

Crop Development in Lower Sindh (Tandojam) (2015)



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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; on plant growth and development during each phenological stage and final yield of cotton crop. For this purpose both meteorological and phenological observation along with soil data have been monitored at different phenological stages of cotton crop, cultivated in the field of plant Physiology Section of Agricultural Research Institute Tandojam (Lower Sindh) during the Kharif Season 2015. 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 4818 heat units in 149 days during its life cycle from emergence to maturity. Water requirement was fulfilled through flood irrigation onward from early growth up to maturity stage. Due to mostly suitable meteorological and non-meteorological factors, like rainfall, air temperature, irrigated water, seed and fertilizer intake to the field, weed removing operations etc. affected positively crop growth and development, resulting above normal yield was achieved. This study is based upon one crop data of one cultivar. Therefore 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 Tandojam and other cotton growing areas of lower Sindh.

Chapter 1

INTRODUCTION

Cotton crop is the major crop as well as one of the main agricultural products in Pakistan. This study is based upon field observations of Cotton crop at Regional Agro meteorological Centre, Tandojam cultivated in the experimental field of Agriculture research Institute, Tandojam. Land at the study site consists of agriculture fields rotated among wheat, rice, cotton and many other seasonal crops. In experimental field Cotton crop variety Sindh-I was cultivated. This study will help in understanding the effect of different climatic parameters on the growth and yield of cotton crop in lower Sindh region.

1.1 Geographical Description and Climate of Pakistan and Lower Sindh (Study Area)

Pakistan has a variable climate, ranging from arid (33-254 mm annual rainfall) in the south to humid (1016-2032 mm per year), sub-humid (508-1016 mm per year) and semi-arid (254-508 mm per year) in the north. The river Indus that originates in the north with its tributaries irrigates the great plain of the country. The area to the left of Indus is much affected by the neighboring arid and hot Rajasthan desert [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. 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 Pakhtunkhuan, where heavy 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 lower than potential evapotranspiration and crop production is not possible without irrigation. Most of the rainfall is received during summer monsoon period and meager rain occurs due to rare westerly waves that extend to the southern parts of the country. The lower parts of Sindh are slightly cooler and more humid than upper parts due to Arabian Sea.

Regional Agromet Center (RAMC) is situated in the Plant Physiological Section of Agricultural Research Center Tandojam, located in the lower parts of Sindh, 20 km way from Hyderabad city on Mirpurkhas-Hyderabad highway. The latitude and longitude of RAMC Tandojam are 25-40° and 68-43° respectively. Total annual rainfall in lower Sindh ranges 145-155 mm (145 mm in Tandojam), 75% of this is received during summer monsoon period July-Sep) and meager rain occurs due to rare westerly waves which pass across lower parts of the country in winter. Temperature ranges cool to cold in winter and hot to very hot during summer. More detail about

the climate of Tandojam is located in the following Figures (1-1 to 1-3), which clearly indicates that highest amount of rainfall occurs during Monsoon / Kharif season in the month of August, followed by July. Whereas lowest amount occurs during Rabi season in January, followed by December and November. Day time mean maximum and mean minimum temperature gradually increase from May to June and then gradually decrease till October during Kharif Season [3].

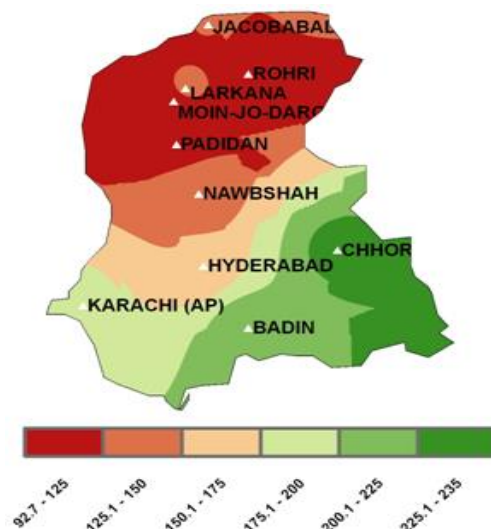


Figure 1.1: Mean Annual Rainfall (mm) of Sindh [Normal (1981-2010)]

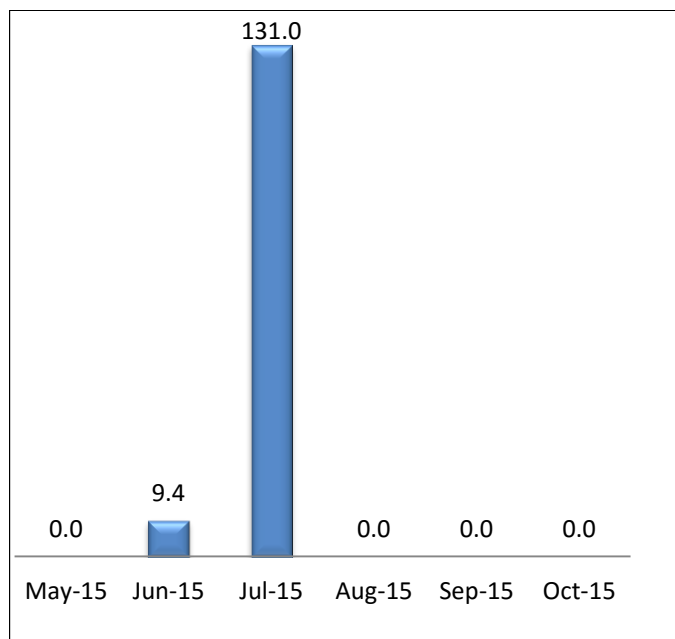


Figure 1.2: Monthly Mean Annual Rainfall (mm) of Tandojam during Kharif Season.

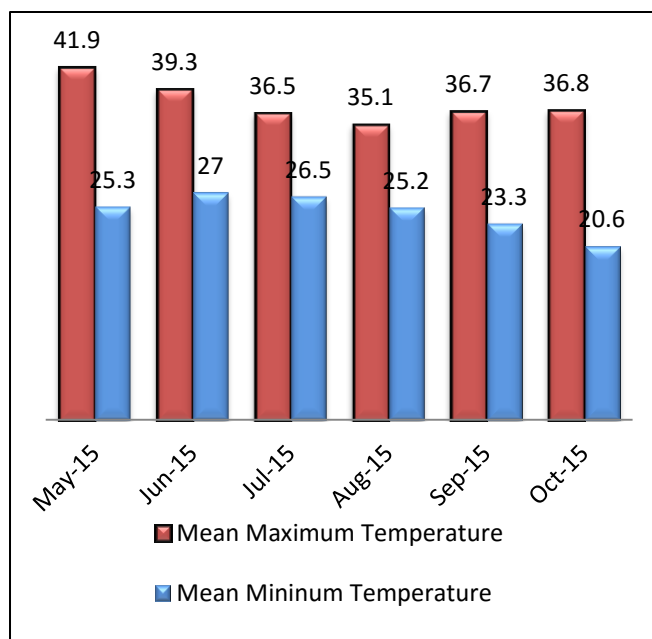


Figure 1.3: Mean daily Maximum and Minimum Temperature (°C) of Tandojam during Kharif Season

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, especially in the sense of rainfall. Therefore every year variation in the spatial and temporal distribution of rainfall causes changes in the amount of available water for irrigated agricultural regions, which consequently bring up and down in the annual yield of cotton. Sometime heavy rains along with persistent cloudy/humid conditions during monsoon season trigger to viral/pest attacks on cotton crop and also cause rapid conditions weeds in the fields and prolongs this crop period, which causes delay in sowing of next Kharif crop. Rain just after sowing, causes decrease in the number of germinated cotton seeds. Heavy rains and stagnant water during monsoon may damage the crop. Abnormal rise in day time temperature due to climatic variability or late sowing raises crop water requirement at a particular phase and also causes 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 analyze and study the impact of various meteorological parameters on crop growth and development.
- To investigate the water satisfaction sensitivity of crop in Tandojam region.
- To develop the relationship between weather parameters, crops life cycle and yield obtained.
- To determine the onset of pests and diseases related to weather elements.
- To get a step forward for formulation of yield estimation.

1.4 Review of Agriculture Production in Pakistan

Pakistan is an agrarian country whose population and economy directly or indirectly (70% directly and 16% indirectly) depends upon agriculture. Agriculture is the mainstay of Pakistan's economy. It accounts for 21% of the GDP and together with agro-based products fetches 80% of the country's total export earnings. More than 43.7% of the labor force is engaged in this sector. [4] The crops is most vibrant sub-sector of agriculture, it consist of 39.6% of agriculture and 8.3% of GDP. Therefore any change in agricultural productivity creates 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. [4]

The Economic development of Sindh largely depends on the progress and growth of Agriculture Sector. The province contributes significantly towards overall national agriculture production in major crops: 32% in National Rice production, 24% in National Sugarcane production, 12% in National wheat production and 21% in National Cotton production.[5]

1.5 Cotton Production in Pakistan and Sindh.

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 of cotton crops has been increased significantly in the last 30 years around 2.25 million hectares in 1990-1991 as compared to 3.054 million hectares in 2007-08 (Agri. Statics of Pakistan). Proper supply of water in feeder Canal in Balochistan and Chashma Right Bank at D.I Khan (KPK) also played a vital role in boosting crop cultivated area. In Sindh, lower parts dominate in cotton production. District Badin dominates in district wise cotton production. In 2008, 2730500 tones cotton was produced, whereas total production of Sindh was 13330300 tones. The most productive districts include Badin, Thatta, Nawabshah, Naushahroferoze, and Mirpurkhas.

The present study was conducted during Kharif Season in 2015 in the experimental farm of plant physiology ARI Tandojam Sindh of crop variety Sindh-I. The study will provide a base to estimate the optimum ranges of various meteorological parameters for getting higher yields of the particular crop variety, grown under different Agro-climatic conditions.

Crop water requirement of cotton in Pakistan varies from 627 mm to 1161 mm, which is maximum in the hot and arid agriculture zone of Sindh [6]. As discussed above, the total annual rainfall in lower Sindh including Tandojam region is much lower than the cotton crop water demand. Therefore it is evident that cotton crop growth is mostly dependent upon irrigated water of Indus canal system in the lower Sindh.

Chapter 2

MATERIALS AND METHOD

The Cotton crop variety Sindh-I was cultivated at Regional Agro meteorological Center, Tandojam in lower Sindh during Kharif season 2015. Both the meteorological and crop phenological data were recorded during the crop season. In order to compile the data of each development stage, careful, precise and timely recording of the following parameters (table 2.1) were undertaken at 0300, 0900 and 1200 (UTC) as routine practice.

Table 2.1: Observed Meteorological Parameters

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

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

2.1. Phenology

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

Table 2.2: Phenological Stages of Cotton Crop 2015

	Phenological stage	Date
1.	Sowing	13-05-2015
2.	Germination.	17-05-2015 to 21-05-2015
3.	Emergence	22-05-2015 to 29-05-2015
4.	Third True Leaf	30-05-2015 to 20-06-2015
5.	Budding	21-06-2015 to 14-07-2015
6.	Flowering	15-07-2015 to 01-08-2015
7.	Boll Opening	02-08-2015 to 08-09-2015
8.	Maturity	09-09-2015 to 15-10-2015
9.	Harvesting.	16-10-2015

2.1.1. Phenological Observations

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

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

2.2. Methodology

In this study the impact of different meteorological/non-meteorological parameters in comparison with the normal (1991-2010), including soil temperature and soil moisture, amount of seed per acre cultivated, time of sowing, fertilizer intake, number and timing of irrigation water added and pest attack/pesticide used over crop growth, development and final yield are discussed.

Chapter 3

RESULTS AND DISCUSSION

In this chapter, variations in meteorological and non-meteorological parameters and their impact on the Cotton crop is analyzed along with a brief summary of whole Cotton crop's life cycle. Normally the Cotton crop takes 125-145 days to get fully mature. The crop is cultivated in the end of April up to the mid of May. In order to investigate the chief causes about variation in the crop's growth, development and yield related to varying weather conditions and some other factors during each phenological stages of cotton crop, different meteorological parameters are studied as well.

Table 3.1: Brief Summary of the Cotton Crop

1	Field Size	4 Kanal
2	Crop variety	Cotton Sindh-1
3	Date of Sowing	13-05-2015
4	Information about any disease /pest attack	Milli Bugs
5	Pesticides and weedicides details.	Senitox
6	Quantity of seed per Acre.	50kg
7	Row spacing	2.5ft or 75cms
8	Schedule and quantity of supplied does of fertilizer	1.5 bag of DAP/at sowing 1 bag Urea at first irrigation, 1 bag Urea at third irrigation
9	Type of irrigation	Tube well+ Irrigation water
10	Irrigation schedule	1 st : 17-05-2015, 2 nd : 21-05-2015, 3 rd : 27-05-2015, 4 th : 09-06-2015, 5 th : 28-06-2015, 6 th : 11-07-2015, 7 th : 12-08-2015, 8 th : 24-08-2015
11	Heat units consumed from sowing to full maturity	4818
12	Total days taken by the crop from sowing full maturity.	149
13	Date of harvesting.	16-10-2015
14	Actual/potential yield.	1200 /1400 kg /Acre

3.1 Rainfall and Cotton Crop Growth

Rainfall is one of the most important factors that affect annual cotton production in Pakistan. Tandojam and its surrounding areas of lower Sindh get most of its total annual rainfall (more than 80%) 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 optimum photoperiodic activity for better biomass and grain yield. [3]

During the crop season 2015, Hot and dry weather in May and 9 mm rainfall reported in month of June only for a single day, and rainfall amounting 131 mm was reported for 07 days in July. However, mostly dry weather was reported in August September and 10mm was reported in October. The rainfall reported for 07 days in July, during flowering stage which became beneficial for the crop. Over all crop remained quit better.

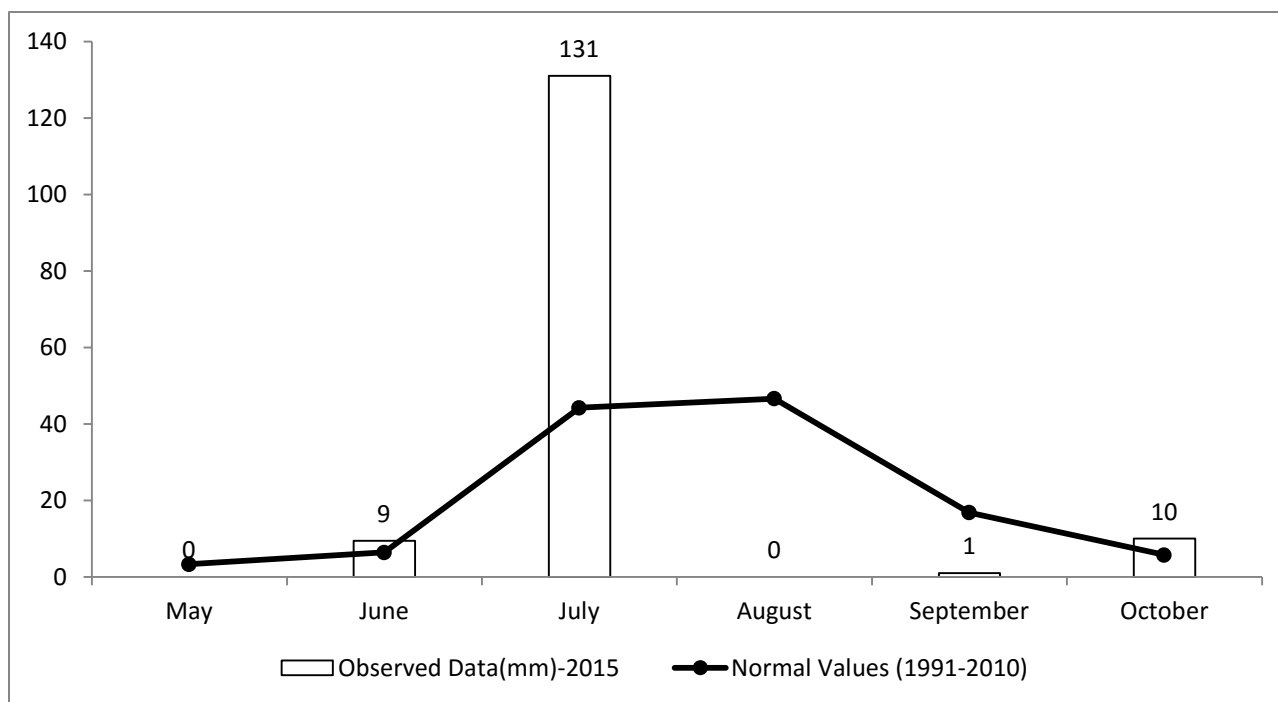


Figure 3.1: Comparison of Monthly observed rainfall with Normal (1991-2010) at Tandojam during Kharif season 2015

3.2 Irrigation during Crop Growth

The Cotton crop was irrigated three times during the entire season before full maturity. First irrigation was made to the Cotton crop 04 days after sowing. During the third Leaf stage, second and third irrigation was given. 4th, 5th and 6th irrigation were given during the Budding stage. 7th and 8th irrigation were given during Boll Opening stage.

3.3 Air Temperature and Cotton Crop Growth

Air temperature is also one of the most important climatic variables that affect plant life. Plants growth is restricted to certain limits of air temperature. The main dry matter process i.e., photosynthesis is also temperature dependant.

The growth and maturity of cotton crop is disturbed at times by up down 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 of 2015, mean daily and day time minimum temperature remained mostly normal throughout the crop life cycle which favored satisfactory crop growth.

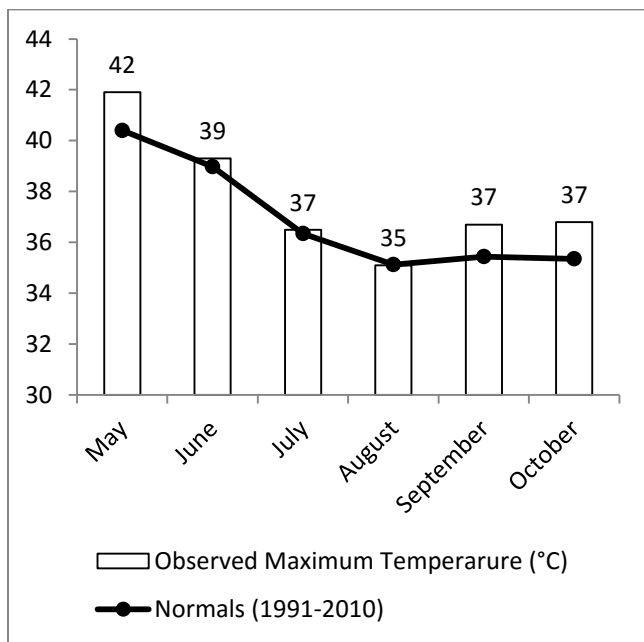


Figure 3.2: Mean daily Maximum Temperature (°C) of Tandojam during Kharif Season

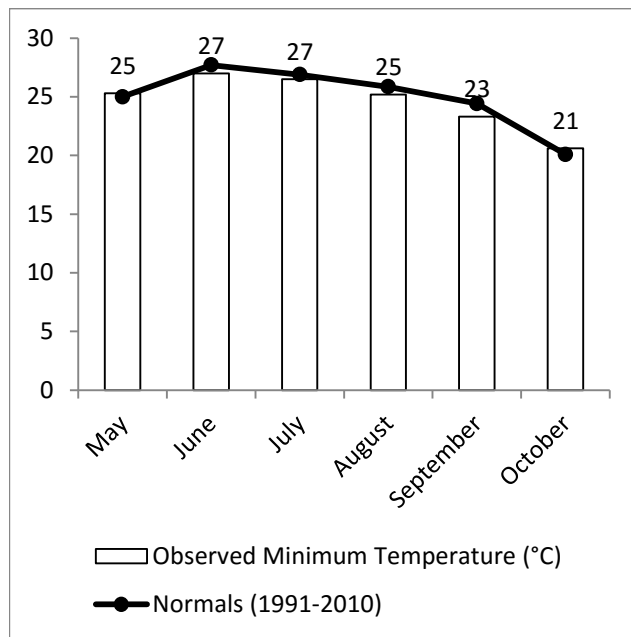


Figure 3.3: Mean daily Minimum Temperature (°C) of Tandojam during Kharif Season

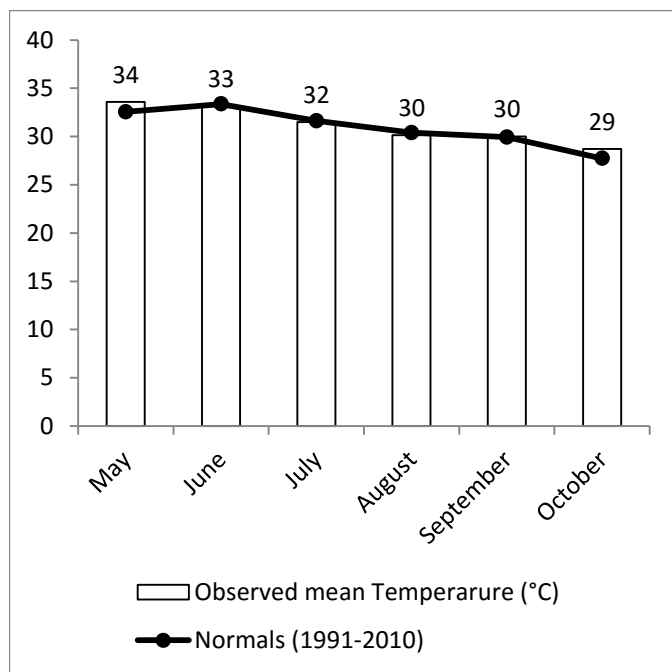


Figure 3.4: Mean Monthly Temperature during 2015

Table3.2: Mean Monthly Temperature during Kharif Season 2015

Month	Mean Monthly (°C)	Monthly Mean Max.(°C)	Monthly Mean Min(°C)	Absolute Max. (°C)	Absolute Min. (°C)
MAY-2015	33.6	41.9	25.3	47.0	21.0
JUNE-2015	33.2	39.3	27.0	42.5	23.5
JULY-2015	31.5	36.5	26.5	39.5	23.0
AGUUST-2015	30.2	35.1	25.2	37.0	24.0
SEPTEMBER-2015	30.0	36.7	23.3	39.0	20.0
OCTOBER-2015	28.7	36.8	20.6	41.0	13.5

3.4 Soil Moisture Observations during Crop Growth

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

To calculate soil moisture, soil samples are taken on 7th, 17th and 27th of each month in four replications at 5, 10, 20, 30, 40, 50, 70, 90 and 110cm depths with the help of auger. However in case of any anomalous event on the specific date, the sample can also be taken on the next day. Soil sample is then weighed and dried in the oven for about 8 hours. The dried sample is weighed again and moisture present in the soil is then calculated by the difference of weight between wet and dry samples as illustrated below:

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

Moisture contents of the soil varied due to dry and wet spells throughout the season. After each effective irrigation or rain the moisture level increased in the shallow layers as compared to deep layers of the soil.

During the crop season 2015, from the observed soil moisture data, depicts that soil moisture remained unsatisfactory during early stages due to rising temperature and dry weather in May, during flowering stage in July due to mostly dry and hot weather and during maturity stage in October. Throughout the crop life soil moisture remained more satisfactory in intermediate or major root zone and deep layers; it remained slightly deficit in shallow layers due to sensible heating of direct solar radiation. Overall condition of soil moisture was satisfactory due to satisfactory availability of irrigated water during crucial stages. However dry and hot weather at crucial stages affected crop growth to some extent especially during the most demanding phases (flowering, maturity and early growing stages).

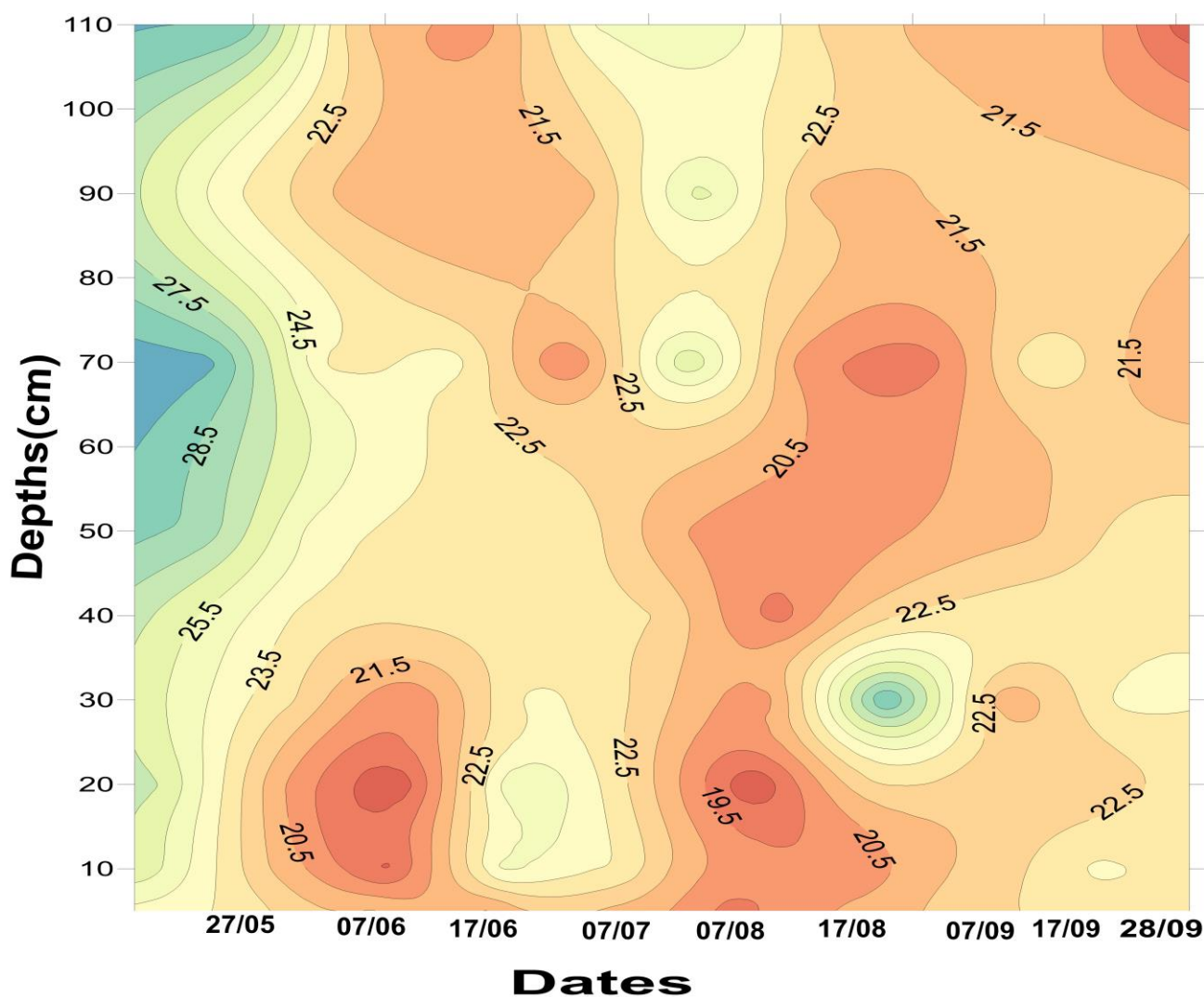


Figure 3.5: Soil moisture chrono Isopleths for Kharif Crop at Tandojam for the year 2015

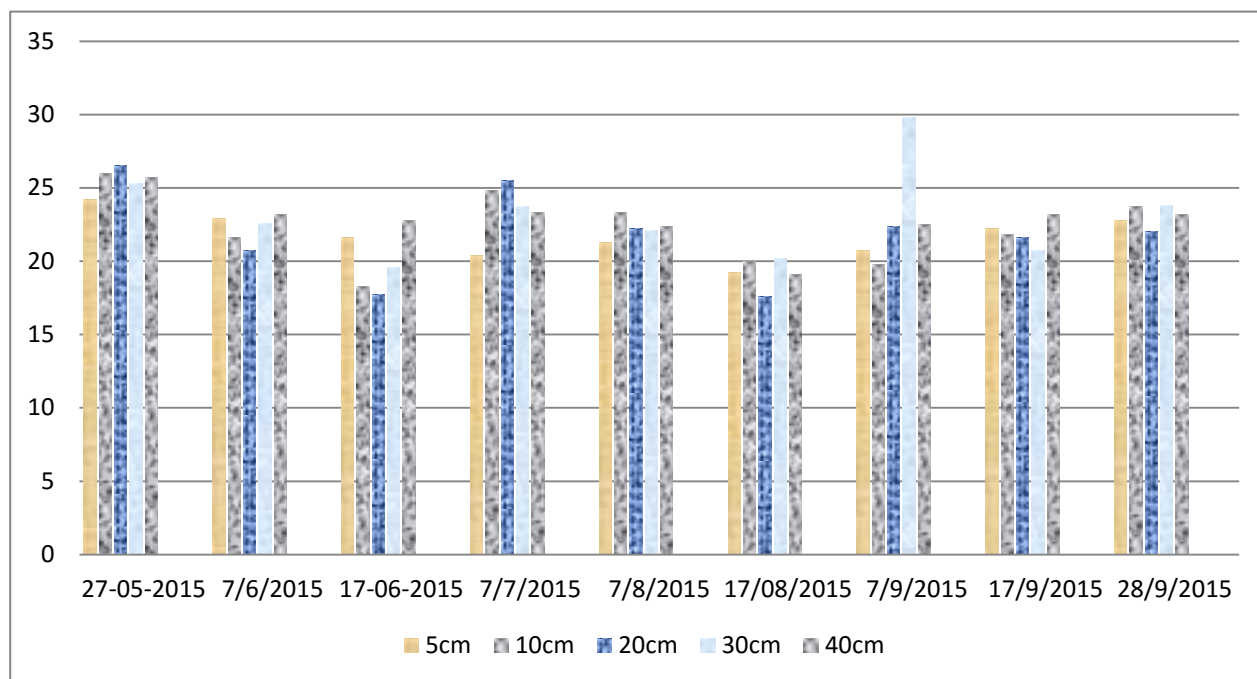


Figure 3.6(a): Soil moisture at different depths during Cotton crop 2015

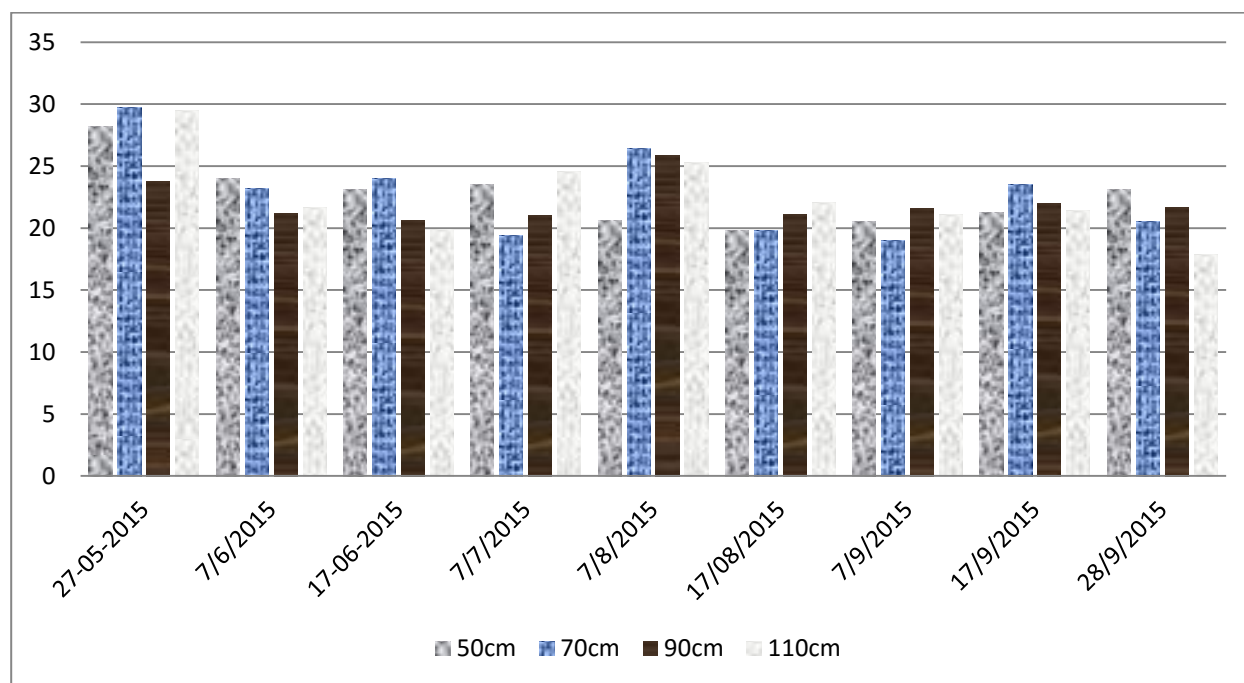


Figure 3.6(b): Soil moisture at different depths during Cotton crop 2015

3.5 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, texture, composition, and organic material of soil. Soil temperature influences the germination of seeds, the functional activity of the root system, the incidence of plant diseases and the rate of plant growth. The day time soil temperature is more important than the night time temperature, because it is necessary to maintain the internal crop water status to match the evaporation rate.

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

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

Note: This soil temperature data is collected from the soil observations taken at Agromet observatory of RAMC Tandojam. 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 2015, soil temperature remained highest during June at all depths except at the deep layer of 50 cm which remained warmest in September and coolest in May.

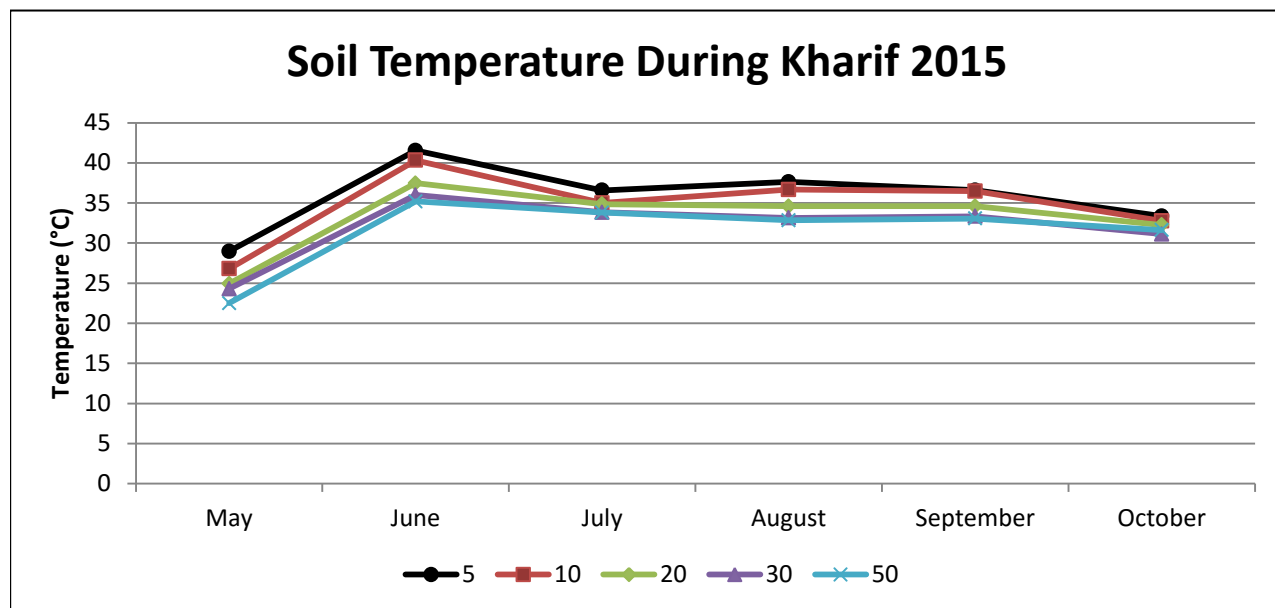


Figure 3.7: Soil temperature during cotton crop 2015

3.6 Heat Units Consumption during Crop Cycle

3.6.1. 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 [8].

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 [9].

3.6.1.1. 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.

$$HU = \sum T; T \text{ is mean daily Temperature}$$

$$HU = 0:$$

If $T < T_b$; where T_b 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:

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

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

3.6.1.2. Heat Units Consumption During 2015

Interphase period for cotton crop during the crop season 2015 of the cotton variety Sindh-1 and corresponding heat units at Tandojam observed at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 4818 accumulated from Germination to Maturity in 149 days.

During the crop season 2015, it is clear from the below graph that crop consumed above normal heat units during the vegetative stages of emergence and Third leaf and from flowering stage to Maturity. But in budding stage it was quite normal.

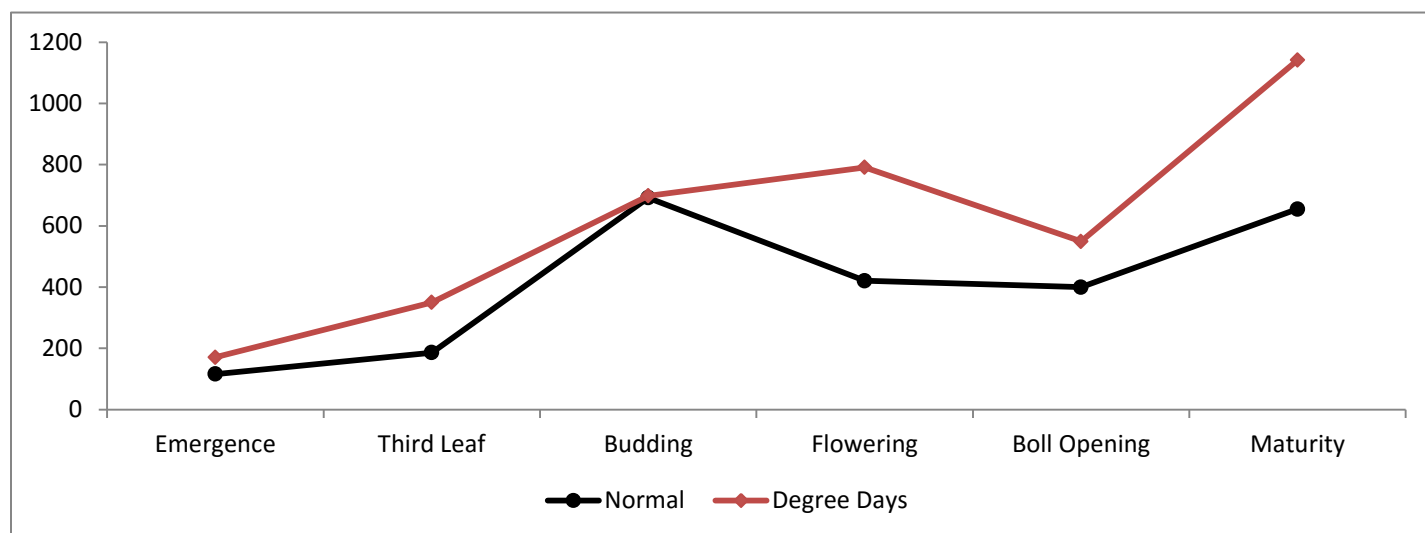


Figure 3.8: Heat units during crop life 2015

Table 3.3: Heat Units Consumed by the Crop during Different Phenological Phases

S. No.	Inter Phase	Period	No. of Days Taken	Cumulative days	Degree Days	Normal Degree Days
1.	Germination.	17-05-2015 to 21-05-2015	05	05	170.8	115.6
2.	Emergence	22-05-2015 to 29-05-2015	08	13	349.7	185.9
3.	Third True Leaf	30-05-2015 to 20-06-2015	22	35	697.8	691.8
4.	Budding.	21-06-2015 to 14-07-2015	24	59	790.9	420.4
5.	Flowering	15-07-2015 to 01-08-2015	17	76	549.2	399.6
6.	Boll Opening	02-08-2015 to 08-09-2015	37	113	1141.1	654.9
7.	Maturity	09-09-2015 to 15-10-2015	36	149	1118.2	759.6
8.	Germination to Maturity	16-05-2015 to 15-10-2015	149	149	4817.7	3227.8

3.7 Relative Humidity (%)

Relative humidity (RH) is simply defined as the ratio of the actual amount of water vapor (grams) in the unit mass of air at a given temperature to the mass of water vapor in the same sample of air when it is saturated at the same temperature. RH tells us about how much a sample of air around the observing station is saturated. It is expressed in percentage. For example if relative humidity of the atmosphere is 60%. It means that 60% of the atmosphere is saturated with water vapor or moisture and 40% of the present moisture may be added more to saturate (100% RH) the atmosphere. RH is temperature and moisture dependent and may vary if moisture content or temperature of the atmosphere is changed. It is always inversely proportional to temperature and ETo. RH is calculated with the help of dry bulb and wet bulb temperatures fitted in the Stevenson screen.

3.8 Reference Crop Evapotranspiration, ETo (mm/day)

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

During the crop season 2015, relative humidity remained above normal throughout 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.

3.9 Wind and Crop Growth

Wind also play significant role in plant growth besides its role in variation of ETo. Normal/gentle wind is necessary for the movement of carbon dioxide to plant canopy so that normal rate of photosynthesis continue in day time. Strong cyclonic or stormy wind accompanied by any severe weather event like hail storm, heavy shower may badly affect/damage the crop. During the Kharif crop period 2015, no such bad weather event 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.

Table 3.4: Summary of some Meteorological Parameters during Kharif Season 2015

Month	Wind speed (km/hr)	RH(%)	Days with mean RH \geq 80%	ETo (mm/day)
May-2015	3.4	49	00	6.9
June-2015	10.4	58	00	7.4
July-2015	14.3	70	04	6.4
August-2015	15.3	68	00	6.8
September-2015	8.8	61	00	6.1
October-2015	6.0	56	00	5.1

3.10 Crop Water Requirement (CWR)

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

The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favorable soil

conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

The crop water need mainly depends on:

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

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

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

3.10.1. Calculation of Crop Water Requirement (CWR)

After determining ET_o , the ET crop/crop water requirement (CWR) can be predicted using the appropriate crop-coefficient (K_c).

$$ET_{\text{crop}} = K_c \cdot ET_o \quad \text{or} \quad CWR = K_c \cdot ET_o$$

Crop coefficient (K_c) is actually the ratio of maximum crop evapotranspiration to reference crop evapotranspiration. For Cotton, this ratio becomes greater than 1 during the reproductive cycle (heading to grain formation) otherwise it remains less than 1 bearing minimum values during the early age of the crop and at maturity. The crop water requirement was calculated for the period from emergence to maturity. After wax ripeness practically there is no need of irrigation because the hot and dry conditions are desirable to achieve rapid hard maturity. A schematic variation of the crop coefficient related to different crop development stages under normal conditions is given in figure 3.10.

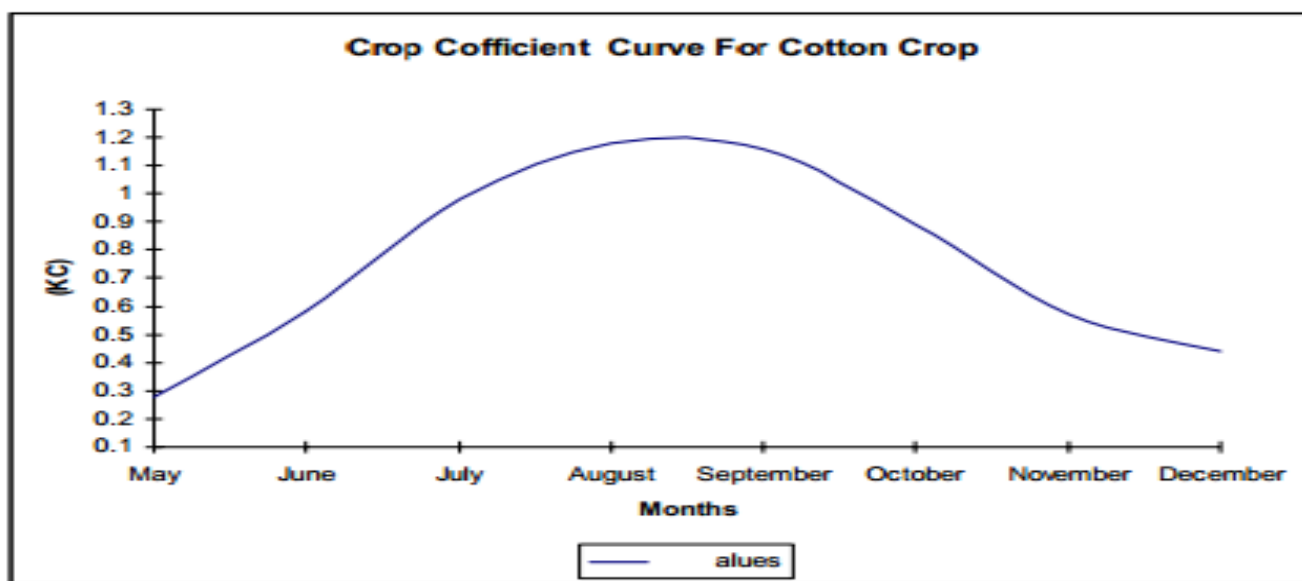


Figure 3.9: March of Crop Coefficient (K_c) for normal duration of Crop growing season (Emergence to Maturity).

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

$$10 \text{ mm} = 1 \text{ cubic meter per hectare}$$

Along with the loss of water through evaporation and transpiration, the compensation of this loss by precipitation may also be considered. Normally most of the plants grow successfully and utilize water for the soil at 50% and above available soil moisture. The maximum demand (daily or seasonal) may be equal to the reference crop evapotranspiration (ET_o) which is utilized through soil moisture [13].

During the Kharif Season 2015, crop water requirement of cotton crop was observed normal to above normal throughout the crop growth except at Boll opening and maturity stage. It means that crop growth did suffer due to sharp rise in crop water demand expect at boll opening and maturity. Thus the available irrigated and rain water satisfied moisture requirement of the crop, which resulted normal crop growth.

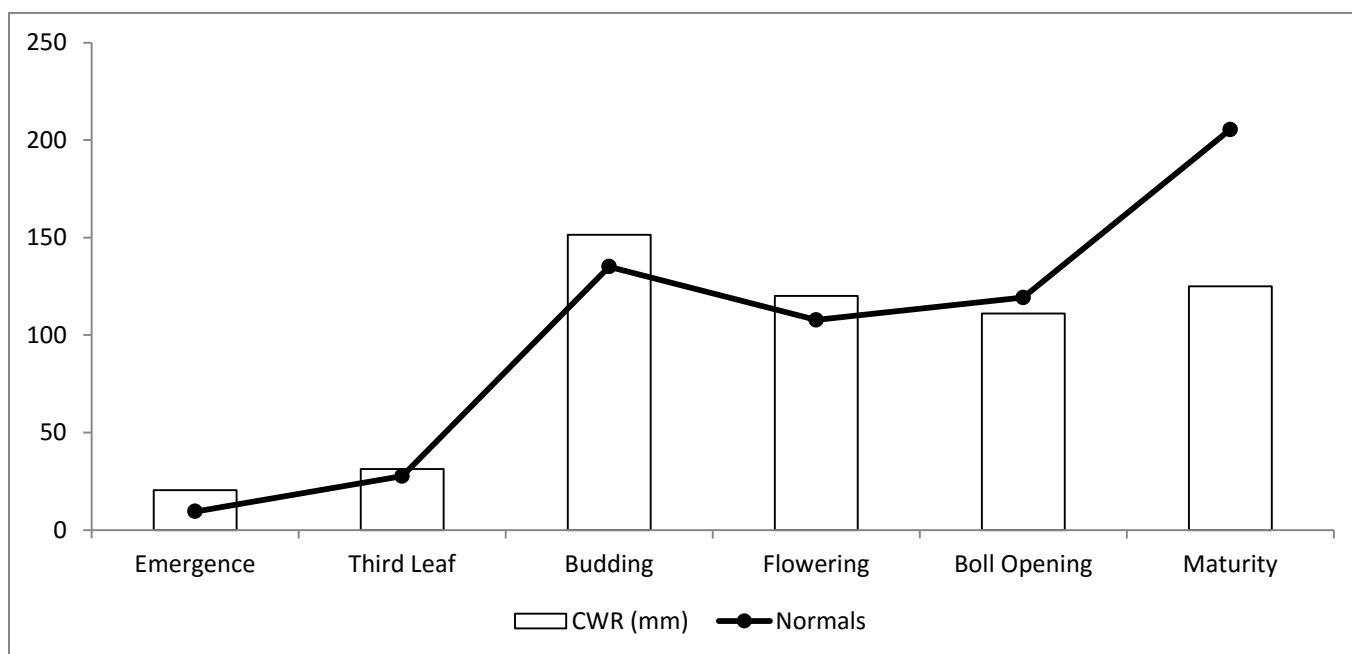


Figure3.10: Crop Water Requirement (CWR) During Crop Life

Table 3.5: Heat Crop water requirement during different phenological phases

S. No.	Inter Phase	Period	No. of Days Taken	ET _o (mm)	*ET _o (mm)	CWR=K _c ET _o	CWR=K _c *ET _o
1.	Germination	17-05-2015 to 21-05-2015	05	75.5	35.2	20.4	9.504
2.	Emergence	22-05-2015 to 29-05-2015	08	66.59	57.6	31.3	27.64
3.	Third True leaf	30-05-2015 to 20-06-2015	22	225.37	198.6	151.5	135.04
4.	Budding	21-06-2015 to 14-07-2015	24	123.8	110.1	120.1	107.7
5.	Flowering	15-07-2015 to 01-08-2015	17	93.27	99.4	111	119.25
6.	Boll opening	02-08-2015 to 08-09-2015	37	105.04	171.4	125	205.38
7.	Maturity	09-09-2015 to 15-10-2015	36	17	205.6	20.4	248.77

3.11 Agro Meteorological Summary of Crop Cycle

Different meteorological parameters were recorded at various phases of Cotton crop during 2015. The impact of these parameters at different phenological stages of Cotton crop is discussed as under.

- **SOWING**

Cotton crop was sown around the mid of May which is the most suitable time for sowing. The temperature was near normal values and there was no rain after sowing so these conditions were favorable for sowing.

- **EMERGENCE**

Emergence phase was distinguished by the appearance of spike above the ground. When plant emergence stage was completed; the field was divided into four replications. The mean relative humidity during this phase was 49%. Mean air temperature during emergence range was 33.8°C to 36.8°C. Weather reported dry during this stage. But crop growth reported satisfactory and no abnormal weather reported during emergence

- **THIRD LEAF**

This phase of crop growth started on 30-05-2015. The mean relative humidity was 58%; mean air temperature range was 29.0°C to 36.0°C. Rainfall reported as 9.4mm during this stage. Normal crop growth was reported during this stage.

- **BUDDING.**

This stage of crop growth started on 21-06-2015 and 75% occurrence was completed on 17-07-2015. During this phenological stage, mean air temperature range was 26.5°C to 33.8°C and mean relative humidity was around 70%. Again no rain was observed during this phase.

- **FLOWERING.**

This stage was mainly accomplished (up to 75% occurrence) up to mid of July 2015. Mean air temperature during the phase ranged 25.5°C – 33.0°C and relative humidity was 71%. Total rain fall recorded during this period was 131.0mm which was beneficiary for crop yield.

- **BOLL OPENING**

The stage was accomplished (up to 75% occurrence) up to 02-08-2015. The mean air temperature was ranged between 24.5°C to 30.9°C and mean relative humidity was 68%. However dry weather reported during this stage.

- **MATURITY**

This stage was accomplished (up to 75% occurrence). It is started on 09-09-2015 and ended on 15-10-2015. Mean air temperature ranged 22.0°C to 30.0°C. Mean relative humidity was 67%. After harvesting rainfall reported as 10.0mm during this stage, crop growth reported satisfactory and no abnormal weather reported during maturity stage.

Chapter 4

CONCLUSION AND RECOMMENDATIONS

The crop variety SINDH-I is one of the recommended variety of cotton in lower Sindh including Tandojam. During flowering and budding stages pest (Milli Bugs) was reported. Crop was cultivated in the experimental field of Agriculture Research Institute Tandojam. The sowing time of Cotton is a very important factor. The time of sowing of Cotton is directly related to yield and quality of grain produced.

According to Table – 3.1 and Chapter-3 (Results and Discussion), the crop was sown slightly later than the proper time. Amount of seed cultivated per acre was 50 kg which is sufficient for the crop cultivated in November. Fertilizer intake was also enough i.e., one bag DAP at the time of sowing and 2 Bags Urea was added to the crop as split does. Rainfall amounting 9.4 mm was reported for one day in June and 131.0mm for 7 days in July 2015. No rainfall was reported till harvesting. Irrigation was made 8 times during the season which mostly fulfilled the water requirement of the crop. Night and day time temperatures also observed in normal to slightly above normal range. RH was observed to be normal throughout the crop life. However ETo remained below normal during most of the crop's growth period. As a result normal moisture content of soil in major root zone was observed during most of the crop life thus contributing to normal crop's growth, development. Air and soil temperature regime remained normal to slightly below normal for most of the crop's period, which also favored crop growth at all stages. Total heat units consumed by the Cotton crop were 4818 accumulated from germination to full maturity in 149 days. On average 32.3 heat units were consumed by the crop per day. Normally these heat units are consumed in 149 days at the rate of 21.65 heat units per day, which shows that the crop reached to full maturity almost in normal thermal time. From figure 3.9 it is clear that crop consumed normal to above normal heat units except vegetative stage of budding during which slightly normal heat units were consumed so that these phases completed earlier than normal time. As a whole the crop took nine more days (149) to reach maturity than normal time span of 140 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 2015 recommended weedicides operations were performed in time, which also reinforced crop's growth and production. Milli Bugs pest or viral attack was observed on the crop during its life cycle. Optimum values / amount of meteorological and non- meteorological factor combined to normal crop growth and development.

4.1. Conclusion

During the Kharif season 2015, most of the air and soil weather parameters like air and soil temperature, rainfall, eight times irrigation with suitable intervals, R.H and crop water requirement favored normal to above normal crop growth. The crop was cultivated in time with normal fertilizer doze and weeds removing spray at suitable intervals. However, heavy precipitation spell at the time of flowering affected adversely the pollination of the Cotton crop which eventually resulted in decreased yield normal comparatively potential yield of the crop.

4.2 Recommendations

Keeping above results and conclusion, following recommendations/suggestions are given to farmers and other related personals to enhance cotton crop yield in central lower Sindh 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 size boll. Late- planted crop has lower germination, fewer flowers, smaller heads, shriveled boll and lower 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.
2. Cotton plant water requirement is excessive 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 mid to get maximum crop yield.
3. Farmers should take in time precautionary measures against any pest/fungus/viral etc. attack on crop, especially hot/humid period of monsoon.
4. The frequency of extreme weather events like heat waves, flash flooding, and heavy spell with stormy winds has increased globally including Pakistan in the last decade due to climate change. 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 judicious use of available irrigation water. Keeping in mind the available water resources, it is also indeed necessary to decide suitable crops 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 get best results of fertilizer and irrigated water used.
6. 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.

7. 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.
8. Timely application of nitrogen-phosphoric fertilizers should be done.
9. Care must be taken to check the pre and post-harvest losses of Cotton. Pre-harvest damage may be checked from attack of birds, animals around Cotton fields. Post-harvest losses must be checked from the attack of rodents and other insects, pests and fungi. After proper picking cotton should be placed under hygienic conditions in fields and in storage places as well.
10. Crop rotation is an important factor that enriches the fertility of the land, which should not be ignored. Pulses are preferred as they enrich the nitrogen content of soil for the coming Cotton crop.

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