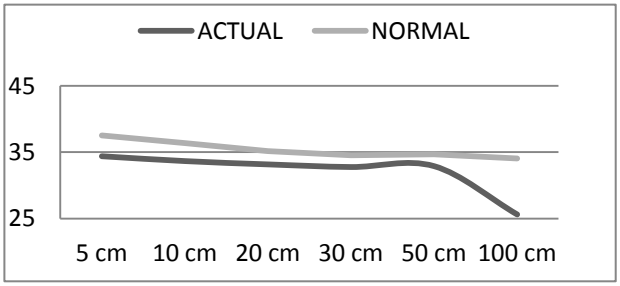


Figure 2-53: Soil temperature during August-2008

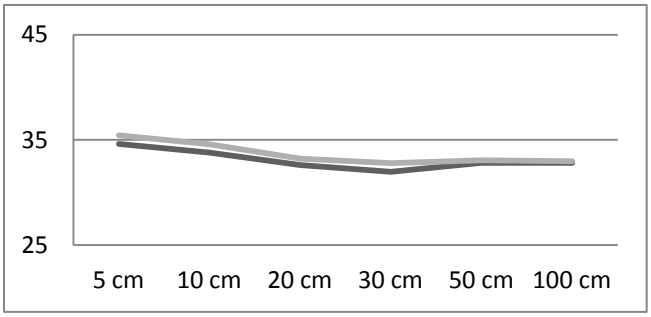


Figure 2-54:Soil temperature during September-2008

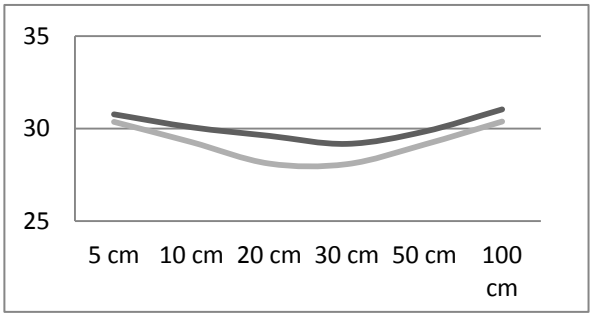


Figure 2-55:Soil temperature during October-2008

During the crop life of 2007, soil temperature was observed mostly normal to above normal during crop life. The rise was more significant during budding and flowering stages in the months of June and August.

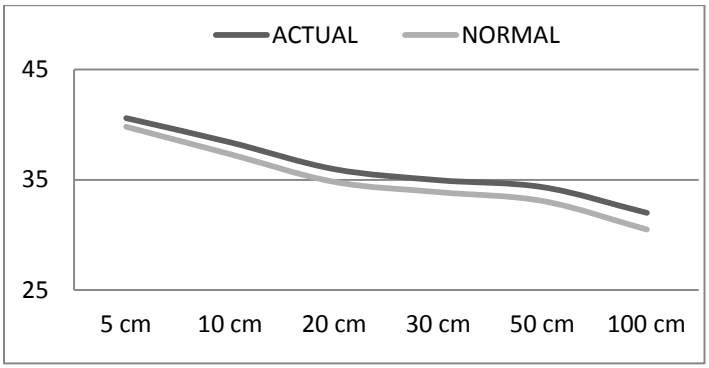


Figure 2-57: Soil temperature during May-2007

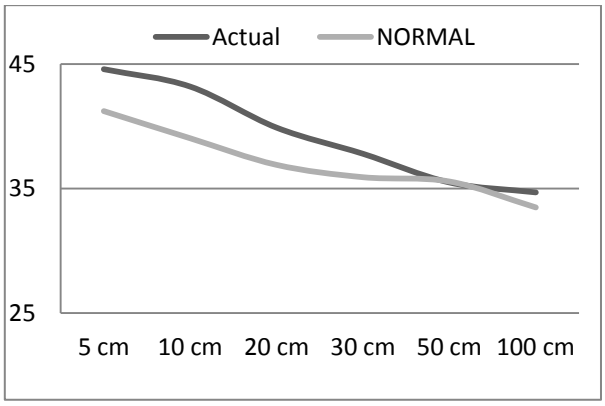


Figure 2-58: Soil temperature during June-2007

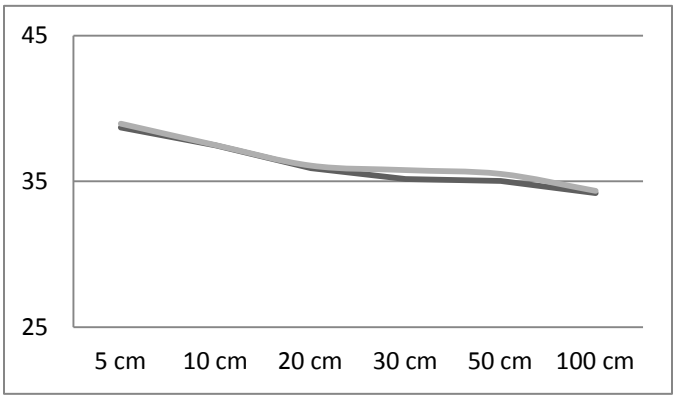


Figure 2-59: Soil temperature during July-2007

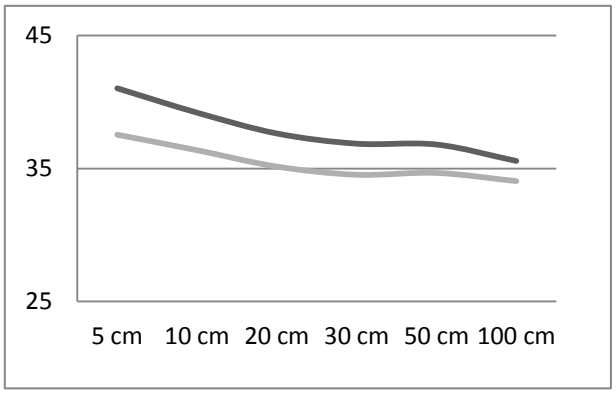


Figure 2-60: Soil temperature during August-2007

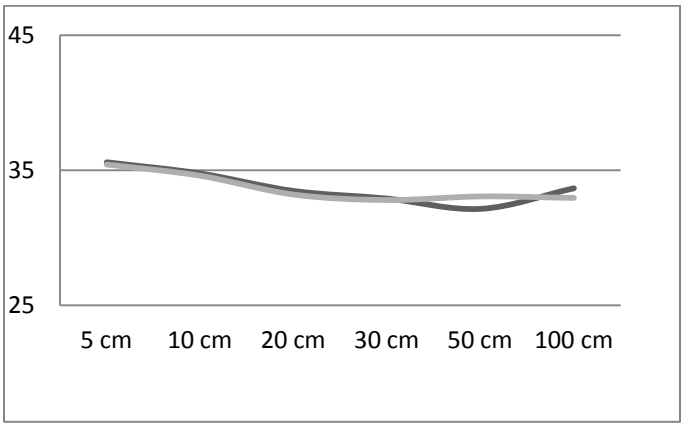


Figure 2-61:Soil temperature during September-2007

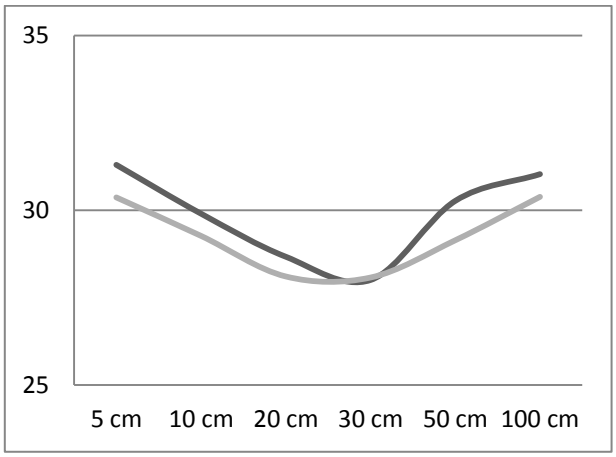


Figure 2-62:Soil temperature during October-2007

2.2.6. Heat Units or Growing Degree Days Consumption during Crop Growth

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

Heat units summation is related to crop development rather than growth because crop growth is related to dry matter formation through photosynthesis. It means that crop requires a particular amount of heat units to be matured/ harvested. If this amount is consumed by the crop, it will be ready for harvesting. But it is not necessary that crop growth may also be completed [10].

2.2.6.1. Methods of Calculation of Heat Units

There are two major methods of calculation of the degree days and they are known as active and effective methods. Calculation procedure is mentioned below.

- **Effective Method:** This is simply the temperature sum during the period under consideration e.g. emergence to flowering etc.

  $H.U = \sum T$; T is mean daily Temperature

  $H.U = 0$:

  If T<Tb; where Tb is biological zero, which is the temperature below which growth stops. For cotton crop its value is 5°C. Crops go in dormancy when temperature drops below the biological zero.

- **Active Method:** This method incorporates the biological zero or base temperature of the crop,

  Heat units with effective method are calculated as under:

  $H.U = \sum (T - Tb)$ if $T > Tb$; $H.U = 0$ if $T < Tb$

In the present case, heat units were calculated by effective method as mean daily temperature never drops below biological zero in centralPunjab during Kharif season.

2.2.6.2. Heat Units Consumption During 2011

Interphase period for cotton crop during the crop season 2011and corresponding heat units at Faisalabadobserved at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 144 accumulated from Germination to Boll formation stages in 4400 days.

Table 2-1: Heat Units Accumulation for the Crop during 2011

Inter-phase	Inter-phase duration	Heat units
Date of Sowing	24-5-2008	
Emergence	8	250
Third True leaf	16	415
Budding	36	793
Flowering	43	1118
Boll Opening	35	720
Total (Sowing to Boll-opening)	144	4400

2.2.6.3. Heat Units Consumption During 2010

Interphase period for cotton crop during the crop season 2010 and corresponding heat units observed at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 3865 accumulated from Germination to boll opening in 125 days. Due to comparatively late sowing and significant rise in daily mean temperature in June during third leaf and budding stages, the crop consumed the required heat units up to maturity earlier.

Table 2-2: Heat Units Accumulation for the Crop during 2010

Inter-phase	Inter-phase duration	Heat units
Date of Sowing	8-5-2009	
Emergence	6	250
Third True leaf	11	415
Budding	18	793
Flowering	17	1118
Boll Opening	20	720
Total (Sowing to Boll-opening)	125	3865

2.2.6.4. Heat Units Consumption During 2009

Interphase period for cotton crop during the crop season 2009 and corresponding heat units at observed at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 5406 accumulated from Germination to Maturity in 176 days.

Table 2-3: Heat Units Accumulation for the Crop during 2009

Inter-phase	Inter-phase duration	Heat units

Date of Sowing	8-5-2009	
Emergence	16	250
Third True leaf	14	415
Budding	19	793
Flowering	43	1118
Boll Opening	75	720
Total (Sowing to Boll-opening)	176	5406

2.2.6.5. Heat Units Consumption During 2008

Interphase period for cotton crop during the crop season 2008 and corresponding heat units observed at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 5105 accumulated from Germination to Maturity in 176 days.

Table 2-4: Heat Units Accumulation for the Crop during 2008

Inter-phase	Inter-phase duration	Heat units
Date of Sowing	30-5-2008	
Emergence	8	250
Third True leaf	17	415
Budding	36	793
Flowering	56	1118
Boll Opening	45	720
Total (Sowing to Boll-opening)	176	5105

2.2.6.6. Heat Units Consumption During 2007

Interphase period for cotton crop during the crop season 2007 and corresponding heat units observed at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 4372 accumulated from Germination to Maturity in 146 days.

Table 2-5: Heat Units Accumulation for the Crop during 2007

Inter Phase	Inter-phase duration	Degree Days
Date of sowing		
Germination	8	244
Emergence	9	290
Third true leaf	19	567
Budding	30	999
Flowering	18	571
Boll opening	33	1029
Total(sowing to boll opening)	176	5105

2.2.7. Relative humidity (R.H) and Reference Crop Evapotranspiration, ETo (mm/day) during crop growth 2007 to 2011

During the crop season 2011, relative humidity remained mostly above normal during the crop, with maximum values during monsoon season, whereas, ETo remained below normal during most of the growing period. Overall soil and air moisture content was favorable for crop growth.

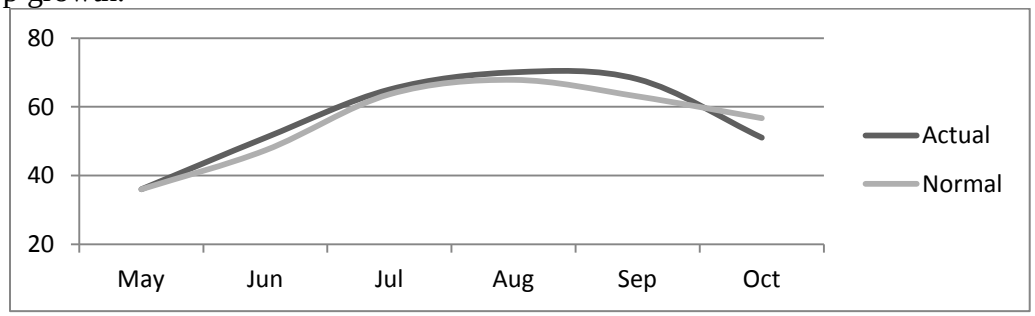


Figure 2-63: Mean RH during 2011

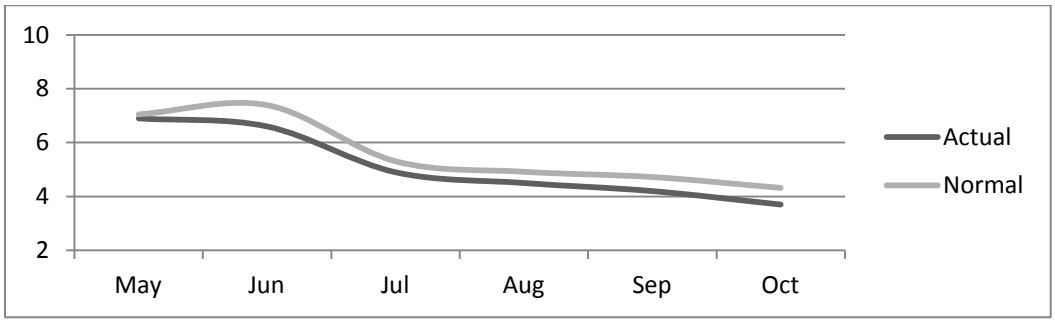


Figure 2-64: Mean ETo during 2011

During the crop season 2010, relative humidity remained below normal during early growing stages from sowing to third leaf stages and remained above normal during remaining stages of the crop life. Whereas,ETo remained below normal during most of the growing period. Overall soil and air moisture content was favorable for crop growth during crucial crop growing stages.

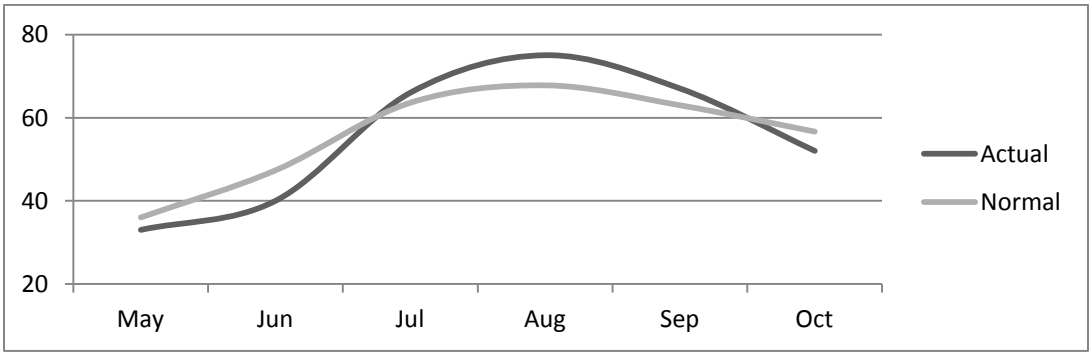


Figure 2-65: Mean RH during 2010

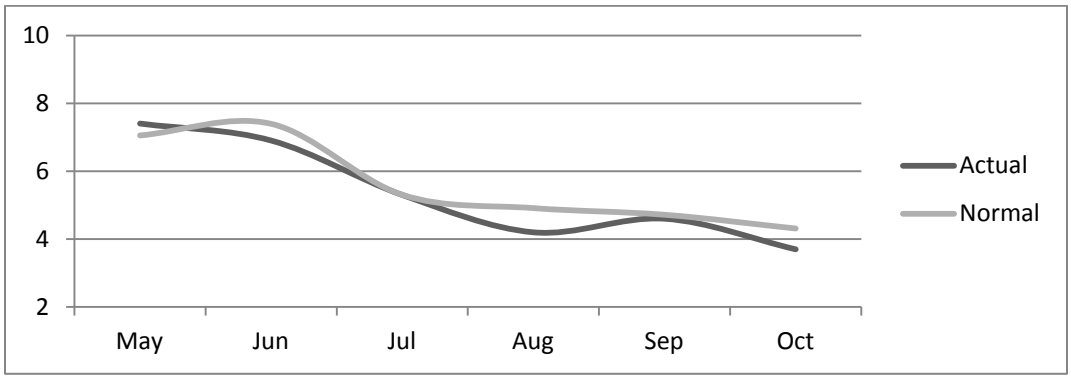


Figure 2-66: Mean ETo during 2010

During the crop season 2009, relative humidity remained below normal throughout the crop, with maximum values during monsoon season, whereas,ETo remained above normal during most of the growing period.

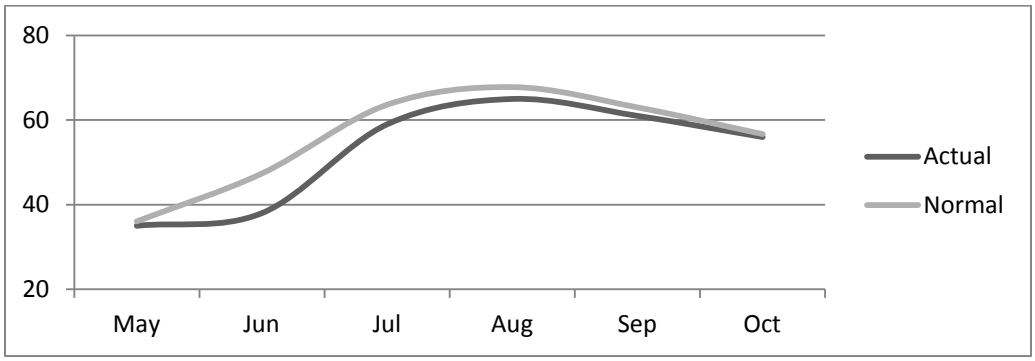


Figure 2-67: Mean RH during 2009

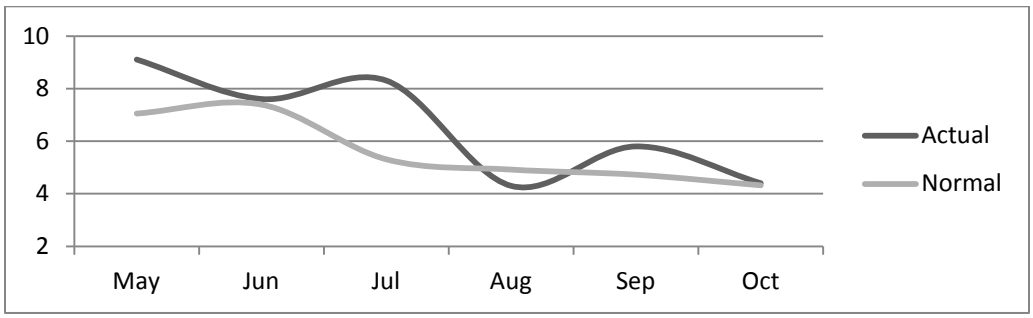


Figure 2-68: Mean ETo during 2009

During the crop season 2008, relative humidity remained normal to above normal from sowing to flowering stages and observed below normal at later boll formation and maturity stages. Whereas ETo remained normal to below normal during most of the crop life. Overall soil and air moisture content was favorable for crop growth.

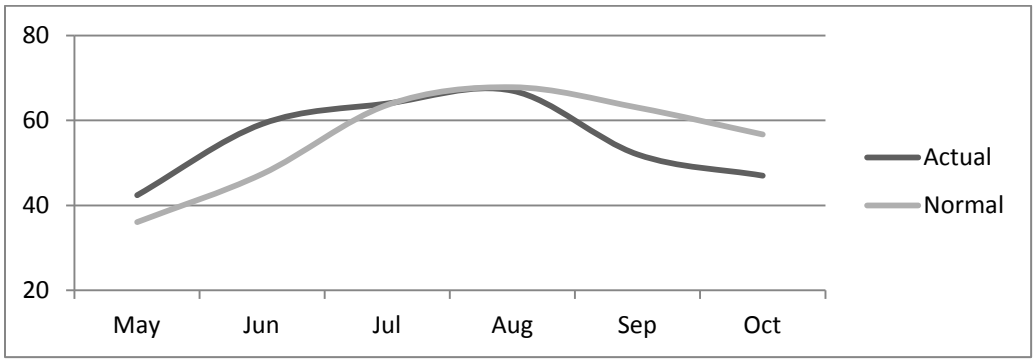


Figure 2-69: Mean RH during 2008

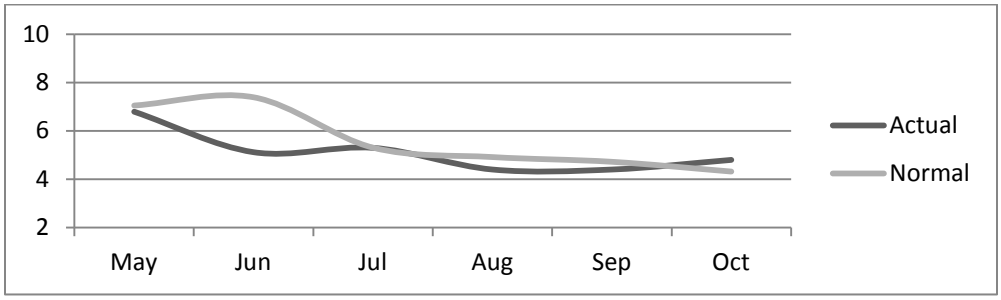


Figure 2-70: Mean ETo during 2008

During the crop season 2007, relative humidity remained normal to above normal during vegetative stages and remained normal to below normal from flowering to later maturity stages, whereas,ETo remained above normal during early growing stages, early flowering stage and later maturity stage and remained below normal during later flowering stage and boll opening stages. Overall soil and air moisture content was favorable for crop growth.

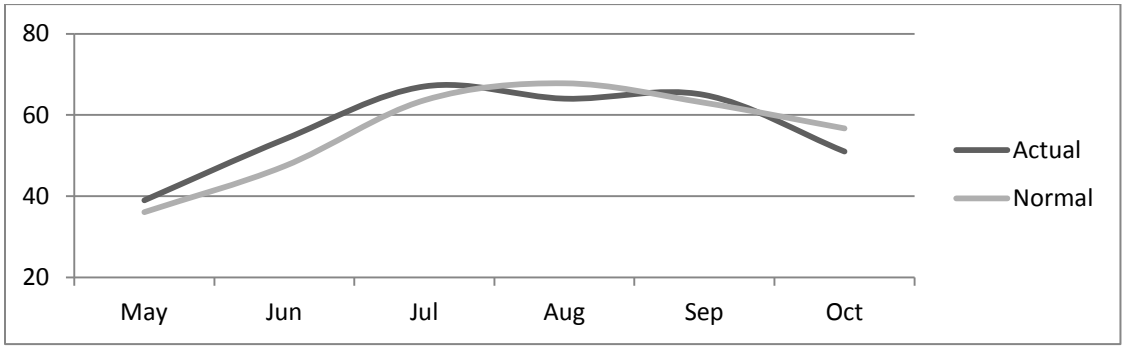


Figure 2-71: Mean RH during 2007

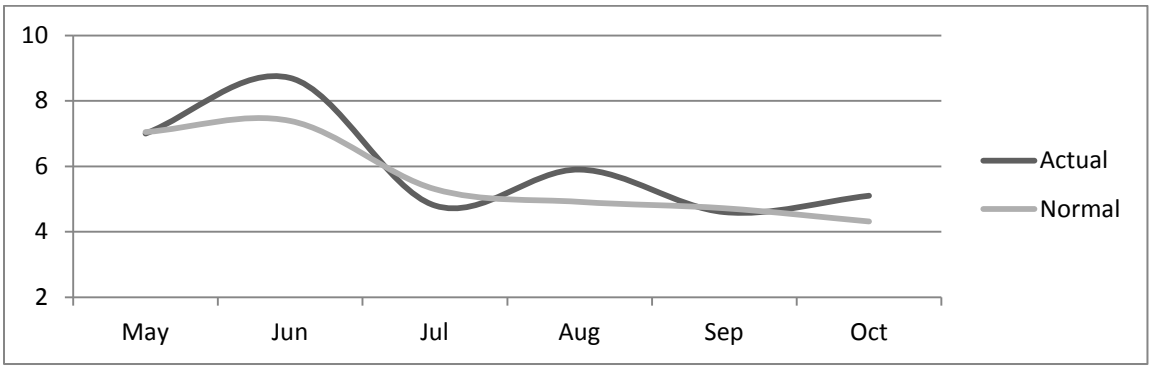


Figure 2-72: Mean ETo during 2007

2.2.9 Wind and Crop Growth during 2007-2011

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 2007-2011, no wind storm was observed. Wind speed was observed mostly normal and any significant wind speed accompanied by any severe weather event was not observed throughout this period.

2.3 Weather Parameters And their Impact on Crop Growth and Development at each Phenological Stage during Crop Period 2007-2011

2.3.1 Agrometeorological Summary of the Crop during each Phenologicalstage during the Crop Season 2011

Summary of crop cycle at each Phonological stage and weather at each phenologicalstage during the **crop season of 2011**are given below;

(i) Emergence

Emergence phase was distinguished by the appearance of cotyledons above the soil surface. When plant emergence stage was completed, the field was divided into four replications. The emergence of cotton was started in last week of May and completed on 04-06-2011. During this phase different meteorological parameters has been observed having great impact on crop. The mean relative humidity was 44% during emergence. Mean air temperature during emergence was found to be 31.6°C. 15mm rainfall was reported on first and 2nd June during the stage, which positively supported the crop growth at this early stage.No abnormal weather event was observed during the stage.

(ii) Third Leaf

In this phase the terminal bud grows between the two cotyledons, produces one true leaf and continues to grow more and more true leaves. The first two true leaves are oval shaped while the third one is spear shaped. The appearance of this leaf is known as third leaf phase. In third leaf phase, mean relative humidity was about 48% and mean air temperature ranged 34.2°C. Dry weather was reported during the phase.

(iii) Bud Formation

This phase usually form in the axil of 5th and 6th leaf. The fruit bud becomes visible to the eyes, in most cases, after the appearance of 7th leaf. The bud is in the shape of a three walled pyramid. It is lighter in color than the plant leaves. This phase is considered established when the bud is 3-5 millimeter in size. This The mean air temperature 31.9°C and mean relative humidity was 62% during this phase. This phase also faced rainfall of total amount of 125mm for 7 days.

(iv)Flowering

Cotton flowering starts from the base and progresses to the top of the plant. During this phase the mean air temperature 30.4°C and mean R.H 70% has been recorded. This phase of cotton was under heavy rainfall recorded at RAMC Faisalabad i-e 353mm, which was considered the maximum amount of rain during flowering phase. Number of rainy days recorded was 26. This rainfall produced stagnant water in the field and badly affected the crop and caused shedding of flowers.

(v) Boll opening

This phase is established when the opening of the top of the ball is one centimeter long and the cotton lint fibers are visible through the opening. The phase is considered established even when only one ball is opened. During ball opening phase, rainfall recorded 106mm for 10 days. The mean temperature of 28.8°C and mean relative humidity 64% has been observed at this stage of cotton crop.

2.3.2 Agrometeorological Summary of the Crop during each Phenological stage during the Crop Season 2010

Summary of crop cycle at each Phonological stage and weather response at the phenologicalstage of the **crop season of 2010** are given below;

i. Emergence

Mean relative humidity was 26% at the time of emergence. Mean air temperature during emergence ranged between 31 and 37°C. Soils temperature at sowing depth was around 35°C. Dry weather was reported during the stage.

ii. Third Leaf

The mean relative humidity during this phase was about 35%; mean air temperature ranged between 30°Cand 39°C. It took almost a month to reach the completion of third true leaf phase.Dry weather was observed during the stage.

Bud Formation

This is the first phase of reproductive cycle and this is sometimes confusing to differentiate between a vegetative bud and a central bud. Here, we are concerned with the central bud. The mean air temperature ranged between 27°C and37°Cand mean relative humidity was around 68%. The growth at this stage was normal. During the stage 134mm rain was recorded for 6 days.

iv. Flowering

Fcentral buds open to fcentrals and hardly take a day to be open central. This stage was mainly accomplished (up to 75% occurrence) up to end of July 2008. Mean air temperature during the phase ranged 25°C–35°C and relative humidity was 79%. Soil temperature was 32°C– 35°C.During this

important stage 414mm rain was recorded for 16 days. Maximum rainfall for a single day was recorded 92mm on 13th July. Heavy rainfall during this phase badly affected flowering stage.

v. Boll Opening

The stage was accomplished (up to 75% occurrence) up to 18-08-2008. The mean air temperature ranged between 25°C-31°C and mean relative humidity was 71%. During this period total 49 mm rain was recorded for 2 days.

2.3.3 Agrometeorological Summary of the Crop during each Phenological stage during the Crop Season 2009

Summary of crop cycle at each Phonological stage and weather at each phenological stage during the crop season of 2009 are given below;

(i) Emergence

The mean relative humidity was 30% at the time of emergence. Mean air temperature during emergence was found to be 31-37°C. Soil temperature at sowing depth was around 35.5°C.dry weather was reported during the phase.

(ii) Third Leaf

Mean relative humidity during this phase was about 34%; mean air temperature ranged between 31°C and 37°C. Rainfall amounting 5mm was reported during the stage.

(iii) Bud Formation

Mean air temperature ranged between 28°C and 35°C and mean relative humidity was around 41%. Rain amounting 29mm was reported during the stage. The growth at this stage was observed normal.

(iv) Flowering

Mean air temperature during the phase ranged 29.8°C – 30.8°Cand relative humidity was 79%. Soil temperature was ranged 38°C –36°C.Normal crop growth was observed during the stage. Whereas mean R.H was reported 56%.Rain amounting 31mm was reported during the stage.

(v) Boll Opening

The stage was accomplished (up to 75% occurrence) up to29-08-2009. The mean air temperature was ranged between 23°C- 32°C and mean relative humidity was 72%.Over all the crop growth at this stage reported satisfactory. Rain amounting 213mm for 8 days was reported during the stage.

Agrometeorological Summary of the Crop during each Phenological stage during the Crop Season 2008

Summary of crop cycle at each Phonological stage and weather response at each Phenological stage during the crop season of 2008 are given below;

(i) Emergence

The mean relative humidity was 52% at the time of emergence. Mean air temperature during emergence was found to be 32 - 35°C. Soil temperature at sowing depth was around 35.1°C.Rain amounting 32mm for 8 days was reported during the stage

(ii) Third Leaf

Mean relative humidity during this phase was about 69%, mean air temperature ranged between 27°C and 34°C. Rain amounting 47mm for 5 days was reported during the stage

(iii) Bud Formation

Mean air temperature ranged between 230°C and 35°C and mean relative humidity was around 67%. The growth at this stage was normal. Rainfall amounting290mm was reported during the stage for 9 days, which positively affected crop growth and development during this stage.

(iv) Flowering

Mean air temperature during the phase ranged 30.5°C – 33.7°Cand relative humidity was 72%. Soil temperature was 27°C – 33°C. Rainfall amounting 102mm for 7 days was reported during this phase, which brought positive impact on crop growth during the decade. But weeds were reported in abundance.

(v) Boll Opening

The stage was accomplished (up to 75% occurrence) up to the end of August. The mean air temperature was ranged between 28°C- 32°C dry weather was reported during the period.

2.3.4 Agrometeorological Summary of the Crop during each Phenological stage during the Crop Season 2007

Summary of crop cycle at each Phonological stage and weather response at each Phenological stage during the crop season of 2007 are given below;

(i) Emergence

When plant emergence stage was completed, the field was divided into four replications. The mean relative humidity was 52% at the time of emergence. Mean air temperature during emergence was found to be 28 - 33.5°C. Soil temperature at sowing depth was around 35.1°C.Dry weather was reported during the phase.

(ii) Third leaf

Mean relative humidity during this phase was about 39%; mean air temperature ranged between 32.5°C and 38°C. Rainfall amounting13mm was reported during the stage for 3 days

(iii) Bud formation

The mean air temperature ranged between 28°C and 34°C and mean relative humidity was around 41%. The growth at this stage was normal. Rainfall amounting105mm was reported during the stage for 3 days.

(iv) Flowering

This stage started from 30-06-2011and ended on 18-07-2011 as table-1 exhibit. Mean air temperature during the phase ranged 25°C – 33°C and relative humidity was 64%. Rainfall amounting130mm was reported during the stage for 6 days

(v) Boll opening

Mean air temperature was ranged between 26°C- 33°C and mean relative humidity was 66%. Total rainfall during this stage was reported 140.6mm for 3 days in August. This heavy rain/stagnant water badly affected/damaged the crop at this very sensitive stage. Dry weather was reported during the phase.

Chapter 3

3. Results and Discussion

Different recommended cotton verities were cultivated during the period 2007 to 2011.

Table 3-1: Brief Summary of Cotton crop cultivated during the period 2007-2011

Crop Season	Date of sowing and first picking	Heat units/ Total days (sowing to maturity)	Quantity of seed per acre(kg)	Fertilizer added per acre	No. of irrigations	yield per hectare (kg)	Normal to potential yield per hectare (kg)	Crop Status
MH-113 2011	24-05-2011 to 14-11-2011	4610/149	8	1 bag DAP+ 1 bag Potash Sulphate	4	1373	2024/9100	Below Normal
FH-113 2010	14-05-2010 to 25-10-2010	4311/140	8	1 bag DAP	4	1249	1937/8200	Below Normal
BT-121 2009	8-05-2009 to 31-10-2009	4642/151	10	1 bag DAP+2 Urea	4	1422	1821/7900	Below Normal
FH-113 2010	30-5-2008 to 13-11-2008	4826/149	14	1 bag DAP	3	1925	1905/6500	Above Normal
Punjab-1 2011	20-5-2007 to 2-11-2011	4372/146	14	1.5 bag DAP+2.5 Urea	3	1396	1708/6200	Below Normal

According to Table-2.1 and Chapter-2 (Materials and Method), **the crop during 2011**was cultivated in time (10May). Amount of seed cultivated per acre was sufficient for the crop. Fertilizer intake was also enough i.e. 1 bag DAP at the time of sowing and 2 bags Urea was added to the crop as split doze. Rainfall reported during the crop growth and available irrigated water did not fulfill crop water requirement at early growing stages from germination to third leaf. However 34.4mm rain for 4 days during budding stage in June decreased moisture deficiency to some extent. Deficiency of soil moisture was observed at early growing stages. But due to satisfactory rains along with irrigated water at later reproductive stages. Therefore available moisture condition favored normal crop growth. Mean daily temperature remained normal to below normal during crop life and day time temperatures observed above normal during early growing stages from planting to flowering stage and normal to below normal during most of the reproductive stages. Crop water requirement of cotton was observed mostly normal from early growing to flowering stage. Whereas it slightly rose above normal at later boll opening and maturity stages (Fig2-22 & Table 2-6). Total heat units consumed by the crop were 4565 accumulated from emergence to maturity stage in 145 days. 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 2007 recommended weedicides operations were performed in time, which also reinforced crop's growth and production. No pest or viral attack was observed on the crop during its life cycle. Optimum values/amount of meteorological and non-meteorological factors combined to normal crop growth and development. Rainfall amounting 72mm for 5 to 6 days slightly affected the crop growth at this important stage, which resultedsome loss in final yield. However in spite of this minor loss overall crop growth, production and final yield was almost normal and no significant damage/loss was reported.

The crop during 2010 was cultivated almost in time (16 May). Amount of seed cultivated per acre was sufficient for the crop. Fertilizer intake was also enough i.e. 1 bag DAP at the time of sowing and 2 bags Urea was added to the crop as split doze. Rainfall reported during the crop growth and available irrigated water fulfilled crop water requirement at satisfactory level, which is also evident from soil moisture observations during crop growth. Soil moisture remained satisfactory at major root zone during most of the crop life. However deficiency to some extent was also observed at later maturity stage in September. Rainfall especially in the month of July and August during monsoon positively supported the crop growth. Mean daily temperature and day time maximum remained mostly normal to below normal during crop life. Soil temperature observed slightly above normal during crop growth. Relative humidity was observed above normal during crop life and ETo remained below normal during most of the crop life, which kept crop water requirement in control. Total heat units consumed by the crop were 4515 accumulated from emergence to maturity stage in 135 days. This concludes that the crop consumed the required amount of heat units earlier. Normally this amount of heat units is consumed by the crop in about 145 days. This is mainly due to above normal rise in daily mean temperature observed in the month of June by 4°C during third leaf and budding stages. During2008 recommended weedicides operations were performed in time, which also reinforced crop's growth and production. Pest attack of Jassides and Aphides were observed during monsoon, which negatively affected crop growth and development and also reduced final yield. Comparatively earlier maturity and mild pest attacks reduced the final yield to some extent.

According to Table-2.1 and Chapter-2 (Materials and Method), **the crop during 2009** was cultivated in time (16 May). Amount of seed cultivated per acre was sufficient for the crop. Fertilizer intake was also enough i.e. 1 bag DAP at the time of sowing and2 bags Urea was added to the crop as split doze. Rainfall reported during the crop growth and available irrigated water did not fulfill crop water requirement completely, which is also evident from soil moisture observations during crop growth. Soil moisture remained satisfactory at major root zone. However deficiency to some extent was also observed at early growing stages, boll opening and later maturity stage. Rainfall especially in the month of August during boll opening phase for a single day damaged/affected the crop to some extent, which also reduced the yield obtained. Mean daily temperature remained normal to below normal during crop life and day time temperatures observed above normal during early growing stages from planting to flowering stage and normal to below normal during most of the reproductive stages. Therefore temperature regime mostly favored satisfactory crop growth and no abnormal rise of fall was observed during crop life. Soil temperature also observed mostly normal to above normal during early growing stages up to flowering stage. Whereas it remained normal to below normal during boll opening and maturity stages. Relative humidity was observed above normal during crop life and ETo remained below normal during most of the crop life, which kept crop water requirement in control. Total heat units consumed by the crop were 4642 accumulated from emergence to maturity stage in 151 days. No pest or viral attack was observed on the crop during its life cycle.

The crop during 2008 was cultivated in time (mid of April). Amount of seed cultivated per acre was sufficient for the crop. Fertilizer intake was also enough i.e. 1 bag DAP at the time of sowing and 2 bags Urea was added to the crop as split doze. In time irrigated water and effective rainfall during hot months from June to September thoroughly supported crop growth and fulfilled crop water requirement completely, which is also evident from soil moisture observations during crop growth. Soil moisture remained satisfactory at major root zone. However deficiency to some extent was also observed at early growing stages due to dry weather reported. Air and soil temperature regime s also supported satisfactory crop growth throughout crop life from planting to flowering stage and final maturity stages. Therefore temperature regime mostly favored satisfactory crop growth and no abnormal rise of fall was observed during crop life. Relative humidity was observed above normal during crop life and ETo remained below normal during most of the crop life, which kept crop water requirement in control. Total heat units consumed by the crop were 4826 accumulated from emergence to maturity stage in 149 days. During the crop season due to available irrigation and above normal rainfall reported at each phenological stage reinforced weeds growth and over growth of cotton plant was also observed, which slightly prolonged crop period from sowing to maturity and reduced the yield to some extent. Recommended weedicides operations were performed in time, which controlled weeds growth.. No pest or viral attack was observed on the crop during its life cycle. Optimum values/amount of meteorological and non-meteorological factors combined to normal growth and development as well as final yield.

According to Table-2.1 and Chapter-2 (Materials and Method), **the crop during 2007** was cultivated almost in time (20^{th} April). Amount of seed cultivated per acre was sufficient for the crop. Fertilizer intake was also enough i.e. 1 bag DAP at the time of sowing and 2 bags Urea was added to the crop as split doze. Rainfall reported during the crop growth and available irrigated water fulfilled crop water requirement completely, which is also evident from soil moisture and soil temperature observations during crop growth. Soil moisture remained satisfactory at major root zone. However rainfall especially in the month of August and September during boll opening, maturity stages and during picking damaged the crop. Stagnant water also affected the crop during August and September. Temperature regime of soil and atmosphere observed mostly observed below normal throughout crop life and no sharp or abnormal variation was observed in soil and air mean and day time maximum temperature. Therefore temperature regime mostly favored satisfactory crop growth. Moisture content of the atmosphere represented by relative humidity was observed above normal during crop life and ETo remained mostly below normal during most of the crop life, which kept crop water requirement in control. Total heat units consumed by the crop were 4565 accumulated from emergence to maturity stage in 145days. Optimum values/amount of meteorological and non-meteorological factors combined to satisfactory crop growth and development. However major negative impact on crop was observed in August and September due to excess of stagnant water which destroyed/damaged the crop as a result of heavy rain spells during monsoon reported consistently from the end of August till the mid of September.

3.1. Conclusion

It is thus concluded that wheat crop growth, development and final yield during Kharif crop period 2007 to 2011 was affected both positively and negatively as result of crop to crop variation in the following meteorological and non-meteorological factors. Supply of irrigation water, timing and amount of rainfall, in time and required amount of fertilizer doze, day time temperature, weeds removing operations, in time use of pesticides, pre-sowing practices on field and so on. Irrigation

water was added 3 to 5 times, which satisfied most of the crops water requirement along with rain water during monsoon season. But the crop cultivated during 2007 and 2008 suffered moisture deficiency to some extent due to deficiency of soil moisture at some stages. Heavy rain spells damaged or negatively affected the crop growth and consequently final yield during 2007, 2009 and 2011.It is also interesting to note that consistent rains along with three irrigations during 2010 produced excess of weeds and above normal height of the plant, which also affected the yield obtained during 2010.Two of the five crops during 2010 and 2011 were planted earlier in April. But it did not produce any positive impact regarding crop water requirement or crop yield. Crop water requirement ranged 545mm to 696mm. Maximum CWR was recorded 696mm in 2010, followed by 626mm in 2008, 599mm in 2007 and 596mm in 2011.Heat units or growing degree days consumed by the crops during the period 2007 to 2011 ranged from 4311 to 4826. On average the crops consumed 4552 heat units in 147 days. On average per day consumption by crops is about 31 heat units.

3.2. Recommendations and Suggestions

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, fewer fcentrals, 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 full 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 weeds growth. Due to which crop stages take more time for completion and number of fcentrals 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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