Crop Development in Lower Sindh
Tandojam (2015-16)

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Abstract

This study was conducted at RAMC (Regional Agro meteorological Center) Tandojam 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 Agriculture Research Institute Tandojam. 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 2015-16. The wheat crop variety TJ-83 sown in the field under observation, used 1480.7 heat units in 115 days during its life cycle from sowing to full maturity. The water requirement of crop was fulfilled by flood irrigation method. Crop was sown on 07-12-2015. Weather during its growth period remained suitable for crop. Normal to slightly above normal air temperature during the grain formation stages provide the grain enough time to grow to its full size before drying.

Chapter 1

INTRODUCTION

Wheat is the major food crop as well as one of the main agricultural products in Pakistan. This study is based upon field observations of wheat 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 wheat crop variety TJ- 83 was cultivated. This study will help in understanding the effect of different climatic parameters on the growth and yield of wheat crop in Southern 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 1016-2032mm 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 Pakhtunkhwa, 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 have mostly arid climate, 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, 20km way from Hyderabad city on

Mirpurkhas- Hyderabad highway. The latitude and longitude of RAMC Tandojam are 25.25º and 68.33º respectively. Total annual rainfall in lower Sindh ranges 145-155 mm (145 mm in Tandojam), of which 75% is received during summer monsoon period July-Sep and meager rain occurs due to rare westerly waves that pass across lower parts of the country in winter (Figure 1.1). Temperature ranges cool to cold in winter and hot to very hot during summer. More detail about the climate of Tandojam during Rabi season is shown in the figures (1.2 & 1.3). The highest amount of rainfall occurs during Rabi season in the month of February followed by March. Day time mean maximum and night time mean minimum temperatures gradually decrease from November till January, then increase up to March [3].

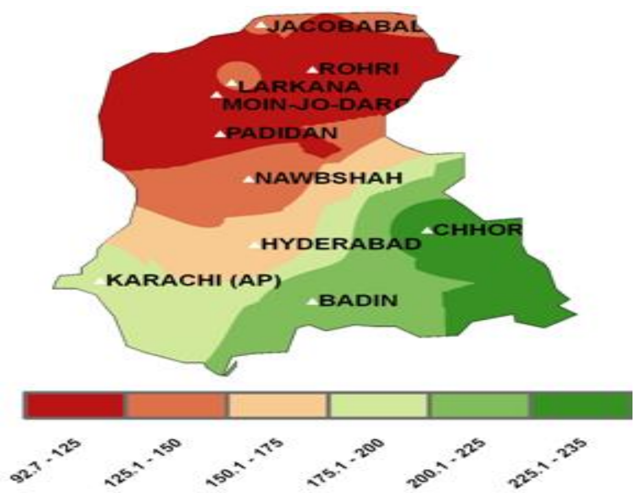

Figure 1.1: Mean Annual Rainfall (mm) of Sindh [Normal (1981-2010)]

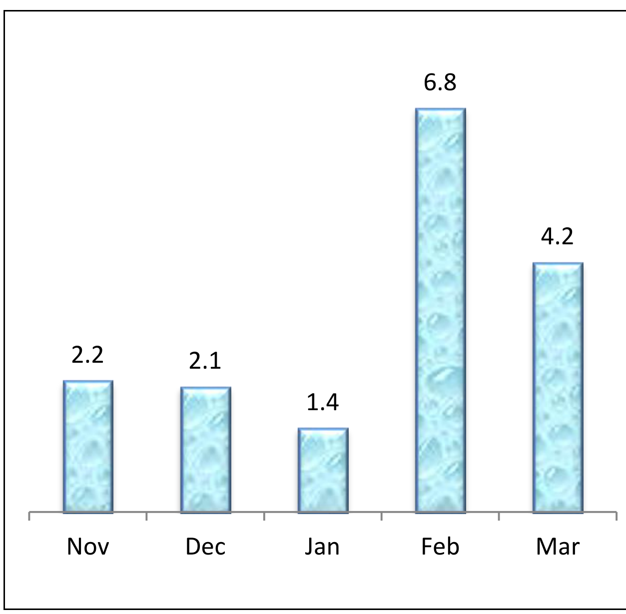

Figure 1.2: Monthly Mean Annual Rainfall (mm) of Tandojam during Rabi Season

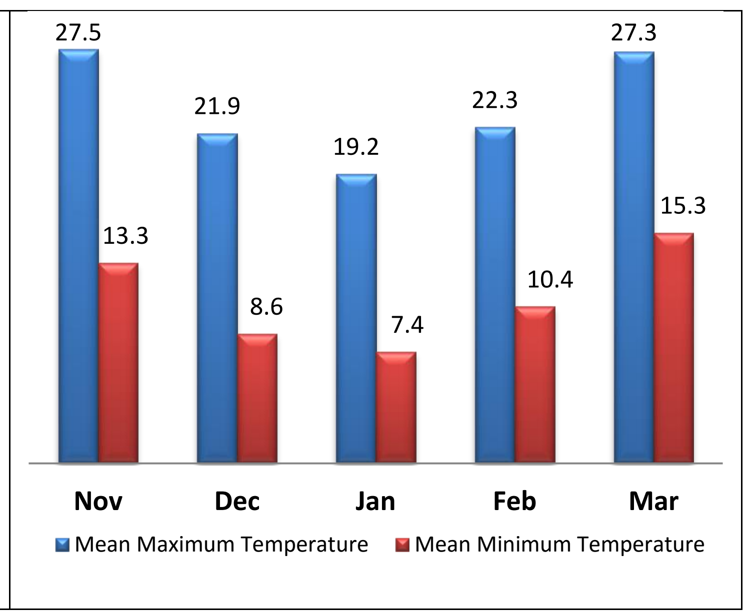

Figure 1.3: Mean daily Maximum and Minimum Temperature (ºC) of Tandojam during Rabi Season

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 pattern resulting 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 impact of various meteorological parameters on crop growth and development in Tandojam area.
- To make an attempt for formulation of yield estimation mechanism, i.e. crop-weather model development.
- To produce valuable information for future research on wheat crop in the region.

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].

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 Cotton Production and 21% in National Wheat Production [6].

1.5 Wheat Production in Pakistan and Sindh

Wheat flour or “Atta” is the staple 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 then most cereals and other food staples. Per capita wheat consumption in our country is estimated at around 124 kg per year. This is among the highest in the world [7].

Keeping above facts in mind; importance of wheat crop is unquestionable for our country. Therefore year to 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 in October to December and harvesting during the month of March to May. In Sindh the crop sowing period is November-December and harvesting period is March-April. Due to climate variation in upper and lower Sindh sowing and harvesting of wheat starts 10 to 15 days earlier in lower Sindh than upper parts. Seed depth for wheat crop in Sindh is 5 cm and row spacing is 23 cm [8]. The growth period of wheat plant is temperature dependant. A fact which not only restricts the choice of the varieties to early maturing types, which grow rapidly, but also influences the geographical distribution of the crop. The wheat season becomes shorter in the direction from north to south in correspondence with the duration of winter, which decreases in the same direction. The crops take 140 -160 days to mature in northern region, 120–140 days in the central region and 100–120 days in the southern warmer parts of the country including Sindh [9].

Chapter 2

MATERIALS AND METHOD

This study is based upon field observations of recommended variety TJ-83 of wheat crop planted in the experimental field of plant physiology section of Sindh Agriculture Research Institute Tandojam in lower Sindh during Rabi season 2015-16.

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

Table 2.1: Observed Meteorological Parameters

1.	Air Temperature (˚C)
2.	Maximum & Minimum Temperature (˚C)
3.	Soil Temperature (˚C)
4.	Relative Humidity (%)
5.	Precipitation (mm)
6.	Pan Evaporation at 0300UTC & 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

A sound understanding of plant growth and development is an essential element of efficient economic wheat management system. The impact of heat, drought, diseases, insects, and weeds can be more accurately predicted with a clear picture of the relationship between growth stage and plant response to stress. The optimum timing of fertilizer, irrigation, herbicide, insecticide, and fungicide applications are also best determined by crop growth or Phenological stage rather than calendar date [12].

Table 2.2: Phenological Stages of Wheat Crop 2015-16

	Phenological stage	Date
1.	Sowing	07-12-2015
2.	Emergence	18-12-2015 To 24-12-2015
3.	Third Leaf	27-12-2015 To 09-01-2016
4.	Tillering	12-01-2016 To 22-01-2016
5.	Shooting	25-01-2016 To 04-02-2016
6.	Heading	07-02-2016 To 17-02-2016
7.	Flowering	20-02-2016 To 04-03-2016
8.	Milk Maturity	07-03-2016 To 14-03-2016
9.	Wax Maturity	17-03-2016 To 22-03-2016
10.	Full Maturity	25-03-2016 To 30-03-2016

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	1 Acre
2	Crop variety	Wheat T-J 83
3	Date of Sowing	07-12-2015
4	Information about any disease/pest attack, Pesticides/weedicides details	No pest attack reported and no pesticides were used.
5	Quantity of seed per acre	50 Kg / acre
6	Row spacing	30 cm
7	Schedule and quantity of supplied dose of fertilizer	2 Bags S.S.P, pre sowing 1 bag Sona Urea @ 1st Irrigation, 1 bag Sona Urea @ 2nd Irrigation, 1 bag Sona Urea @ 3rd Irrigation.
8	Type of irrigation	Tube well + Irrigation
9	Irrigation schedule	**1st** 21/01/2016, **2nd** 12/02/2016, **3rd** 27/02/2016
10	Heat units consumed from sowing to full maturity	1480.7
11	Total days taken by the crop from sowing to full maturity	115
12	Date of harvesting	31-03-2016
13	Actual/ Potential yield	1100/1200 Kg/acre (29.5/30 Mounds)

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 Rabi season 2015–16, no rainfall was reported in Rabi season 2015-16.

Table 3.2: Daily Rainfall History of the Crop Life 2015-16

Year	Phenological stage	Month	Day	Rainfall (mm)	Monthly Total (mm)
2015-16	No Rainfall during Rabi season				

3.2 Irrigation during Crop Growth

The wheat crop was irrigated three times during the entire season before full maturity. First irrigation was made to the wheat crop on 21-01-2016. During the heading stage, second irrigation was given. Third irrigation was given during the flowering stage.

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 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 [14].

The growth and maturity of wheat crop is disturbed at times by abnormal rise in temperature during grain formation stages, due to which the crop is harvested well before its normal harvesting dates and reduced shriveled grain is obtained.

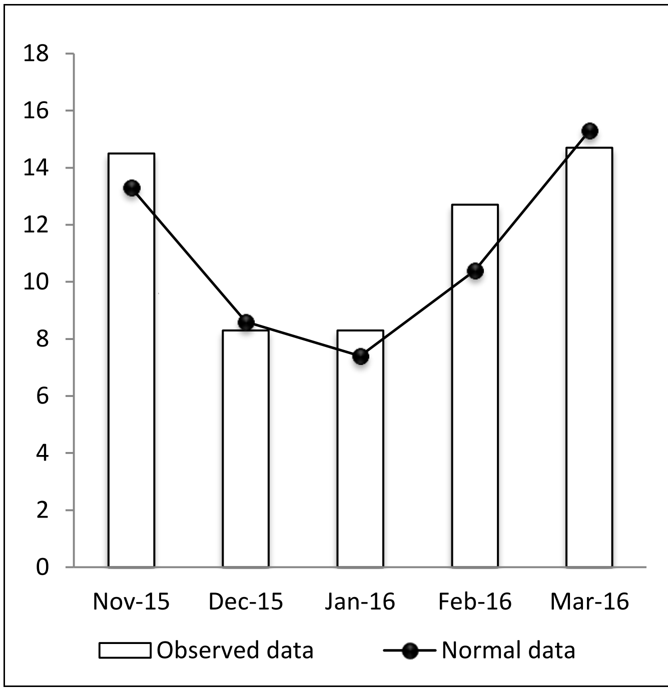

Figure 3.1: Mean daily Minimum Temperature (°C) of Tandojam during the Rabi Season

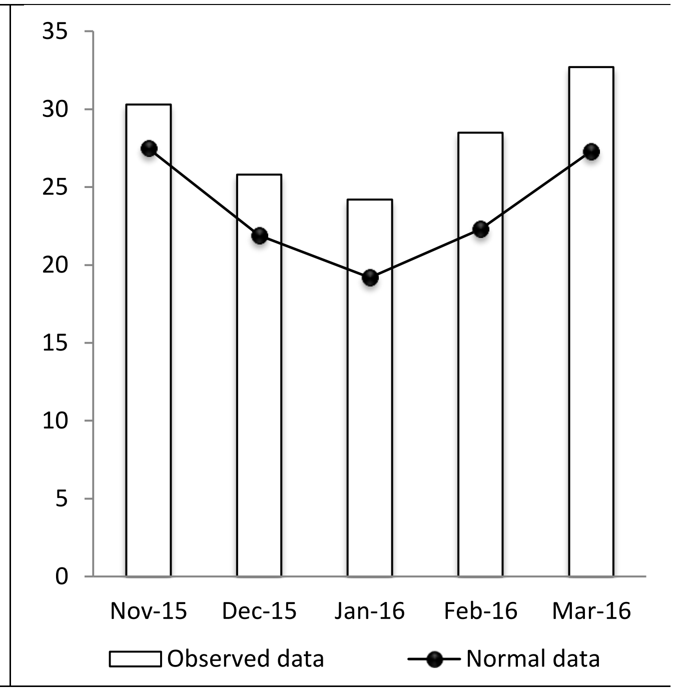

Figure 3.2: Mean daily Maximum Temperature (°C) of Tandojam during the Rabi Season

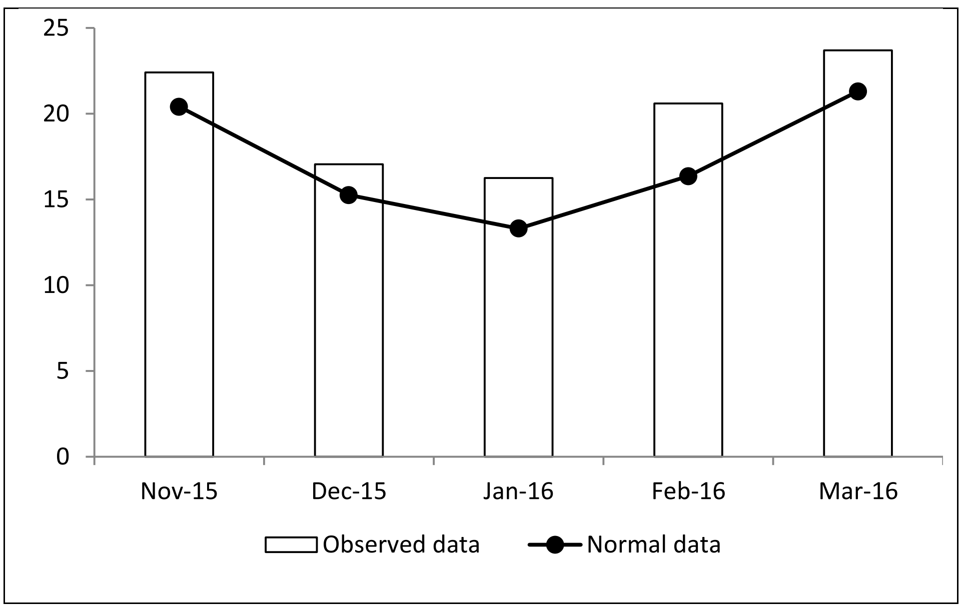

Figure 3.3: Mean Monthly Temperature during 2015-16

During the Rabi season of 2015-16, mean daily and day time maximum temperature remained above normal during the crop life cycle. whereas mean daily minimum temperature remained normal to above normal during early growing stages and maturity stages and remained below normal during middle stages.

Table 3.3: Mean Monthly Temperature during Rabi Season 2015-16

Month	Mean Monthly (°C)	Monthly Mean Max (°C)	Monthly Mean Min (°C)	Absolute Max. (°C)	Absolute Min. (°C)
Dec-2015	17.1 (19.8)	25.8 (26.3)	8.3 (12.5)	32.0 (35.6)	4.5 (3.0)
Jan-2016	17.8 (18.1)	25.4 (25.0)	10.3 (11.1)	29.5 (35.0)	7.0 (-1.0)
Feb-2016	18.8 (20.9)	28.4 (28.1)	9.2 (13.6)	34.0 (39.0)	7.0 (2.0)
Mar-2016	25.7 (26.2)	34.1 (33.9)	17.1 (18.5)	39.0 (47.0)	13.5 (5.0)
*** ( ) 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 [15].

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

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

During the Rabi season of 2015-16, from the observed soil moisture data, figure 3.4 to figure 3.7 depicts that soil moisture remained satisfactory during intermediate stages of the crop due to in time supply of irrigation water. It remained on lower side during early growth (December) due to absence of irrigation and rain water (first irrigation was given to the crop on 21st of January). Throughout the crop life soil moisture remained more satisfactory in intermediate or major root zone and deep layers, whereas, it remained slightly deficit in shallow layers due to sensible heating of direct solar radiation. Overall condition of soil moisture was satisfactory especially during the most demanding phases.

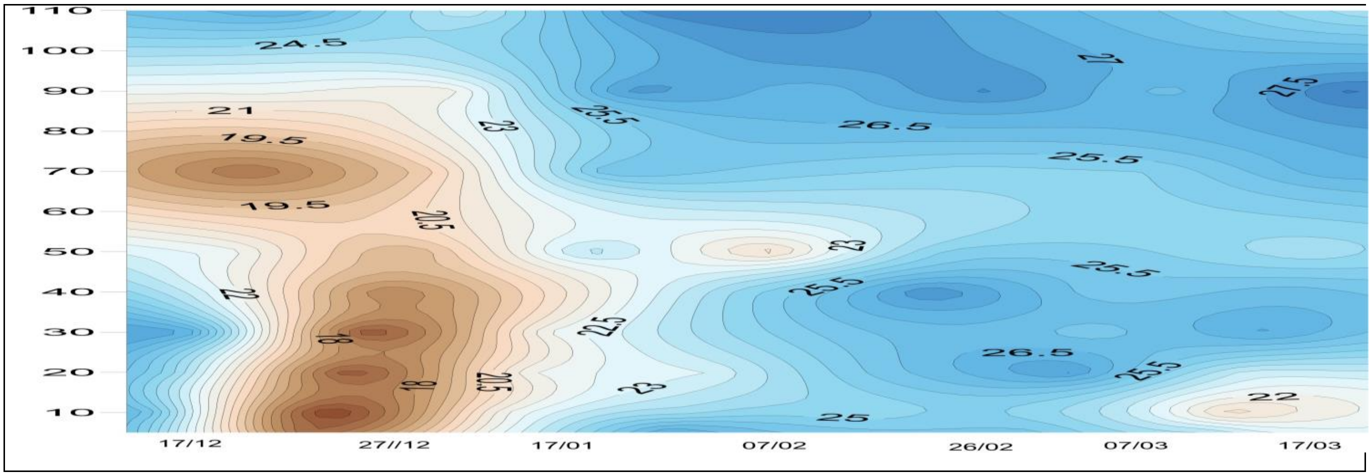

Figure 3.4: Soil Moisture Chrono Isopleths for Rabi Crop at Tandojam for the Year 2015-16

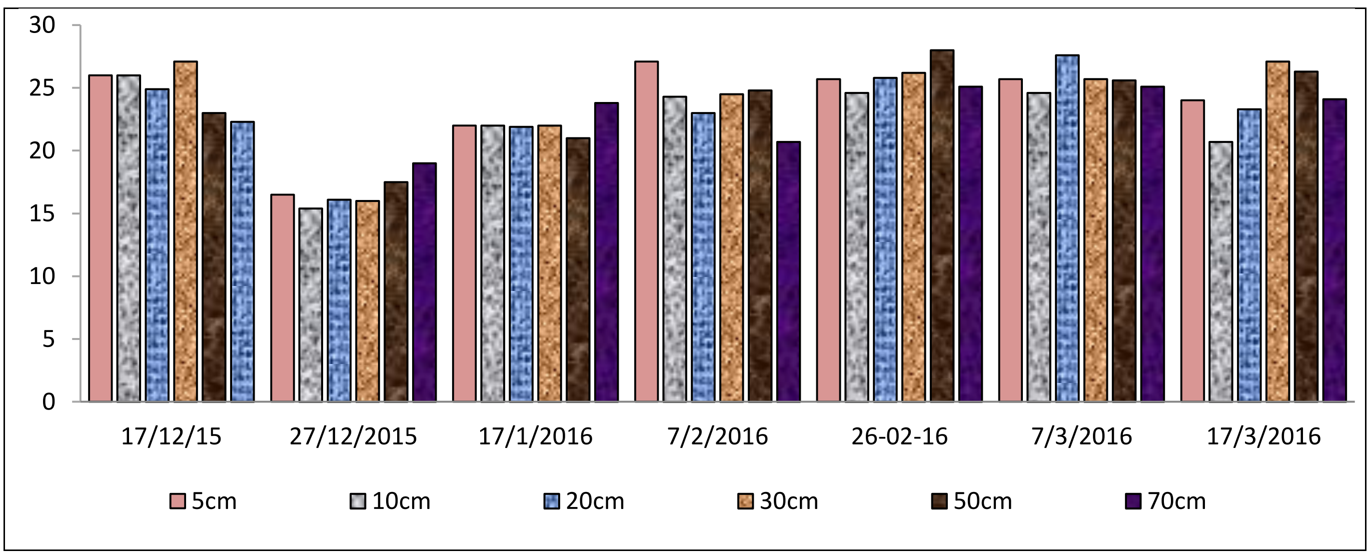

Figure 3.5: Soil Moisture at Different Depths During Rabi Season 2015-16

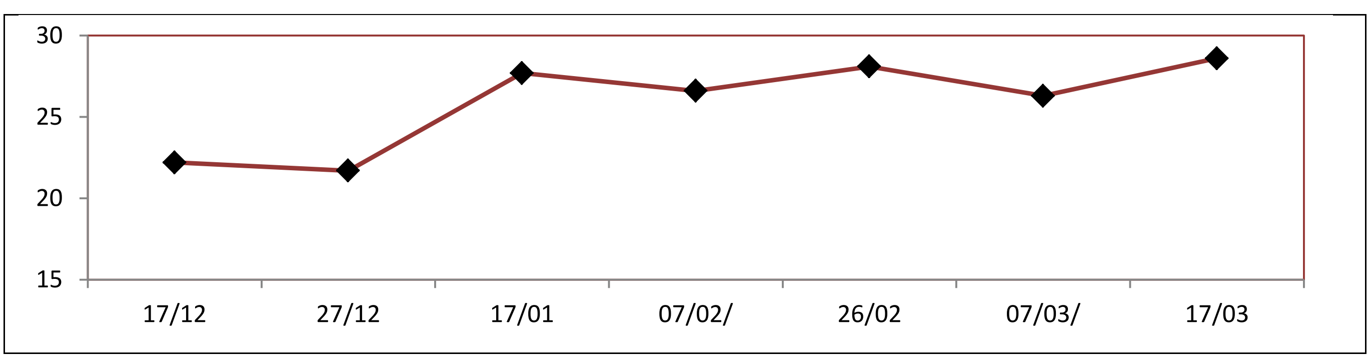

Figure 3.6: Soil Moisture at Deep Soils (90cm) Depths during Rabi Season 2015-16

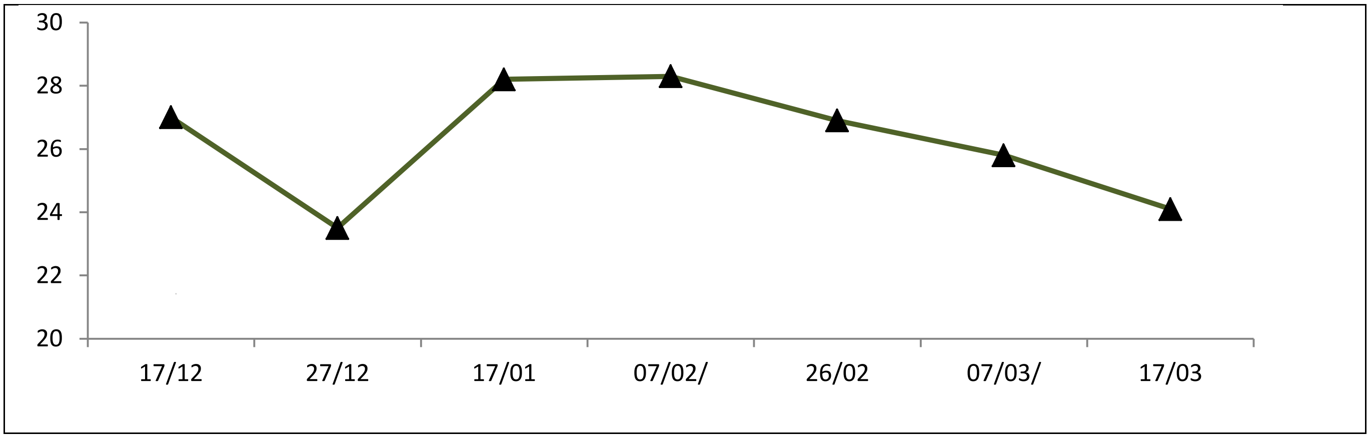

Figure 3.7: Soil Moisture at Deep Soils (110cm) Depths during Rabi Season 2015-16

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 and composition of soil. Soil temperature influences the germination of seeds, the functional activity of the root system, the incidence of plant diseases and the rate of plant growth. Optimal soil temperature for growth of wheat plant roots during the vegetative stage is below 30°C and is further lower than that for the shoots. Temperature higher than 35°C has been shown to reduce terminal root growth [14]. 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. Diurnal variations in soil temperature are more significant at shallow layers than deep soils. Soil temperature varies as soil moisture varies from depth to depth and time to time. Soil thermometers in °C were installed at depths of 5cm, 10cm, 20cm, 30cm, 50cm ,70cm, 90cm and 100 cm to monitor thermal regime of the soil. The soil temperature was observed and then recorded three times a day i.e., 0300, 0900 and 1200 UTC.

Note: This soil temperature data is collected from the soil observations taken at Agro met observatory of RAMC Tandojam 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 Rabi season 2015-16, soil temperature remained normal to above normal during December. It remained below normal at shallow layers and normal to above normal for intermediate layers during the month of January, February and March. The overall effect of the soil temperature favoured crop growth throughout its life cycle.

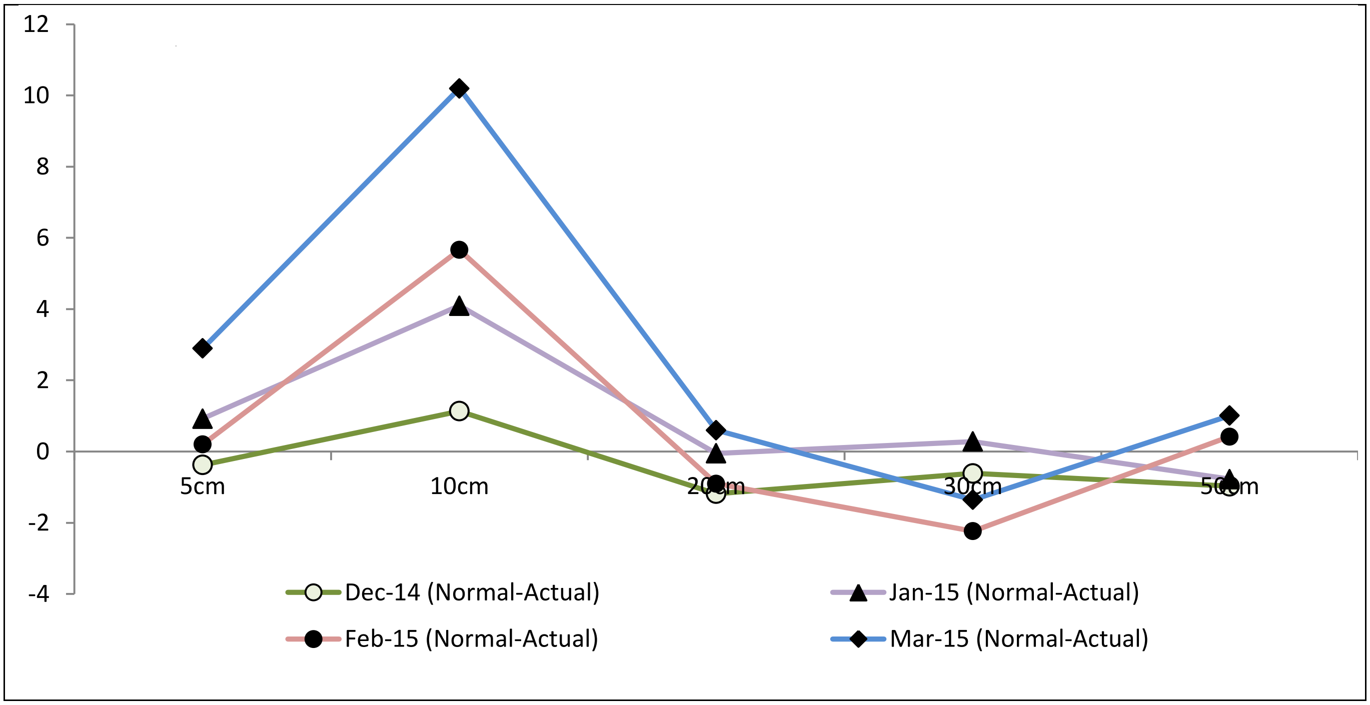

Figure 3.8: Soil Temperature during Rabi Season 2015-16

3.6 Heat Units Consumption during Crop Cycle

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

Heat units, 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].

Heat Units Consumption During 2015-16

Interphase period for wheat crop during the Rabi season 2015-16 of the wheat variety TJ-83 and corresponding heat units at Tandojam 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 1480.7 accumulated from sowing to full maturity in 115 days. On average 13 heat units were consumed by the crop per day. From figure 3.9 it is clear that crop consumed normal to above normal heat units except at emergence and heading stages during which slightly below normal heat units were consumed so that these phases completed slightly later than normal time.

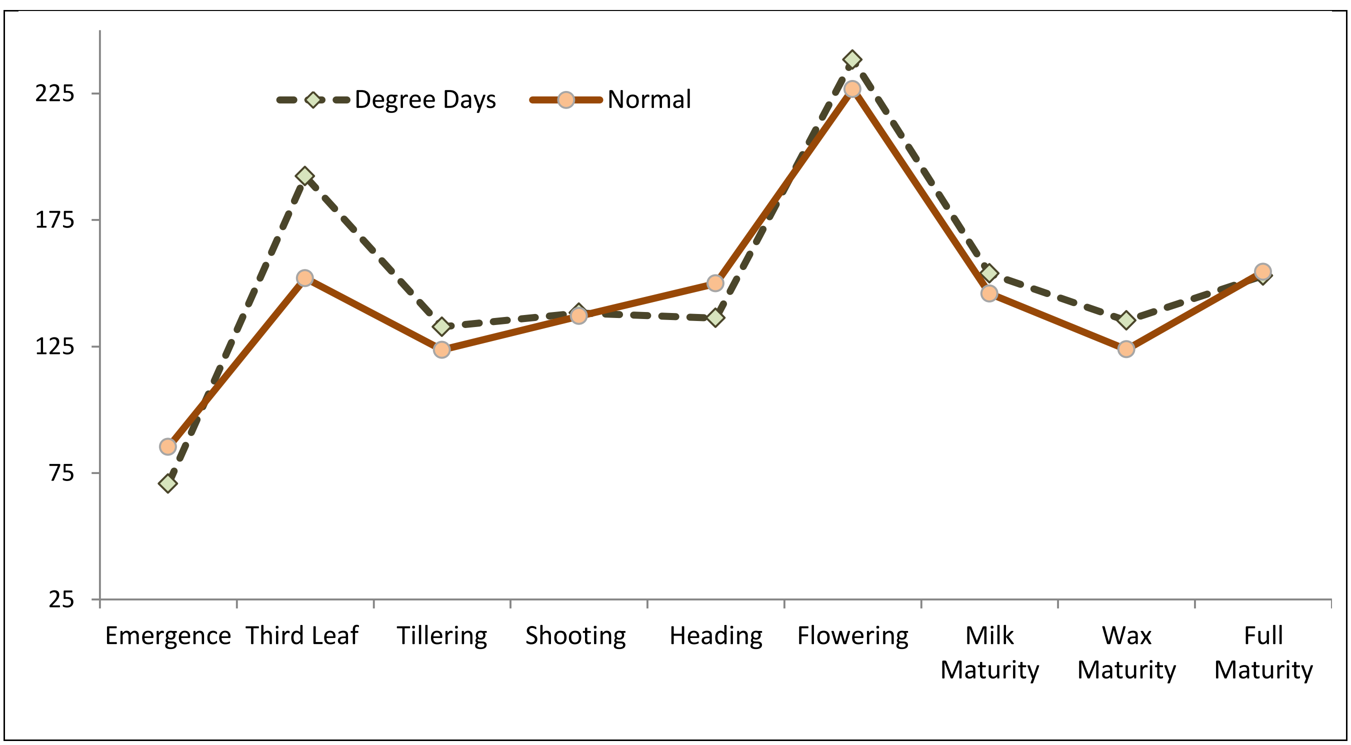

Figure 3.9: Heat Units Consumed by Wheat Crop during Rabi Season 2015-16

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
1.	Sowing to Emergence	07-12-2015 To 17-12-2015	11	129.8	146.3
2.	Emergence to Third Leaf	18-12-2015 To 25-12-2015	08	70.8	85.3
3.	Third leaf to Tillering	26-12-2015 To 10-01-2016	16	192.3	152.0
4.	Tillering to shooting	11-01-2016 To 23-01-2016	13	132.8	123.6
5.	Shooting to heading	24-01-2016 To 05-02-2016	13	138.3	137.0
6.	Heading flowering	06-02-2016 To 18-02-2016	13	136.3	149.9
7.	Flowering to Milk maturity	19-02-2016 To 05-03-2016	16	238.4	226.7
8.	Milk maturity to wax maturity	06-03-2016 To 15-03-2016	10	153.8	146.0
9.	Wax maturity to full maturity	16-03-2016 To 30-03-2016	15	288.2	278.4
10.	**Sowing to Maturity**	**07-12-2015 To 30-03-2016**	**115**	**1480.7**	**1445.2**

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 (According to FAO technical paper on water management for crops) 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, solar radiation and relative humidity. Solar radiations are calculated with the help of "total bright sunshine hours data" and "bright sunshine hours data of a particular station". Sunshine recorders with sunshine cards are used for sunshine hours recording.

During the Rabi season 2015-16, relative humidity remained normal to below normal, whereas, ETo remained below normal during most of the growing period. Below normal RH during vegetative stages of the crop did not produce any harmful effects on crop growth due to in time irrigation and below normal ETo. 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 Rabi season 2015-16, no such bad weather event was observed. Wind speed was observed mostly normal and any significant wind speed accompanied by severe weather event was not observed throughout this period.

Table 3.5: Summary of some Meteorological Parameters during Rabi Season 2015-16

Month	Wind speed (km/hr)	RH (%)	Days with mean RH ≥ 80%	ETo (mm/day)	Solar Radiation Mj/M^2/day
Nov-15	3.0	48	0	3.0	17.2
Dec-15	2.3	58	0	2.0	13.2
Jan-16	2.2	59	0	3.0	13.2
Feb-16	2.8	44	0	3.2	16.3
Mar-16	5.8	47	0	5.1	20.2

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 wheat 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 [17].

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),

$$ET_{crop} = Kc.\ ETo \quad \text{or} \quad CWR = Kc.\ ETo.$$

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.

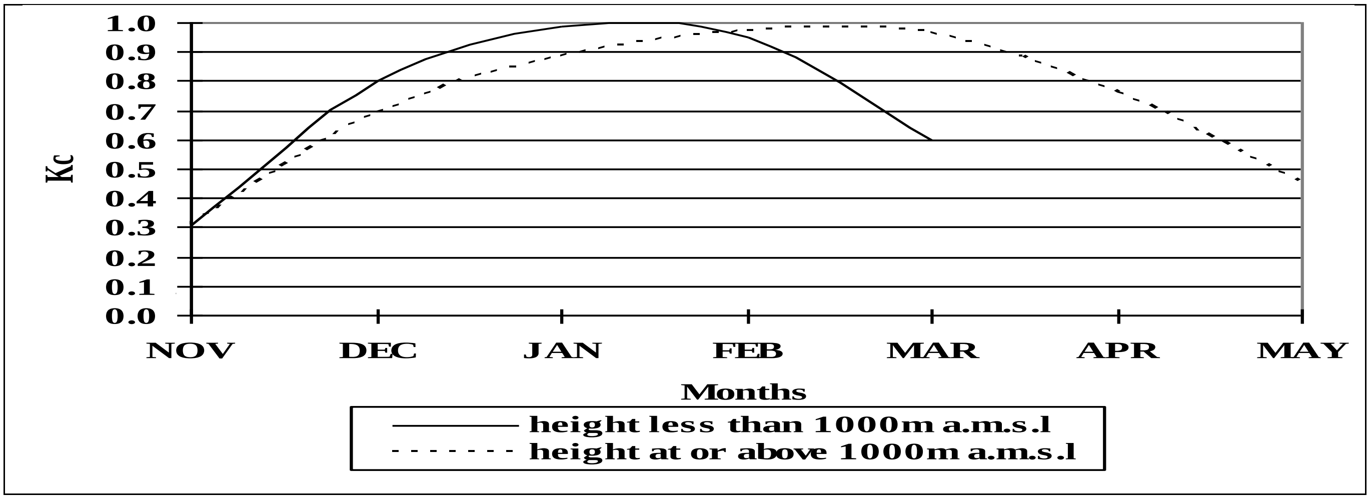

Figure 3.10: Graph of Crop Coefficient (Kc) for normal duration of Wheat growing season (Emergence to Wax Maturity)

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

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

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 (ETo) which is utilized through soil moisture [13].

During the Rabi Season 2015-16, crop water requirement of wheat crop was observed normal to below normal throughout the crop growth (Figure 3.11 & Table 3.7). It means that crop growth did not suffer in any phase due to sharp rise in crop water demand. Thus the available irrigated and rain water fully satisfied moisture requirement of the crop, which resulted normal crop growth.

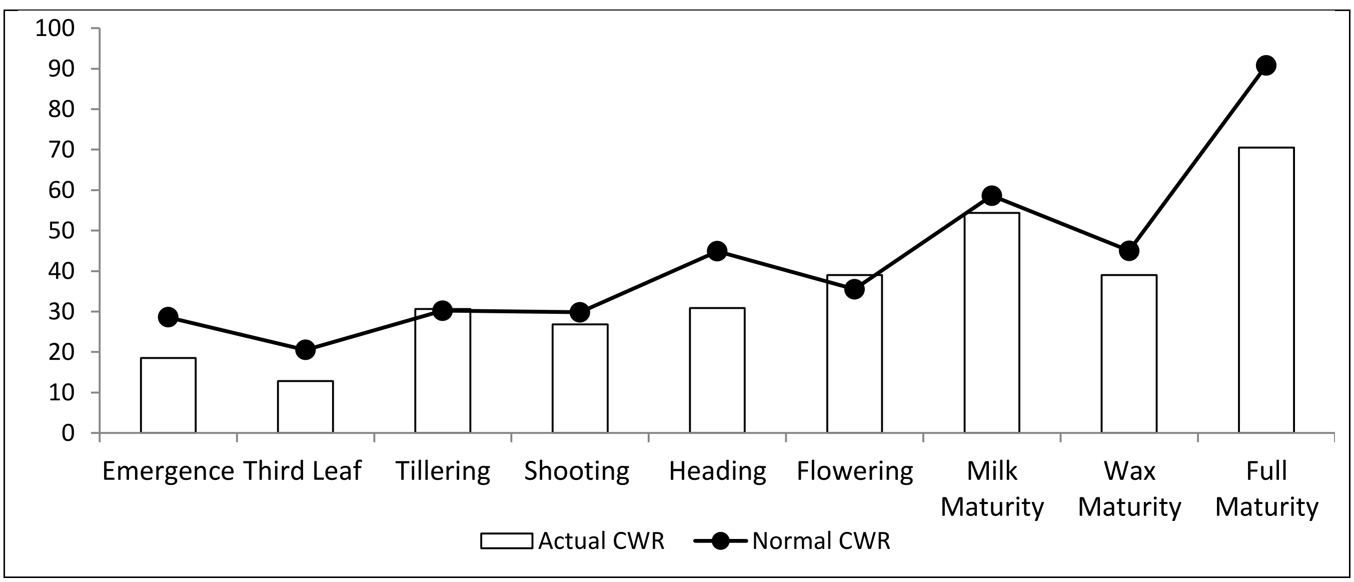

Figure 3.11: Crop Water Requirement (CWR) During Crop Life

Table 3.7: Crop Water Requirement During Different Phenological Phases

S. No.	Inter Phase	Period	No. of Days Taken	ETo (mm)	*ETo (mm)	CWR=Kc ETo	*CWR=Kc ETo
1.	Sowing to Emergence	07-12-2015 To 17-12-2015	11	23.1	35.8	18.5	28.6
2.	Emergence to Third Leaf	18-12-2015 To 25-12-2015	08	16.0	25.6	12.8	20.5
3.	Third leaf to Tillering	26-12-2015 To 10-01-2016	16	33.6	33.2	30.6	30.2
4.	Tillering to shooting	11-01-2016 To 23-01-2016	13	27.3	30.4	26.8	29.8
5.	Shooting to heading	24-01-2016 To 05-02-2016	13	31.2	45.3	30.9	44.9
6.	Heading to flowering	06-02-2016 To 18-02-2016	13	39.0	35.5	39.0	35.5
7.	Flowering to Milk maturity	19-02-2016 To 05-03-2016	16	54.4	58.6	54.4	58.6
8.	Milk maturity to wax maturity	06-03-2016 To 15-03-2016	10	39.0	45.0	39.0	45.0
9.	Wax maturity to full maturity	16-03-2016 To 30-03-2016	15	70.5	90.8	70.5	90.8
10.	**Sowing to Maturity**	**07-12-2015 To 30-03-2016**	**115**	**334.1**	**400.2**	**322.4**	**383.9**

*** Normal Values (1981-2010)**

3.11 Agro Meteorological Summary of Crop Cycle

Different meteorological parameters were recorded at various phases of wheat crop during 2015-16. The impact of these parameters at different phenological stages of wheat crop is discussed as under:

3.11.1 Sowing

Wheat crop was sown during the first week of December on 07-12-2015. The temperature was suitable during this stage.

3.11.2 Emergence

Emergence phase was distinguished by the appearance of cotyledons. When plant emergence stage was completed, the field was divided into four replications. The mean relative humidity was 55% at the time of emergence. Mean air temperature during emergence was found to be 13.5°C – 16.3°C. However optimum ranges vary generally for all varieties of wheat crop. Soil temperature at the sowing depth was 23.4°C – 36.3°C.

3.11.3 Third Leaf

In third leaf phase, with 75% occurrence, mean relative humidity was about 57% and mean air temperature ranges between 17.3°C – 20.5°C. This phase ended up to 09-01-2016.

3.11.4 Tillering

This stage of crop growth started on 12-01-2016 and 75% occurrence was completed on 22-01-2016. The mean air temperature ranged between 15.8°C – 18.5°C and mean relative humidity was 54%. This phase was considered as the active period of tillering process, although it continued during shooting also. First irrigation was given during this stage on 21-01-2016.

3.11.5 Shooting

This is the most important growth period of plant development. During this stage stem extension occurred in the crop. For the wheat crop, mean air temperature ranged between 15.5 – 20.8°C, the soil temperature at the sowing depth remained 22.5°C at 5cm depth, while the relative humidity remained 56%.

3.11.6 Heading

It was the initiation of reproductive stage of wheat crop. Heading stage started on 07-02-2016 and was completed 17-02-2016. The mean air temperature was about 14.5°C - 20.0°C, during this stage soil temperature was not 22.5°C and mean relative humidity was 44%. Second irrigation was given during this stage on 12-02-2016.

3.11.7 Flowering

Flowering started in the last week of February and completed till first week of March. Mean air temperature was recorded 20.0°C – 24.5°C and mean relative humidity was 49%. Third irrigation was given during this stage on 27-02-2016.

3.11.8 Milk Maturity

Wheat has varying requirements for temperature and soil moisture during seed formation. This phase started on 07-03-2016 and ended on second week of March. The mean air temperature ranged 21.5°C – 26.0°C.

3.11.9 Wax Maturity

This started on 17-03-2016 and ended on 22-03-2016.The mean air temperature ranged 26.5°C – 28.8°C. The mean relative humidity during this phase was 40%.

3.11.10 Full Maturity

Wheat requires high temperature at this stage. The mean relative humidity at this stage was 45%, mean air temperature recorded was 25.3°C – 30.3°C. The highest temperature recoded at this stage was 39.0°C.

Chapter 4

CONCLUSION AND RECOMMENDATIONS

The crop variety TJ-83 was cultivated in the experimental field of Agriculture Research Institute Tandojam. 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 on 07-12-2015. Amount of seed cultivated per acre was 50 kg which is sufficient for the crop cultivated in December. Fertilizer intake was also enough i.e., 2 bags SSP before sowing , 1 bag sona urea at 1st irrigation, 1 bag sona urea at 2nd irrigation during tillering stage, and 1 bag sona urea at 3rd irrigation during heading stage, was added to the crop. No rainfall was reported during Rabi season from December to March. Irrigation was made 3 times during the season which mostly fulfilled the water requirement of the crop. Mean daily and day time maximum temperature remained above normal during the crop life cycle, whereas mean daily minimum temperature remained normal to above normal during early growing stages and maturity stages and remained below normal during middle stages. RH was observed normal to below normal throughout the crop life. However ETo remained below normal during most of the crop's growth period. As a result soil moisture content remained on lower side during early growth (December) due to absence of irrigation and rain water (first irrigation was given to the crop on 21st of January). Overall condition of soil moisture was satisfactory especially during the most demanding phases. 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 wheat crop were 1480.7 accumulated from sowing to full maturity in 115 days. On average 13 heat units were consumed by the crop per day. From figure 3.9 it is clear that crop consumed normal to above normal heat units except at emergence and heading stages during which slightly below normal heat units were consumed so that these phases completed slightly later than normal time. Overall the crop consumed almost normal heat units and matured in normal time period.

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 2015-16 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 Conclusion

During the Rabi season 2015-16, most of the air and soil weather parameters like air and soil temperature, rainfall, three times irrigation with suitable intervals, R.H and crop water requirement favored normal crop growth. The crop was cultivated in time with normal fertilizer doze and weeds removing spray at suitable intervals. Normal weather conditions throughout the crop life cycle favoured its growth and hence the yield of the crop.

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 lower Sindh 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, wheat sowing should be carried out well in time.

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 o facing water shortages and drought conditions for the last several years due to lesser rains and high temperatures due to global warming which resulted in hampering of 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 go downs 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.

11– Latest recommended varieties of wheat crop by Agricultural department for Sindh are: TD-1, TJ-83, Anmol-91, Moomal-02 and Abadgar-93, Bhittai, Marvi-2000.

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