Crop Development in Central Punjab, Faisalabad (2017 – 2018)

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Abstract

This study was conducted at RAMC (Regional Agrometeorological Center) Faisalabad to investigate the impact of weather conditions on the growth and development of wheat crop. Impact of variations in the meteorological parameters on different phenological phases and hence on final yield of wheat crop was analyzed. For this purpose, both meteorological and phenological data along with soil moisture data was collected from the meteorological observatory and agricultural field of physiology section of Ayub Agriculture Research Institute, Faisalabad. Besides this record, other necessary features like sowing time, fertilizer, weeds removing operations and irrigation schedule are also included in the current report for the Rabi season 2017-18. The wheat crop variety Galaxy sown in the field under observation used 1748 heat units in 129 days during its life cycle from sowing to full maturity. The water requirement of crop was fulfilled by flood irrigation method. Crop was sown almost at the proper time. Air temperature remained above normal during the most of the crop life. Rainfall received was below normal during most of the crop season. The water requirement of crop was fulfilled by irrigation method. Crop was sown on the proper time. The wheat crop needs high humidity and low rate of ETo during the early maturity stages to gain the full grain size but the crop was negatively affected by the decrease of humidity in air during the early stages of maturity which, alternatively increased the rate of ETo. In result the grain size shrinked and did not gained its original volume. The actual yield by the crop variety grown is 1640 kg acre^{-1} while its potential yield is 2400kg acre^{-1}. This shows that the crop yield was worst affected by the meteorological phenomena i.e. ETo, temperature and RH, so that the yield obtained is unsatisfactory.

Chapter 1

INTRODUCTION

Wheat is the major food crop as well as one of the main agricultural products of Pakistan. This study is based upon field observations of wheat crop at Regional Agrometeorological Centre, Faisalabad cultivated in the experimental field of Ayub Agriculture research Institute, Faisalabad. Land at the study site consists of agriculture fields rotated among wheat, rice, cotton and other seasonal crops. In experimental field wheat crop variety Galaxy was cultivated. This study will help in understanding the effect of different climatic parameters on the growth and yield of wheat crop in central Punjab region.

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

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

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

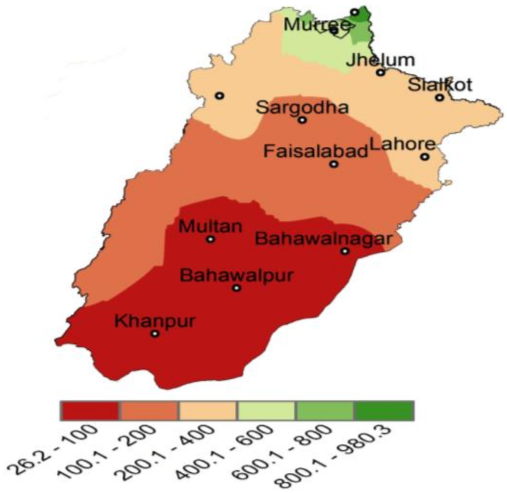

Figure 1.1:Mean Annual Rainfall (mm) of Punjab

[Normal (1981-2010)]

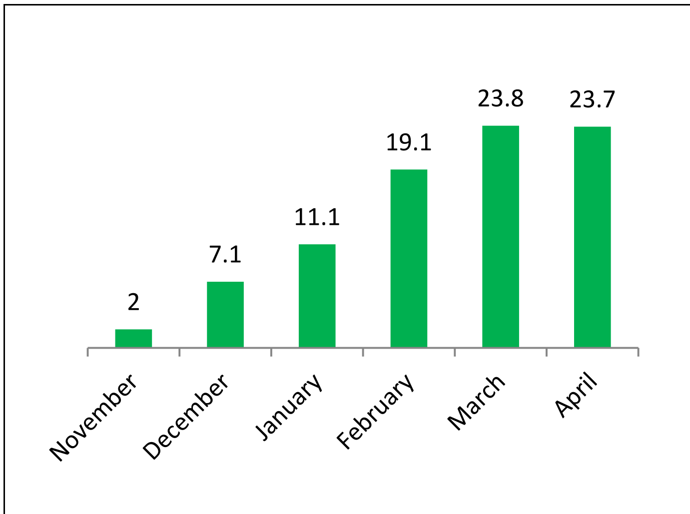

Figure 1.2: Mean Monthly Rainfall (mm) of Faisalabad during Rabi Season

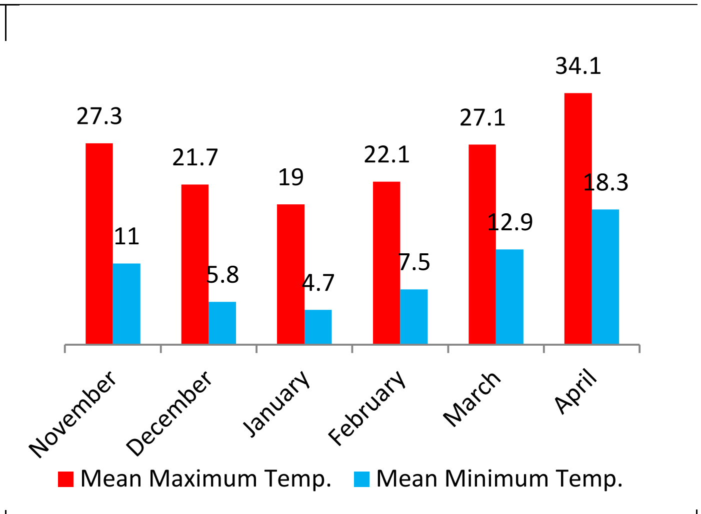

Figure 1.3: Mean daily Maximum and Minimum Temperature (°C) of Faisalabad during Rabi Season

1.2 Scope of the Study

Pakistan experiences a more variable and unpredictable behavior of weather systems as compared to other countries of the region. This type of weather patterns result in the variations in the amount of available water both for irrigated and rain fed agricultural lands, which consequently results in the fluctuations in annual yield of wheat. Sometime heavy rains along with persistent cloudy conditions trigger the viral or pest attack on wheat crop and also cause rapid growth of weeds in the fields. It also prolongs the crop period, which causes delay in sowing of next Kharif crop. Rain just after sowing causes decrease in the number of germinated wheat seeds and also at the time of harvesting/threshing badly damage the final yield. Abnormal rise in day time temperature or late sowing raises crop water requirement at a particular phase. This could also cause early completion of phase and early maturity of grains. Due to which shriveled grain is obtained. Therefore, in this study the impacts of variations of meteorological parameters along with variations in soil temperature and moisture are analyzed to understand crop growth and development throughout the crop life and their impact on final yield of the crop.

1.3 Objective of the Study

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

1.4 Review of Agriculture Production in Pakistan

Pakistan is an agrarian country whose population and economy directly or in directly (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. [5]

Punjab contributes about 76% to annual food grain production in the country. According to the Punjab Agriculture department "Punjab has 57% of the total cultivated and 69% of the total cropped area of Pakistan. [6] It provides about 83% of cotton, 80% of wheat, 97% fine aromatic rice, 63% of sugarcane and 51% of maize to the national food production. Among fruits, mango accounts for 66%, citrus more than 95%, guava 82% and dates 34% of total national production of these fruits. [7]

1.5 Wheat Production in Pakistan

Wheat flour or "Atta" is the common food for most Pakistanis, supplying 72% of caloric energy in the average diet. It is the main food cereal crop in Pakistan and is essentially better from nutritional point of view than most of the cereals and other foods. It is estimated that in our country wheat consumption per capita is 124 kg per year, which is the highest amount over the world. [5] The above fact reflects the importance of wheat crop for our country. Therefore every year variation in the total yield of wheat due to several factors including climate and weather variations directly affects the economy and social balance of the country.

Wheat is a Rabi crop that is grown in the winter season. In Pakistan sowing of wheat takes place from October to December and harvests from the month of March to May. In Punjab sowing months of wheat are November and December whereas harvesting period is April and May.

Chapter 2

MATERIALS AND METHOD

The wheat crop variety Galaxy was cultivated at Regional Agrometeorological Center, Faisalabad in central Punjab during Rabi season 2017-18. 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 Wheat Crop 2017-18

	Phenological stage	**Date**
1.	Sowing	01-12-2017
2.	Emergence	11-12-2017 To 22-12-2017
3.	Third Leaf	23-12-2017 To 02-01-2018
4.	Tillering	03-01-2018 To 13-02-2018
5.	Shooting	14-02-2018 To 02-03-2018
6.	Heading	03-03-2018 To 09-03-2018
7.	Flowering	10-03-2018 To 23-03-2018
8.	Milk Maturity	24-03-2018 To 01-04-2018
9.	Wax Maturity	02-04-2018 To 11-04-2018
10.	Full Maturity	12-04-2018 To 18-04-2018

2.1.1 Phenological Observations

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

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

2.2 Methodology

In this study the impact of different meteorological/non-meteorological parameters in comparison with the normal (1981-2010), 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 wheat crop is analyzed along with a brief summary of whole wheat crop's life cycle. Normally the wheat crop takes 100-120 days to get fully mature. The crop is cultivated in the start of November up to the mid of December. 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 wheat crop, different meteorological parameters are studied as well.

Table 3.1: Brief Summary of the Wheat Crop

1	Field size	4 kanal
2	Crop variety	Galaxy
3	Date of Sowing	01-12-2017
4	Information about any disease/pest attack,	Nil
5	Pesticides And weedicides details	Buctrilsaper 300ml/Hec, Axil 330 ml/Hec
6	Quantity of seed per acre	50 Kg
7	Row spacing	30cm
8	Schedule and quantity of supplied dose of fertilizer	1 bag Potash,2 bag DAP at sowing 1 bag Urea during 1st irrigation.
9	Type of irrigation	Flood irrigation
10	Irrigation schedule	• 22-12-2017 (at Emergence) • 10-01-2018 (at Tillering) • 06-02-2018 (at Tillering) • 21-02-2018 (at Shooting) • 14-03-2018 (at Flowering)
11	Heat units consumed from sowing to full maturity	1748
12	Total days taken by the crop from sowing to full maturity	129
13	Date of harvesting	30-04-2018
14	Actual/ Potential yield	1640/2400 kg /acre

3.1 Rainfall and Wheat Crop Growth

Rainfall is one of the most important factors that affect annual wheat production in Pakistan. In time or effective rainfall i.e., before sowing and shooting to grain formation stage is greatly beneficial. In the same way, rain after sowing and before germination and at the time of full maturity negatively affect crop growth and ultimately reduce the yield. [9]

During the crop season 2017–18, below normal rainfall received throughout the season this year. The highest rainfall received was in flowering stage i.e. 10 mm, which is even not satisfactory for this stage. As this crop was grown on irrigated land so the field was irrigated time to time to meet the need.

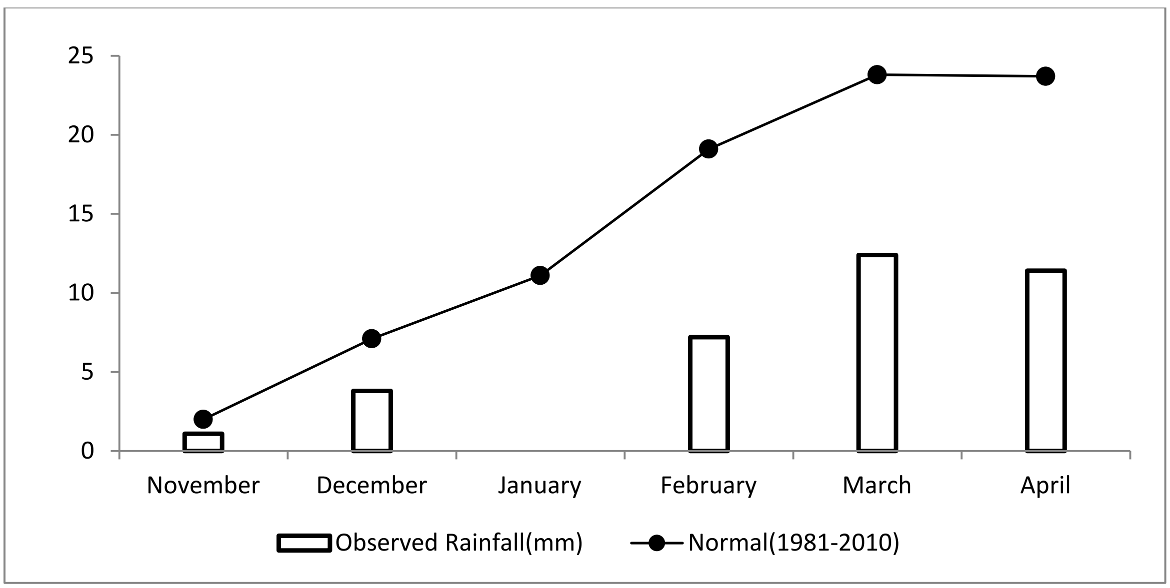

Figure 3.1: Comparison of Monthly observed rainfall with Normal (1981-2010) at Faisalabad during Rabi season 2017-18

Table 3.2: Daily Rainfall History of the Crop Life 2017-18

Year	Phenological stage	Month	Day	Rainfall(mm)	Monthly Total (mm)
2017	Germination	December	10	2.2	
2017	Emergence	December	11	1.6	3.8
2018	Tillering	February	11	1.6	
2018	Tillering	February	12	TR	
2018	Shooting	February	23	5.4	
2018	Shooting	February	24	TR	7.2
2018	Shooting	March	02	1.4	
2018	Heading	March	03	1.0	
2018	Heading	March	8	TR	
2018	Flowering	March	19	5.0	
2018	Flowering	March	20	5.0	12.4
2018	Full Maturity	April	15	1.2	
2018	Full Maturity	April	16	0.6	
2018	Full Maturity	April	19	2.8	
2018	Full Maturity	April	20	6.8	11.4

3.2 Irrigation during Crop Growth

The wheat crop was irrigated five times during the entire crop season before full maturity. First irrigation was made to the wheat crop 22 days after sowing after completion of emergence. During the tillering stage, second and third irrigation was given. And Fourth and fifth irrigation was made during shooting and flowering stages respectively. This completed the crop water demand.

3.3 Air Temperature and Wheat 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. Hence three temperature values for a plant growth are of particular importance.

They are;

- Biological Zero: is the minimum temperature below which plant growth stops; for wheat crop it ranges between 0°C and 5°C.
- Optimum Temperature: at which maximum plant growth occurs. For wheat crop its value is 25°C.
- Maximum Temperature: above which the plant growth stops. For wheat crop its value is 30-32°C. [10]

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

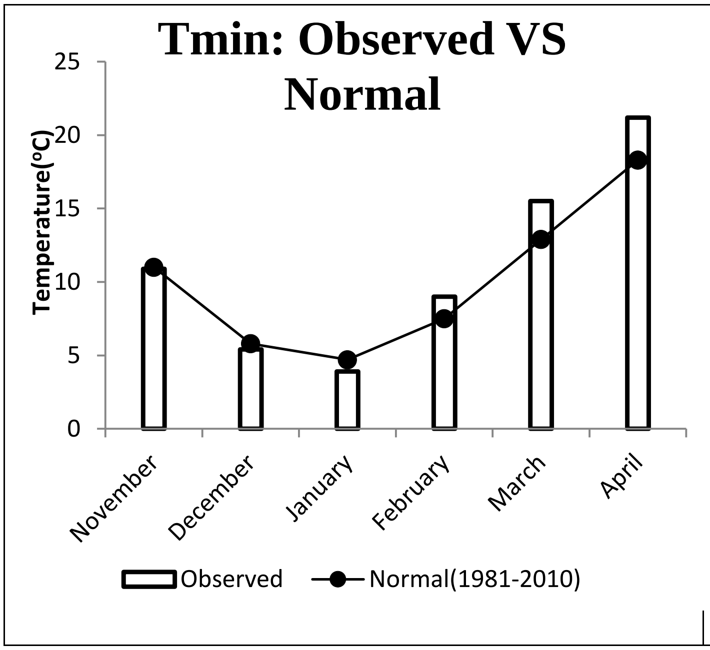

Figure3.2: Mean Monthly Minimum Temperature (ºC) of Faisalabad during the Rabi Season

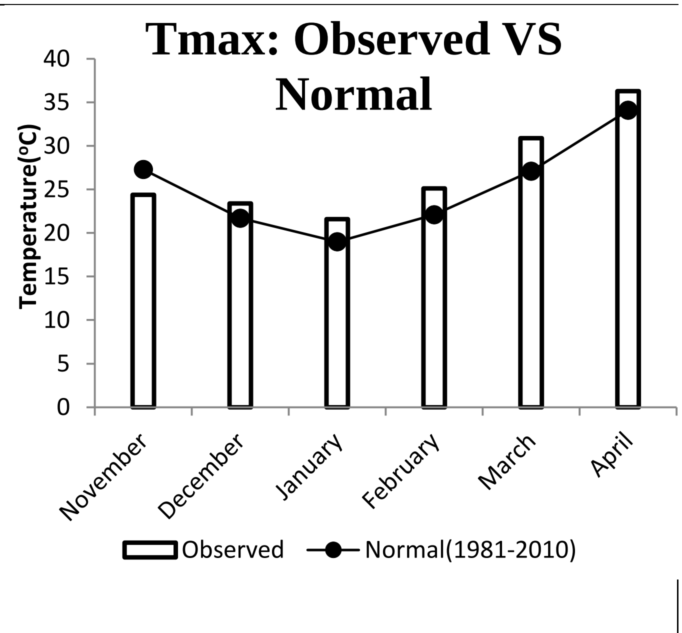

Figure3.3: Mean Monthly Maximum Temperature (ºC) of Faisalabad during the Rabi Season

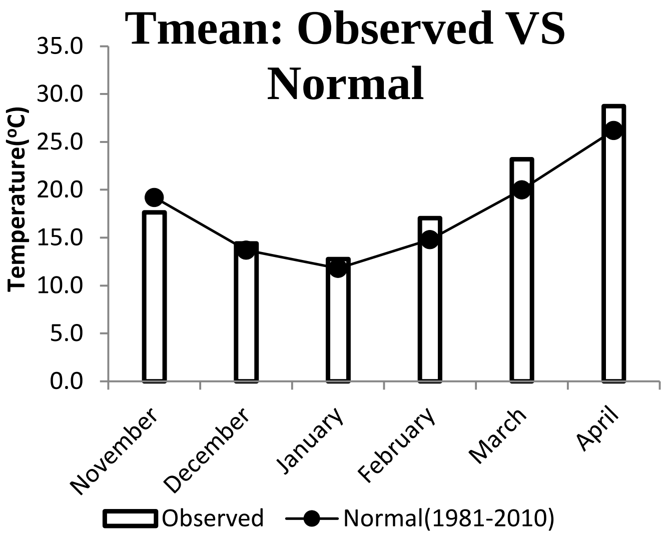

Figure 3.4: Mean Monthly Temperature during 2017-18

During the crop season of 2017–18, mean day time maximum temperature remained above normal throughout the crop life cycle. Mean night time minimum temperature remained below normal during the months of December and January while in the remaining period of crop cycle it remained higher than normal. Mean daily temperatures remained higher than the normal values throughout the crop life. The values were much higher than normal during the month of February, March and April .During the month of January, the crop was in tillering stage. And the minimum temperature remained mostly below 5^{o} C, which affected the stage by restricting the growth and elongated the stage duration. And during March and April a sudden rise in temperature was recorded and decrease in RH, which affected the crop during early maturity stages.

Table3.3: Mean Monthly Temperatures during Rabi Season 2017-18

Month	**Mean Monthly (°C)**	**Monthly Mean Max.(°C)**	**Monthly Mean Min(°C)**	**Absolute Max. (°C)**	**Absolute Min. (°C)**
Nov-2017	17.7 (19.2)	24.4 (27.2)	10.9 (11.5)	27.8 (34.0)	5.5 (2.5)
Dec-2017	14.4 (13.7)	23.4 (21.6)	5.4 (6.3)	27.5 (29.2)	2.0 (-1.3)
Jan-2018	12.8 (11.8)	21.6 (18.7)	3.9 (5.0)	25.0 (26.2)	2.3 (-1.0)
Feb-2018	17.1 (14.8)	25.1 (22.0)	9.0 (7.9)	29.5 (30.8)	3.5 (0.0)
Mar-2018	23.1 (20.0)	31.2 (27.6)	15.5 (13.7)	38.5 (37.0)	11.8 (3.5)

April-2018	28.8 (26.2)	36.3 (34.1)	21.2 (18.9)	43.0 (44.0)	15.5 (7.0)

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

3.4 Soil Moisture Observations during Crop Growth

Soil moisture plays a vital role during crop's life. Soil moisture content is proportional to rainfall and intake of irrigated water and is inversely proportional to evapotranspiration from the plant and its surroundings. Variation in soil moisture during crop's life play important role in plant growth and development. Water or soil moisture requirement of wheat 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, 17thand 27th of each month in four replications at 5, 10, 20, 30, 40, 50, 70 and 90 cm depths with the help of auger. However in case of any anomalous event on the specific date, the sample can also be taken on the next day. Soil sample is then weighed and dried in the oven for about 8 hours. The dried sample is weighed again and moisture present in the soil is then calculated by the difference of weight between wet and dry samples as illustrated below:

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

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

During the crop season 2017–18, from the observed soil moisture data, figures(3.7 – 3.11)depicts that soil moisture remained satisfactory during early and intermediate stages of the crop life whereas it remained slightly deficit in shallow layers during milk maturity and wax maturity stages (March & April) due to seasonal rise in direct solar radiation. But due to below normal crop water requirement (figure 3.11) and in time irrigation during the crop growth remained mostly normal throughout the crop life. Rainfall received during the crop life also help to fulfill the soil moisture requirement.

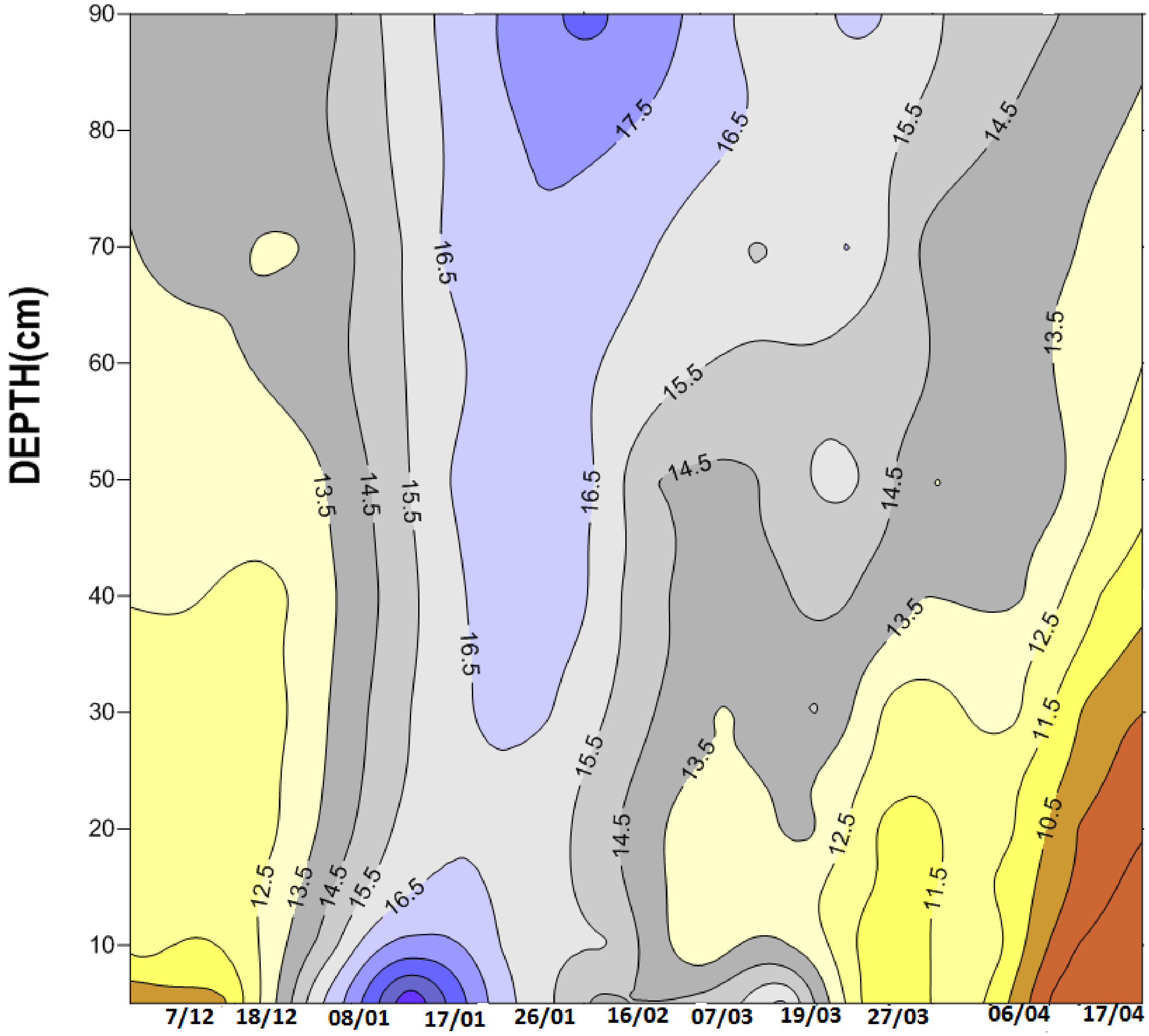

Figure 3.5: Soil moisture chrono Isopleths for Rabi Crop at Faisalabad for the year 2017-18

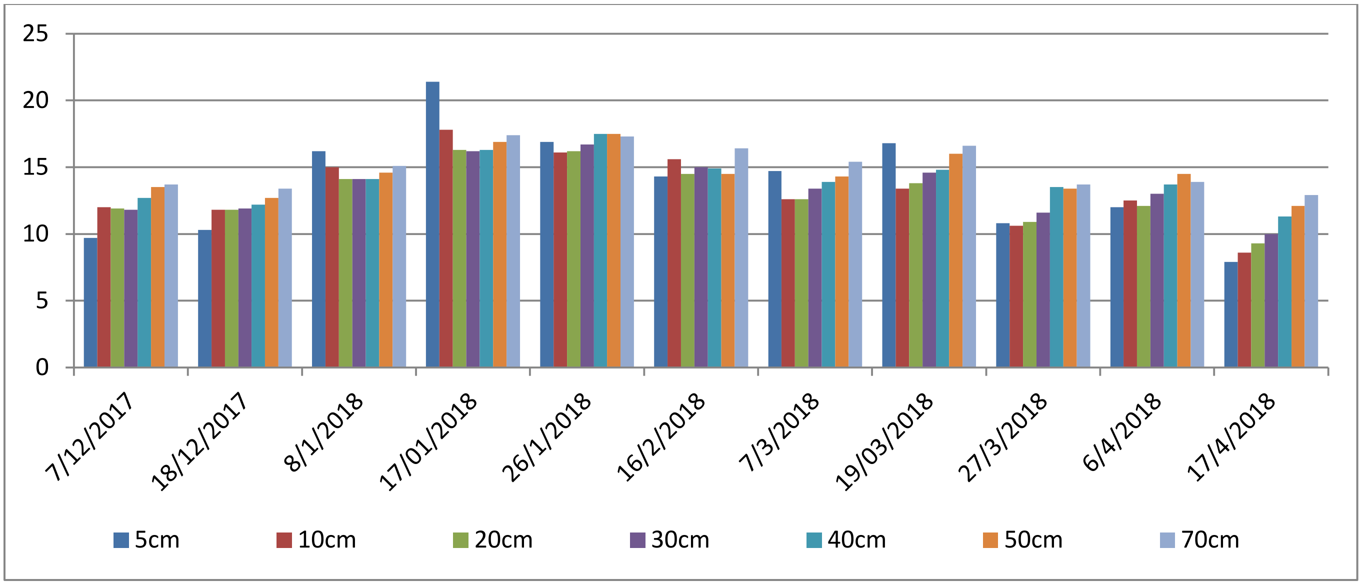

Figure3.6: Soil moisture at different depths during wheat crop 2017-18

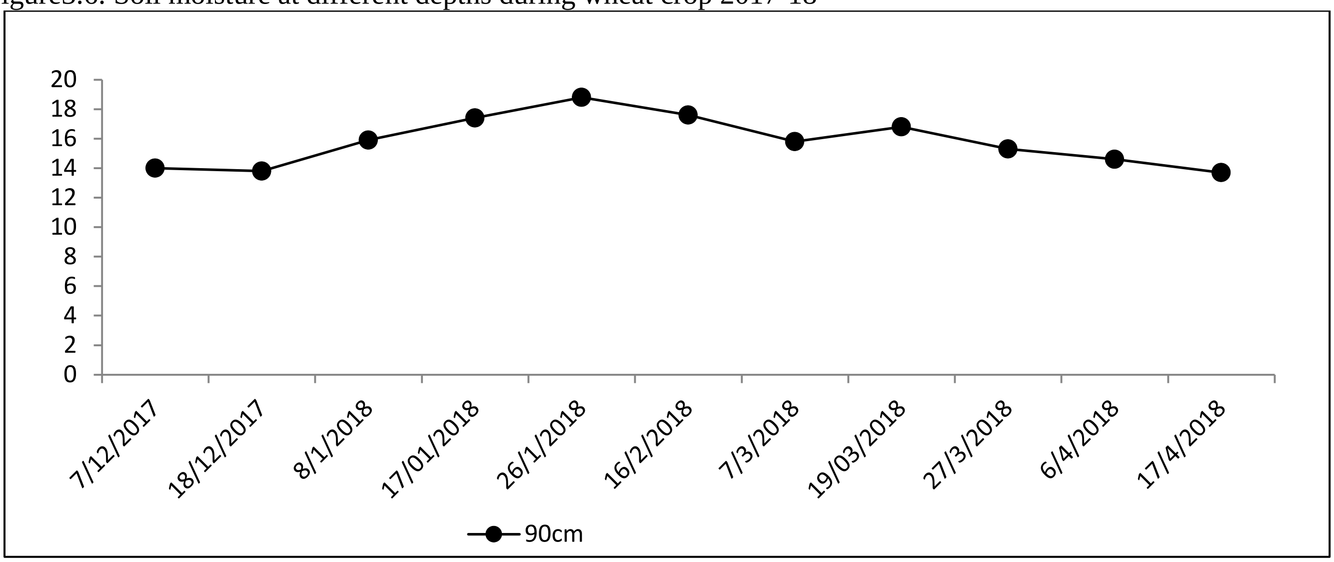

Figure 3.7: Soil moisture at deep soils (90cm) during wheat crop 2017-18

3.5 Soil Temperature and Crop Growth

Soil temperature is the most important parameter affecting growth of the crop. Plants roots are very sensitive to the soil temperature. In comparison to air temperature, the amplitude of variation in soil temperature is much more pronounced because of the varying characteristics, texture, composition, and organic material of soil. Soil temperature influences the germination of seeds, the functional activity of the root system, the incidence of plant diseases and the rate of plant growth. The daytime soil temperature is more important than the night time temperature, because it is necessary to maintain the internal crop water status to match the evaporation rate. Optimal soil temperature for growth of wheat plant roots during the vegetative stage is below 20°C and is further lower than that for the shoots. [10]

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

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

Note: This soil temperature data is collected from the soil observations taken at agromet observatory of RAMC Faisalabad situated near the experimental field of wheat 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 2017-18, soil temperature remained highest at all depths during month of April, whereas it remained coolest in the month of January.

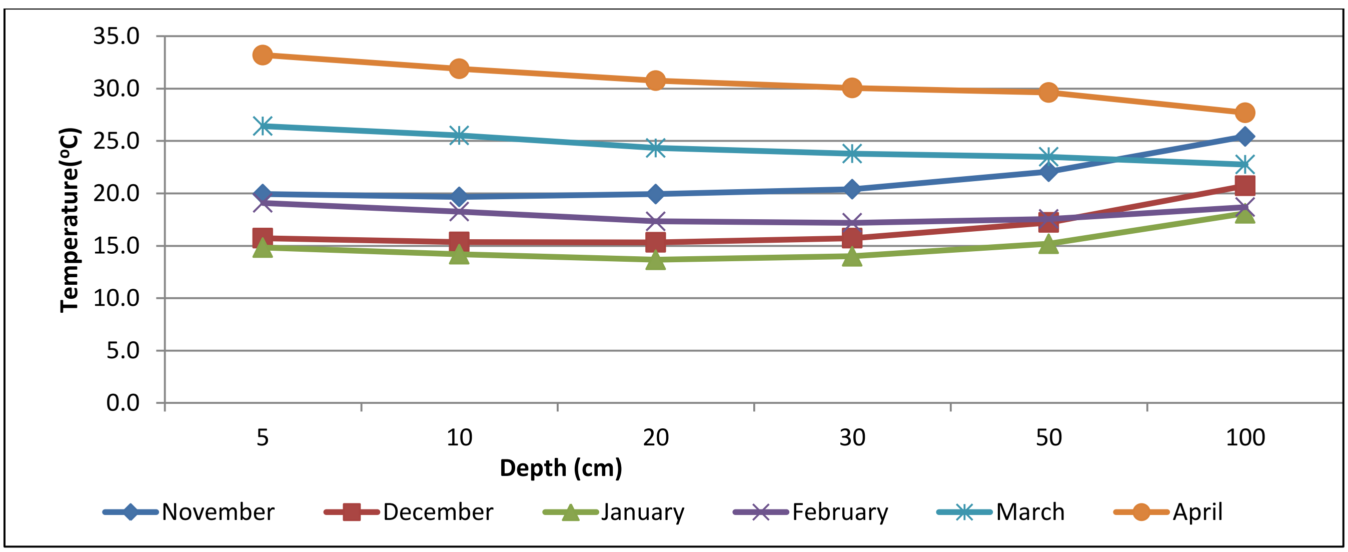

Figure 3.8: Soil temperature during wheat crop 2017-18

3.6 Heat Units Consumption during Crop Cycle

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

The heat unit concept assumes a direct and linear relationship between plant growth and temperature. It starts with the assumption that total plant growth is dependent on the total amount of heat to which it is subjected during its life time. The heat units for a particular crop on any day are the difference between the daily mean temperature (T) and the base temperature (Tb) of the crop. Base temperature or Biological zero is the minimum temperature below which no growth occurs. The base temperature or threshold varies with different plants, and for the majority it ranges from 4.5 to 12.5°C.Here for wheat crop base temperature is 5°C. This concept assumes that a given cultivar requires the same summation (k) of the daily mean temperature for going one phenological stage to next stage, regardless of temperature distribution. Generally only positive values above the biological zero (Tb) are considered. The period of negative value is termed as “dormant” because crop does not grow under such conditions.

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

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

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

Inter Phase period for wheat crop during 2017-18 and corresponding heat units at RAMC Faisalabad observed at different phenological stages varies from phase to phase. Heat unit requirements of different phases and cumulative heat units for the crop have been worked out, are shown in figure 3.9 and Table–3.4. Total heat units consumed by the wheat crop were 1748 accumulated from germination to full maturity in 129 days. On average 13.5 heat units were consumed by the crop per day. Normally these heat units are consumed in 140 days at the rate of 11.6 heat units per day, which shows that the crop reached to full maturity in earlier than normal time. From figure 3.9 it is clear that crop consumed normal to below normal heat units during most of the stages. Above normal heat units were consumed during tillering and wax maturity stages stage. The crop consumed more heat units during the phase because the mean temperature suddenly raised and the RH decreased. As a whole the crop took eleven day less (129) to reach maturity than normal time span of 140 days.

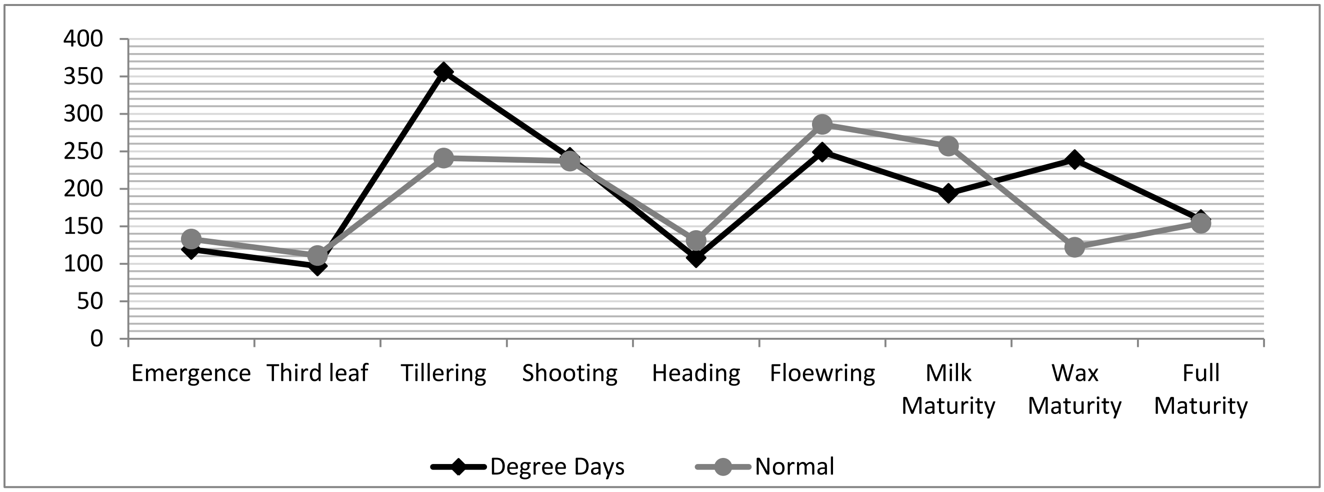

Figure 3.9: Heat units during crop life 2017-18

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

S. No.	Inter Phase	Period	No. of Days Taken	Degree Days (T-5℃)	Normal Degree Days
2.	**Emergence**	11-12-2017 To 12-12-2017	12	105	132.5
3.	**Third leaf**	23-12-2017 To 02-01-2018	11	97	111
4.	**Tillering**	03-01-2018 To 13-02-2018	42	355	241
5.	**Shooting**	14-02-2018 To 02-03-2018	17	242	237
6.	**Heading**	03-03-2018 To 09-03-2018	7	111	131
7.	**Flowering**	10-03-2018 To 23-03-2018	14	249	286
8.	**Milk maturity**	24-03-2018 To 01-04-2018	9	194	257
9.	**Wax maturity**	02-04-2018 To 11-04-2018	10	237	122
10.	**Full maturity**	12-04-2018 To 18-04-2018	07	159	154
11	**Emergence to Maturity**	11-12-2018 To 18-04-2018	129	1748	1671

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. During the crop season 2017-18 RH remained below than the normal values. The effect of low RH during the early maturity stages adversely affected the seed size.

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 2017-18, relative humidity remained below normal, whereas, ETo remained normal to below normal during most of the growing period. Above normal ETo during early maturity stages of the crop effected the crop production. Hence, shrinked the grain size.

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 Rabi crop period 2017-18, no such weather event was observed. Wind speed was observed normal to above normal but no significant wind speed accompanied by any severe weather event was not observed even after irrigation.

Table 3.5: Summary of some Meteorological Parameters during Rabi Season 2017-18

Month	Wind speed (km/hr)	RH (%)	Days with mean RH ≥80%	ETo (mm/day)
Nov-17	1.5(0.5)	68 (71.2)	13	3.0(3.1)
Dec-17	1.4 (0.5)	57(74.7)	02	2.1(2.0)
Jan-18	1.9 (1.5)	60 (76.5)	0	2.6(2.1)
Feb-18	2.6 (1.5)	55(71.2)	0	3.8(2.6)
Mar-18	3.3 (1.8)	48 (65.6)	0	6.1(3.9)
Apr-18	3.4(2.6)	43 (50.8)	0	6.5(5.4)

2.1. 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 Calculation of Crop Water Requirement (CWR)

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

ETcrop = Kc. ETo or CWR = Kc. ETo

Crop coefficient (Kc) is actually the ratio of maximum crop evapotranspiration to reference crop evapotranspiration. For wheat, this ratio becomes 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 wax 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.

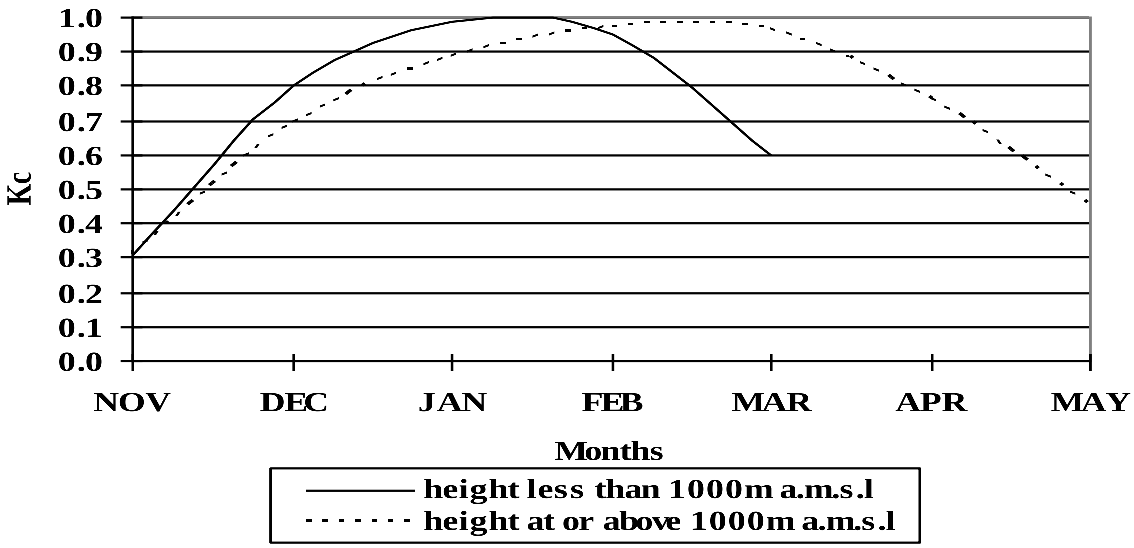

Figure 3.10: March of Crop Coefficient (Kc) for normal duration of Wheat growing season (Emergence to Wax- Maturity).

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

10 mm = 1 cubic meter per hectare

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

During the Rabi Season 2017-18 in Faisalabad, crop water requirement of wheat crop was observed normal to above normal from emergence to maturity stage. (Fig 3.11& Table 3.6). It might be due to high temperatures, high level of ETo and below normal RH. The available irrigated and rain water satisfied moisture requirement of the crop.

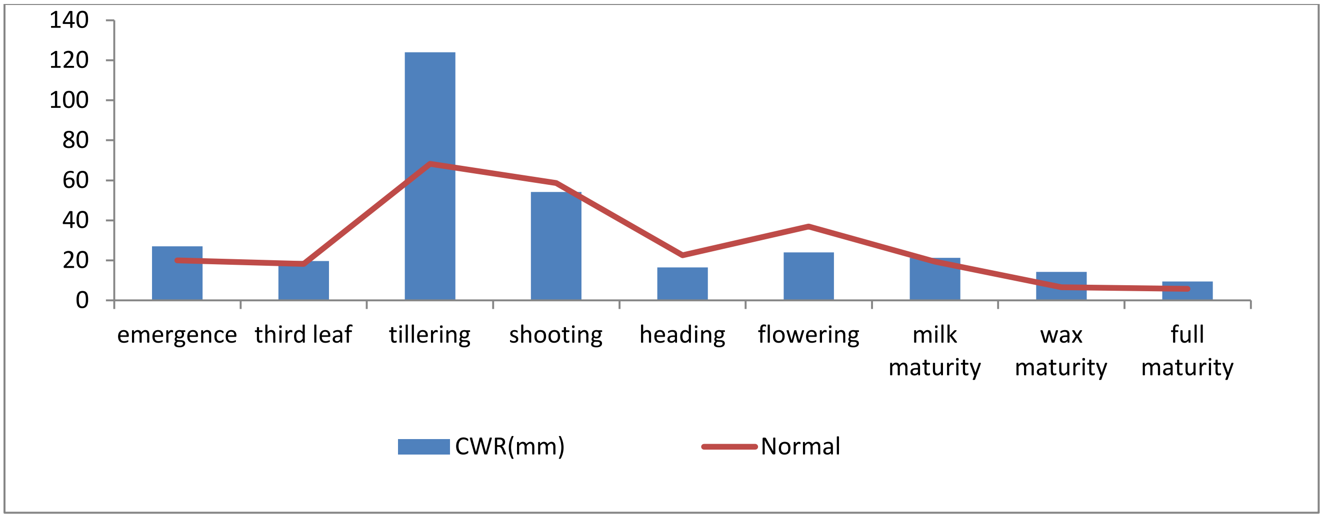

Figure3.11: Crop Water Requirement (CWR) During Crop Life

Table 3.6: Heat Crop water requirement during different phenological phases

S. No.	Inter Phase	Period	No. of Days Taken	ETo (mm)	*ETo (mm)	CWR=Kc ETO	CWR=Kc *ETO
2.	**Emergence**	11-12-2017 To 22-12-2017	12	28.4	29.5	27.0	20
3.	**Third leaf**	23-12-2017 To 02-01-2018	11	20.0	24	19.7	18.2
4.	**Tillering**	03-01-2018 To 13-02-2018	42	124	74	124	68.2
5.	**Shooting**	14-02-2018 To 02-03-2018	17	68	64	54.1	58.6
6.	**Heading**	03-03-2018 To 09-03-2018	07	37	32.5	16.4	22.6
7.	**Flowering**	10-03-2018 To 23-03-2018	14	80	74.1	24	37
8.	**Milk maturity**	24-03-2018 To 01-04-2018	09	71	62.1	21.3	19.4
9.	**Wax maturity**	02-04-2018 To 11-04-2018	10	72	32.4	14.3	6.5
10.	**Full maturity**	02-04-2018 To 11-04-2018	07	48	37.8	9.5	5.7
11	**Emergence-Full maturity**	30-11-2017 To 17-04-2017	129	547	430.4	310	256

*Normals based upon 1991-2010 data.

3.10 Agro Meteorological Summary of Crop Cycle

Different meteorological parameters were recorded at various phases of wheat crop during 2017-18. The impact of these parameters at different phenological stages of wheat crop is discussed as under.

3.10.1 Sowing

Wheat crop was sown during the first decade of December which is the almost normal time for sowing. The mean temperature was near normal values and there small amount of rain after sowing so overall conditions were satisfactory for sowing.

3.10.2 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 61%. Mean air temperature during emergence was 13.8°C. Rainfall of 1.6mm was reported during this stage. But crop growth reported satisfactory and no abnormal weather reported during emergence

3.10.3 Third Leaf

This phase took 05 days to complete. The mean relative humidity was 60%; mean air temperature was13.8°C. This phase also did not experience any precipitation. Normal crop growth was reported during this stage.

3.10.4 Tillering

This stage of crop growth started on 03-01-2018 and completed on 08-01-2018. The mean air temperature during this phenological stage was 13.4°C and mean relative humidity was 57%. 1.6 mm rain was recorded during this stage.this stage took long time to complete than normal because the minimum temperature droped below 5^{o} C. so, the growth of crop was disturbed.

3.10.5 Shooting

During this phase stem extension occurred in the crop. The mean air temperature was 19.2°Cand mean relative humidity was 58% during this stage. 7.01mm of rainfall received during this phase.

3.10.6 Heading

It is the initiation of reproductive stage of wheat crop. The mean air temperature was 20.9°C during the heading phase. The relative humidity was around 53%. Only 1.0mm of rain was received during this stage.

3.10.7 Flowering

The mean air temperature during this stage was recorded as 22.8°C and mean relative humidity was 51%. Precipitation amount to 10.0 mm distributed over 2 consecutive days was experienced during this stage which affected the pollination process to some extent as it causes shedding of flowers.

3.10.8 Milk Maturity

Seed formation is considered as the most important phenological stage of the plant growth. The mean air temperature was recorded as 26.6°C whereas mean relative humidity during this phase was 38%. No precipitation was recorded during this phase. Higher temperature and dry weather do not allow the grain to grow to its full size.

3.10.9 Wax Maturity

The mean air temperature was 28.7°C and relative humidity was recorded as 39% during wax maturity phase. This stage took 10 days for its completion. This phase also experienced no rainfall. Same happened in the stage too due to higher temperature and dry weather means low RH in air shrinked the grain size.

3.10.10 Full Maturity

Wheat requires high temperature at this stage for maturity. This phase took 7 days to complete. The mean air temperature recorded during this phase was 27.7°C and the relative humidity was 43%.1.80mm rainfall was observed during this phase.

Chapter 4

CONCLUSION AND RECOMMENDATIONS

The crop variety Galaxy was cultivated in the experimental field of Ayub Agriculture Research Institute Faisalabad. The sowing time of wheat is a very important factor. The time of sowing of wheat 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 almost at the proper time. Amount of seed cultivated per acre was 50 kg which is sufficient for the crop cultivated at the start of December. Fertilizer intake was also enough i.e., 2 bags DAP and 1bag Potash at the time of sowing were added to the crop while 1 bag urea during 1st irrigation was added. No rainfall was reported in the month of January. Below normal precipitation was observed throughout the crop season. Irrigation was made five times during the crop season which mostly fulfilled the water requirement of the crop. Day and night time temperatures also observed mostly above normal range except December and January when night temperatures fall below normal values. RH was observed to be below normal throughout the crop life. However ETo remained normal to above normal during most of the crop's. But the high level of ETO, due to high temperatures and below level of RH in early maturity stages affected the crop production. 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. Total heat units consumed by the wheat crop were 1748 accumulated from germination to full maturity in 129 days. On average 13.5 heat units were consumed by the crop per day. Normally these heat units are consumed in 140 days at the rate of 11.6 heat units per day. Crop reached to full maturity eleven days earlier than normal period consuming more heat units per day. From figure 3.9 it is clear that crop consumed above normal heat units at tillering, and wax maturity stages for all the remaining stage it used normal to below normal heat units. As a whole the crop took eleven days less (129) to reach maturity than normal time span of 140 days.

During 2017-18 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.

4.1 Conclusions

During the Rabi season 2017-18, most of the air and soil weather parameters like soil temperature, rainfall, five times irrigation with suitable intervals, were in range required for normal crop growth. But the air temperature which is a very important parameter remained above than normal values. Hence increasing the ETo rate because the RH was low in the crop cycle .But the higher temperature during the milk maturity stage did not allow the grain to grow to its normal size and weight which ultimately lower the final yield of the crop. An addition to high ETo rate, the two days consecutive rain spell of 5 mm per day in flowering stage shaded the flowers of the crop, which can also contribute to reduction in yield. The actual yield of the crop was 1640 kg acre^{-1} while the potential yield of the variety was 2400 kg acre^{-1}. So, the yield obtained was not satisfactory.

4.2 Recommendations

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

1 – Farmers generally plant wheat late in rice-wheat, sugarcane-wheat, and cotton-wheat areas due to late harvesting of Kharif crop which results in drastic low yields because the crop is exposed to heat stress at grain formation stages (milk and wax maturity stages) leading to the formation of shriveled grain. Late-planted crop has lower germination, fewer tillers, smaller heads, shriveled grain and lower biomass than the timely planted crop. Any delay in planting would reduce yield drastically. To achieve good yield, sowing of wheat should be completed up to the mid of November in the irrigated planes of Punjab.

2 – Wheat plant water requirement is maximum during flowering and early grain formation stages (milk and wax maturity stages) followed by vegetative stages. Therefore farmers and other decision makers should make possible the availability of irrigation water to wheat crop keeping this order in mind to get maximum crop yield.

3 – Diseases, especially rusts (Stripe/Yellow Rust, Stem Rust, and Leaf Rust) and emerging scenario of increased incidences of Powdery Mildew and aphid are major biotic stresses of wheat crop that inflict heavy losses when in epidemic form. A simple one-year disease epidemic could cause a 2-3 billion-rupees loss to the country because of reduction in wheat yield (an example of 1977-78 epidemics). Therefore, breeders and pathologists should join hands to develop disease resistant and high yielding varieties in order to cope with threats created by ever changing rust races by using approaches like durable resistance. Farmers should use approved verities of pesticides and insecticides.

4 – The frequency of extreme weather events like heat waves, cold waves, flash flooding, and heavy snowfall 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 wheat production both in irrigated and rainfed areas. 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. Researches should also keep focus on to update sowing dates due to late arrival of winter season and winter rainfall in most of the agricultural plains of Pakistan. 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 wheat 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 wheat 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 wheat. Pre-harvest damage may be checked from attack of birds, animals around wheat fields. Post-harvest losses must be checked from the attack of rodents and other insects, pests and fungi. After proper trashing, wheat grains should be placed under hygienic conditions in fields and in storage places as well. Uses of powdered neem leaves in the bags of wheat grains will also seemed to be useful, which is a traditional treatment for preservation of cereal grains.

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 wheat crop.

References

[1] Chaudhry, Q. Z. and G. Rasul (2004): Agroclimatic Classification of Pakistan, Science Vision Vol.9 No.1-2 (Jul - Dec, 2003) & 3-4 (Jan - Jun, 2004).

[2] Shamshad, K.M. (1988): Meteorology of Pakistan, Royal Book Agency, Karachi, Pakistan.

[3] Monthly Climatic Normals of Pakistan, 1981-2010 (January 2013): Climate Data Processing Center, Pakistan meteorological Department, Karachi.

[4] Economic Survey of Pakistan, 2013-14: http://budget.par.com.pk/dll/1189/

[5] Punjab Agriculture Department 2014: http://www.agripunjab.gov.pk

[6] Pakistan Agricultural Department: http://www.defence.pk/forums/national-political-issues/102679-punjab-door-revolution.html#ixzz2PWvbxY6r/

[7] USDA Foreign Agriculture Service Report (2014): www.fas.usda.gov

[8] Fowler, D. B. (2002): Growth stages of Wheat, Chapter 10: http://www.usask.ca/agriculture/plantsci/winter_cereals/index.php

[9] Imran, A, Q. Zaman and M. Afzal (2013): Temporal Trends in the peak monsoonal precipitation events over Northeast Pakistan, Pakistan Journal of Meteorology. Vol. 10, Issue 19: July 2013.

[10] Mavi, H. S. and Graeme J. T. (2005):Agrometeorology; principals and applications of climate studies in agriculture, international book distributing company, Lucknow, India.

[11] FAO Irrigation and Drainage Paper 33.

[12] Crop water needs chapter10. FAO.(http://www.fao.org/docrep/S2022E/s2022e07.htm).

[13] Naheed, G. Rasul (2009). Water requirement of Wheat crop in Pakistan, an MS dissertation,COMSATS, Islamabad.