An Analysis of Weather and Cotton Crop Development in Central Punjab (Faisalabad) (2014)

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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; 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 2014. Beside this some other factors e.g. time of sowing, fertilizer intake, insecticides, weeds removing operations and supplied irrigated water have also been studied. The crop accumulated 3479 heat units in 159 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 the data collected at the 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

1. Introduction

This study is based upon field observations of cotton crop by Regional Agrometeorological Center Faisalabad, cultivated in the experimental field of Plant Physiological section of AARI Faisalabad during the Kharif season2014. The study permits the cotton MNH-886. 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 Central Punjab (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. 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 Pakhtunkhwa, 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 Balochistan is 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 Ayub Agricultural Research Institute Faisalabad in central Punjab. The latitude and longitude of RAMC Faisalabad are 31.43ºN and 73.06ºE 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 [3]. The probability of heavy rainfall events is also increasing in the main monsoon region of Punjab province [4]. 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 season occurs in the month of July, followed by August. Day time mean maximum and night time mean minimum temperatures gradually increase from May to June and then gradually decrease till October during Kharif Season.

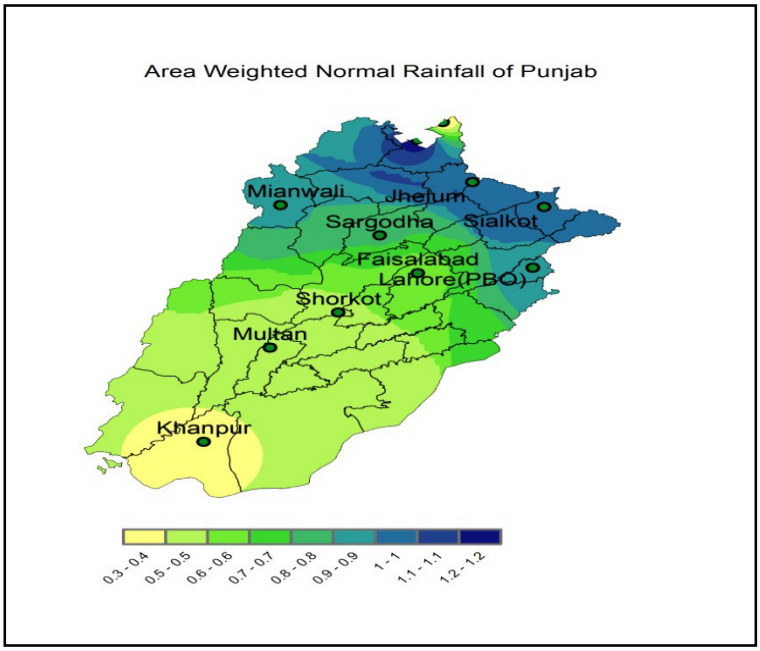

Figure 1-1: **Area weighted Normal Annual Rainfall (mm) of Punjab**

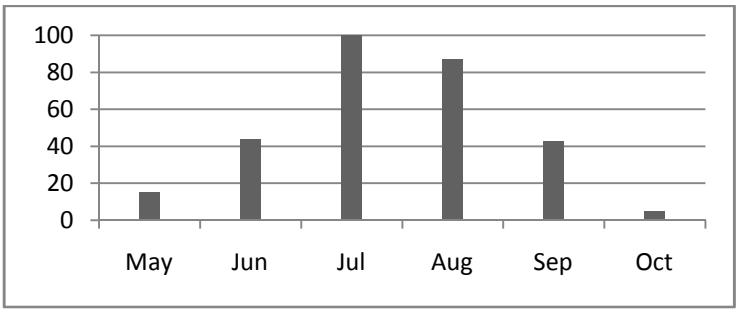

Figure 1-2: Monthly Mean Annual Rainfall (mm) of Faisalabad

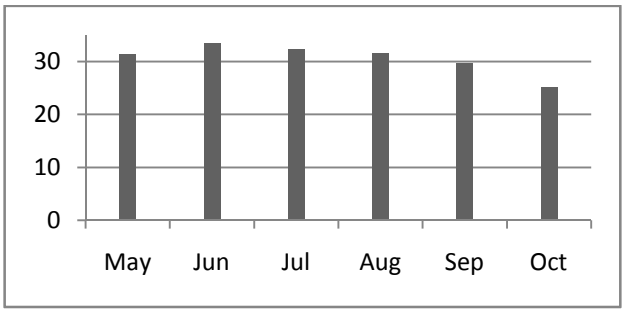

Figure 1-3: Mean daily Maximum and Minimum Temperature (ºC) of Faisalabad during Kharif Season

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 precipitation causes 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 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 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 [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 to55% 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 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. 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

2. Materials and Method

This study is based upon field observations of recommended varieties of cotton crop planted in the experimental field of Plant Physiological section of AARI (Ayub Agricultural Research Institute) Faisalabad during the Kharif seasons 2014.

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 [8].

2.1.1. Phenological Stages of Cotton Crop

Growth period of cotton crop consists of the following phenological 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 appearance of 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 3^{rd} or 4^{th} leaf). The fruit bud becomes visible to the eye, in most cases after the appearance of the 5^{th} 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 flower lasts only one day. Therefore when counting the plants in flowering, it is necessary to include the bushes bearing the first open flower and those with flower already wilted. The bud unfolded in the morning and the flower is already wilted by the evening. When the flowers 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 [9].

Table2-2 Date-wise occurrence of Phenological Stages 2014

Stage	Date
Sowing	23-04-2014
Emergence	26-04-2014 to 05-05-2014
Third leaf	06-05-2014 to 23-05-2014
Budding	24-05-2014 to 13-06-2014
Flowering	14-06-2014 to 20-07-2014
Boll opening	21-07-2014 to 31-08-2014
Maturity	01-09-2014 to 30-09-2014
First picking	01-10-2014

2.1.2. Phenological Observations in the field station for Cotton Crop at AARI, Faisalabad

Generally the field selected for Phenological observations should be of one hector size and divided into four 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-Meteorological Parameters and their Impact on the Crop Growth 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 are studied/analyzed in the following manner.

2.2.1. Rainfall and Cotton Crop Growth during Kharif Season 2014 in Faisalabad

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 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 addition rainfall also provides clean environmental conditions to support optimum photoperiodic activity for better biomass and grain yield [10].

During the crop season, above normal precipitation was recorded only in May and September. In September precipitation amount to 209 mm which was largely above normal (1981-2010). This is due to a very heavy spell at the start of the month. All other months of the season received below normal rainfall. Overall the precipitation remained above normal during the kharif season 2014 at RAMC, Faisalabad.

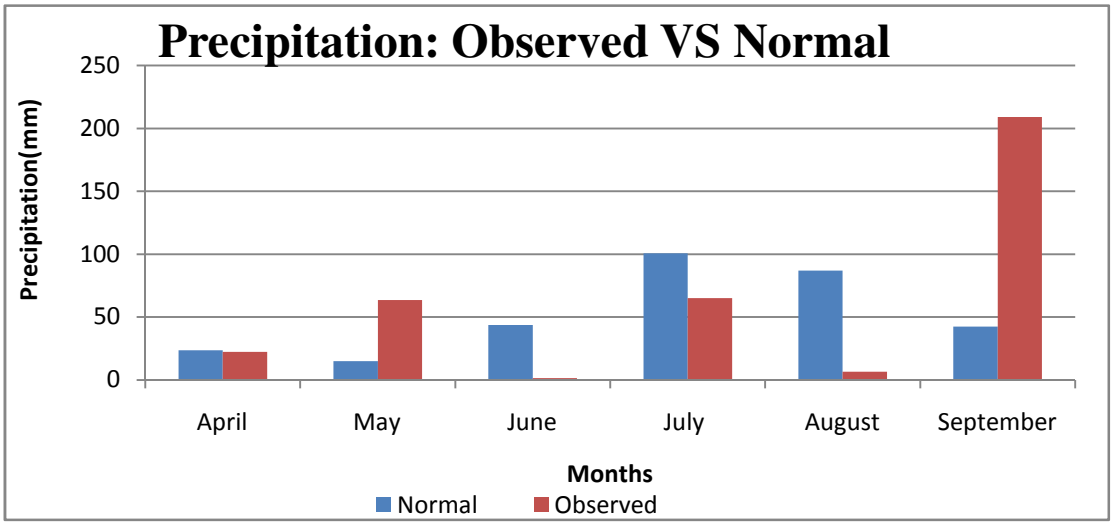

Figure 2-5: Rainfall during Kharif Season 2014

2.2.2. Irrigated Water during Crop Growth

During kharif season 2014, irrigated water was added to the field 11 times; first irrigation was done 11 days after sowing during third true leaf stage. Remaining irrigations were done during other phenological stages at the time of need. Below normal rains from June to August increase the need for irrigated water.

2.2.3. Air Temperature and Cotton Crop Growth during Crop Seasons 2014

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 [11].

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

During the crop season 2014, both mean daily temperature and day time maximum temperature observed below normal during most of the crop life except for the months of June and August when temperature rises slightly above normal.

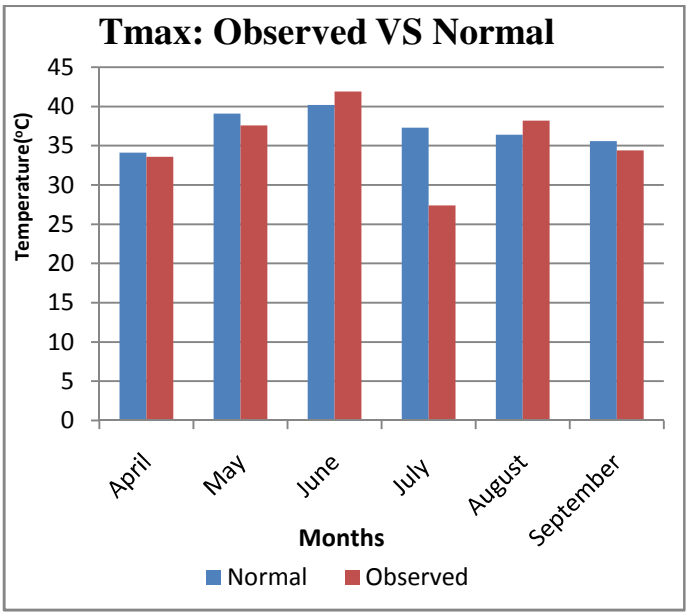

Figure 2-6: Mean Maximum Temperature during 2014

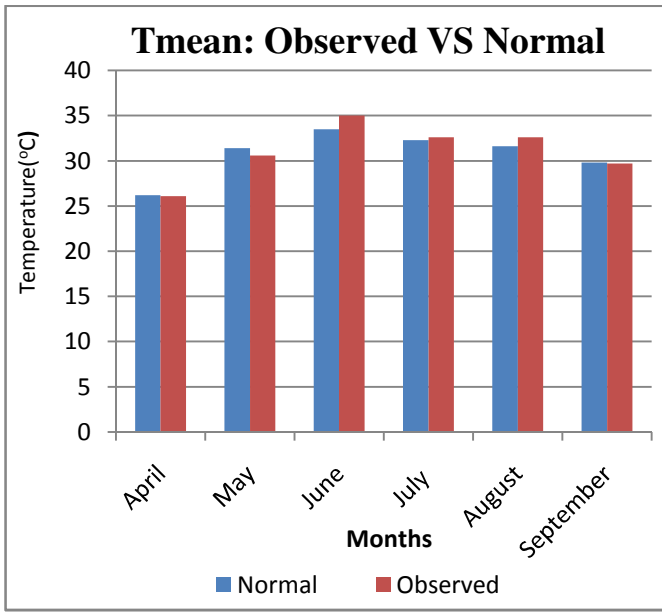

Figure 2-7: Mean Monthly Temperature during 2014

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. Highest amount is needed during flowering/boll opening stage followed by maturity and early vegetative stages [12].

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 2014, 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. Overall condition of soil moisture was satisfactory due to satisfactory availability of irrigated water during crucial stages.

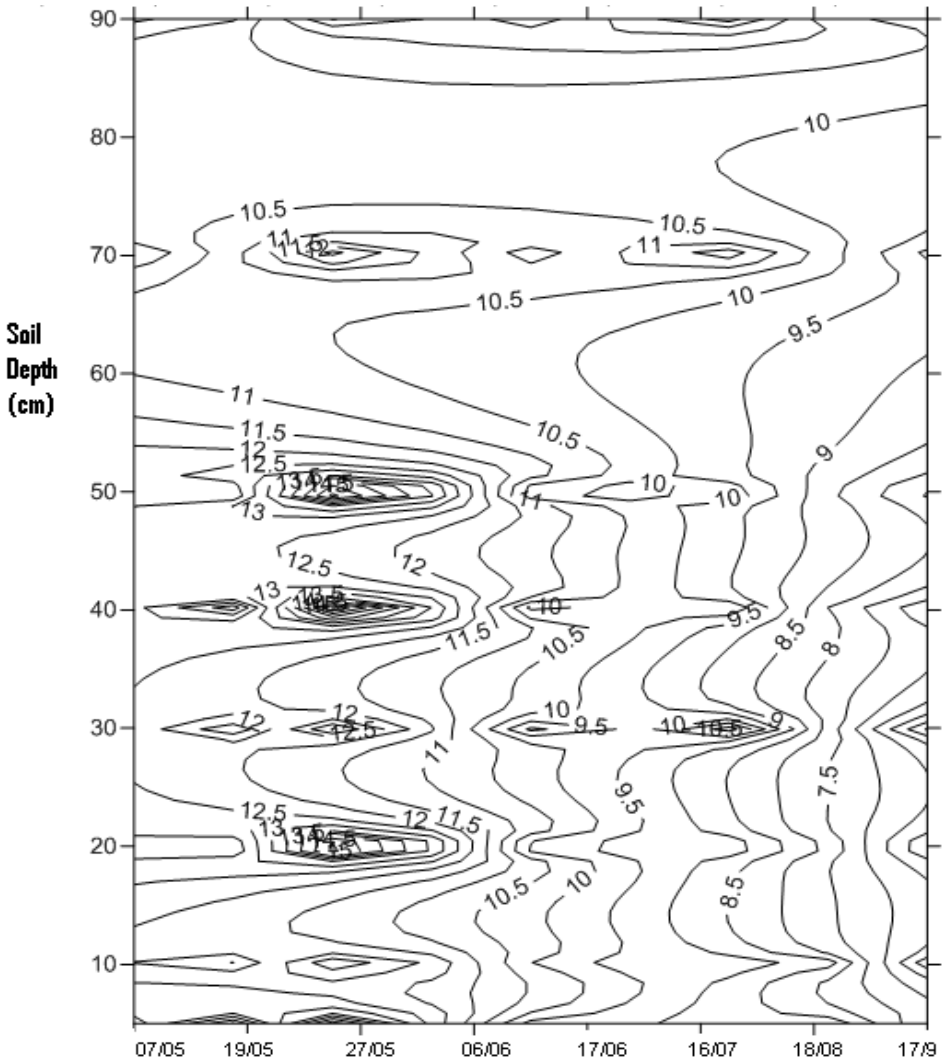

Figure 2-8: Soil moisture chrono-Isopleths for Kharif Crop at Faisalabad for the year 2014

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 [13].

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 soil. 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 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 2014, soil temperature was highest during June at all depths except at the deep layer of 100 cm which was warmer in July and August while soil temperature dropped in September.

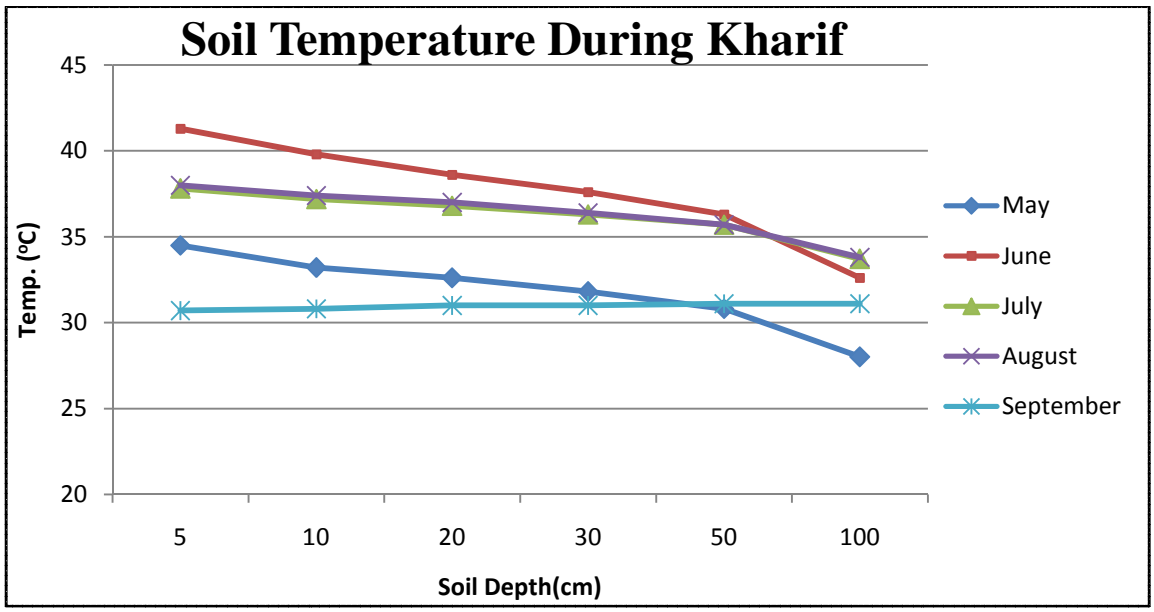

Figure 2.9: Soil Moisture at different depth during Kharif season 2014

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 unit's 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.

$$H.U = \sum T;\ \text{T is mean daily Temperature}$$
$$H.U = 0:$$

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:

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

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

2.2.6.2. Heat Units Consumption During 2014

Inter phase period for cotton crop during the crop season 2014 and corresponding heat units at Faisalabad observed at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 3479 accumulated from Germination to Boll formation stages in 159 days.

Table 2-3: Heat Units Accumulation for the Crop during 2014

Inter-phase	Inter-phase duration	Heat units
Date of Sowing	23-04-2014	
Emergence	10	216
Third True leaf	19	330
Budding	21	520
Flowering	37	877
Boll Opening	42	945
Maturity	30	591
Total (Sowing to Maturity)	**159**	**3479**

2.2.7. Relative humidity and Reference Crop Evapotranspiration, ETo (mm/day) during crop growth

During the crop season 2014, relative humidity remained below normal during the whole crop season; it follows almost the same trend as that of normal values pattern except for August when it drops further because of very little rain during the month. ETo also remained below normal during the whole growing period. Overall soil and air moisture content was satisfactory for crop growth.

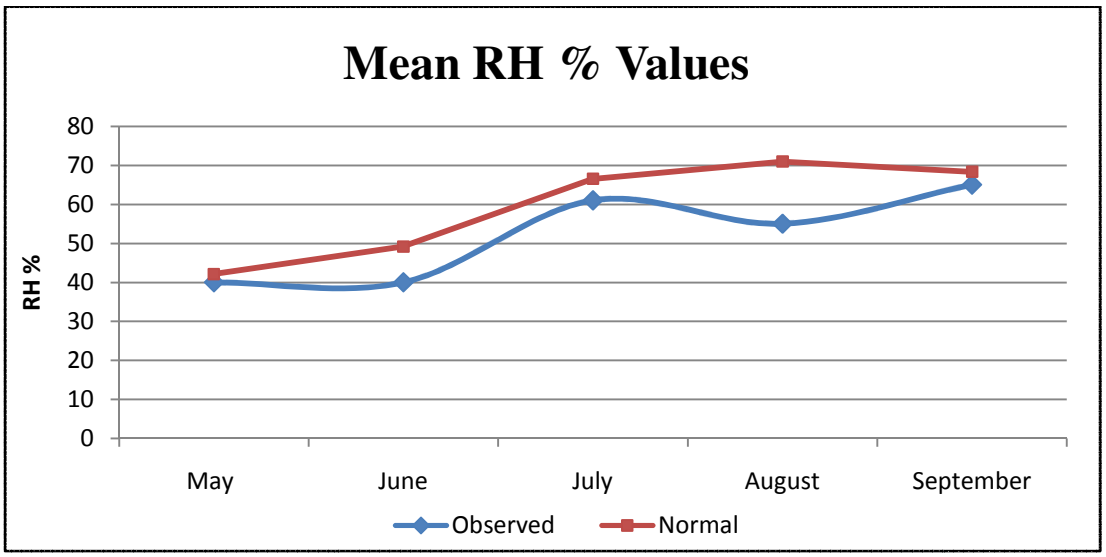

Figure 2-10: Mean RH during 2014

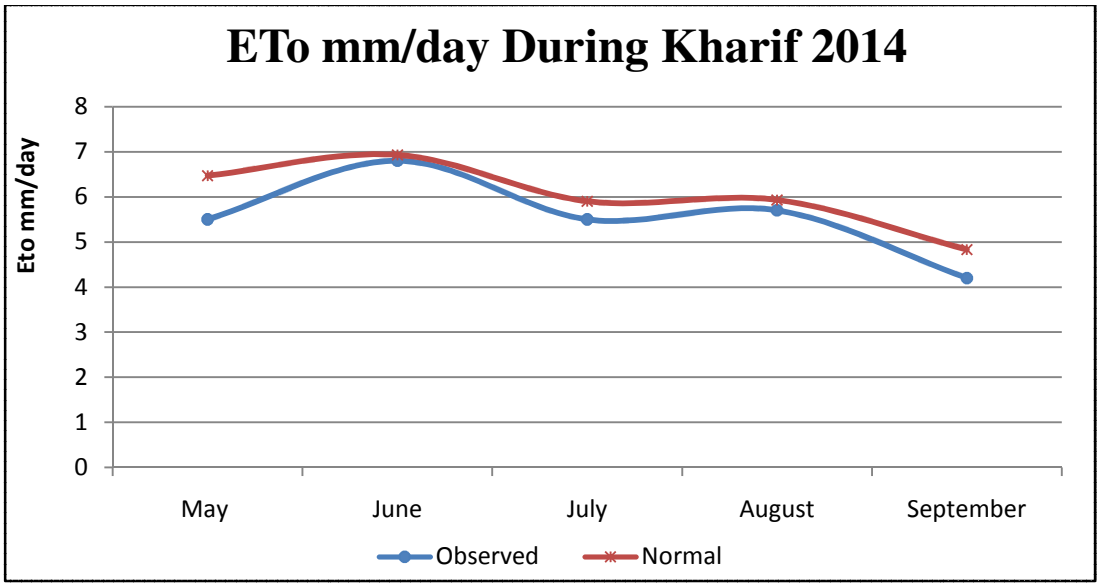

Figure 2-11: Mean ETo during 2014

2.2.8. Wind and Crop Growth during 2014

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 2014, a severe wind storm was observed on 12th and 13th of May. Wind gust was observed ranging from 45 kt to 60 kt during the two days. Wind remains mostly normal during the most of the crop period.

2.3 Weather Parameters and their Impact on Crop Growth and Development at each Phenological Stage during Crop Period 2014

2.3.1 Agrometeorological Summary of the Crop during each Phenological stage during the Crop Season 2014

Summary of crop cycle at each Phonological stage and weather at each phonological stage during the crop season 2014 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 April and completed on 05-05-2014. During this phase different meteorological parameters has been observed having great impact on crop. The mean relative humidity was 30% during emergence. No abnormal weather event was observed during the stage. No rain was reported during this phase while mean temperature ranges from 28.8 to 34.7^{o}C.

(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 40%. An amount of 31.5mm of rain was recorded during this phase. Temperature range was between 28.4 to 32.6 ^{o}C.

(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. Mean relative humidity was 29% during this phase while mean temperature range was 31.0-35.6 °C. No rain was observed during this phase.

(iv) Flowering

Cotton flowering starts from the base and progresses to the top of the plant. During this phase mean R.H was recorded to be 46%. Only 1.6mm of rainfall was recorded at RAMC Faisalabad during flowering phase. Mean daily temperature range was from 30.6 to 38.0 ^{o}C.

(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 to be 48.2mm. The mean temperature range was 25.2 to 35.0 ^{o}C and mean relative humidity of 60% was observed during this stage of cotton crop.

3. Results and Discussion

Table 3-1: Brief Summary of Cotton crop cultivated during the period 2014

Crop Variety, Season	Date of sowing and first picking	Heat units/ Total days (sowing to maturity)	Quantity of seed per acre(kg)	Row Spacing	Fertilizer added per acre	Pesticides used	No. of irrigations	yield per hectare (kg)	Crop Status
MNH-886 Kharif 2014	23-04-2014 to 01-10-2014	3479/159	8	75cm	DAP 1 bag+Urea 2 bag	Polo 200ml Comfedor 250ml	11	800	Normal

According to Table-2.1 and Chapter-2 (Materials and Method), the crop during 2014 was cultivated in time (23rd 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 fulfill crop water requirement. However 20.2mm rain during budding stage decreased moisture deficiency to some extent. Due to satisfactory rains along with irrigated water at later reproductive stages, 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 to below normal during early growing stages from planting to flowering stage and normal to above normal during later 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. Total heat units consumed by the crop were 3479 accumulated from emergence to maturity stage in 159 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. 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.

3.1. Conclusion

It is thus concluded that cotton crop growth, development and final yield during Kharif crop period 2014 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, all these factors influences the growth and development and hence the final yield of the crop.. Irrigation water was added satisfied most of the crops water requirement along with rain water during monsoon season. Excess of weeds at the early growing period effect the growth of plants negatively.

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, 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 in the month of May.

2– Cotton plant water requirement is maximum during flowering, 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 variability. Pakistan has also been 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 select 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 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 and should not be ignored.

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