Crop Development in Lower Sindh (Tandojam) (2016-17)

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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 2016-17. The wheat crop variety Imdad was sown in the field under observation. The crop used 2090 heat units in 129 days during its life cycle from sowing to full maturity. 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 shrived and did not gained its original volume. The actual yield by the crop variety Imdad grown is 750 kg acre^{-1} while its potential yield is 1200kg 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 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 Imdadwas cultivated. This study will help in understanding the effect of different climatic parameters on the growth and yield of wheat crop in South 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, which is 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, 20 km 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), shown in figure 1.1, 75% of this 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. Temperature ranges cool to cold in winter and hot to very hot during summer [3]. More detail about the climate of Tandojam in the Rabi season is given below in the figures 1.2 and 1.3. The figure 1.2 shows that the lowest amount of rainfall is received in January, followed by November and December and the highest amount of rainfall is received during the month of March. And the figure 1.3 shows about the mean maximum and mean minimum temperatures, which gradually decreases from November to January and then increases till March during the crop season.

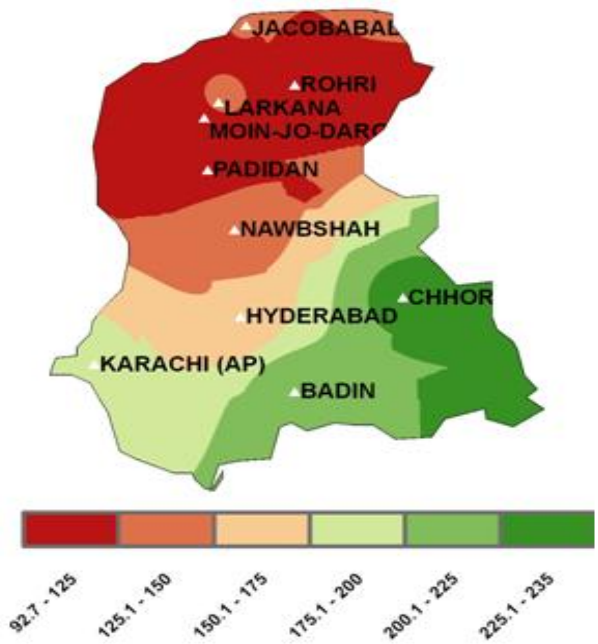

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Figure 1.1:Mean Annual Rainfall (mm)of Sindh [Normal (1981-2010)

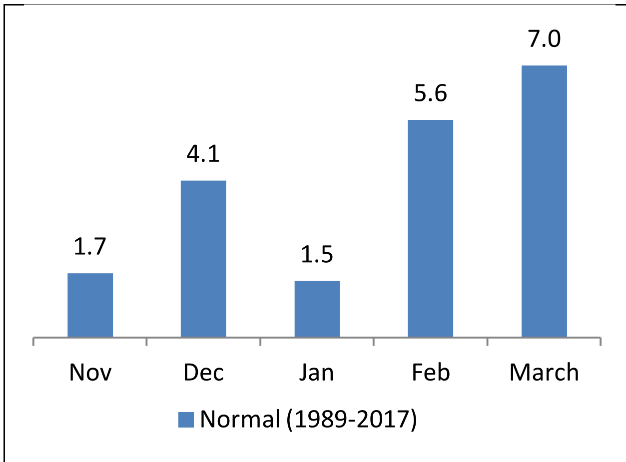

Figure 1.2: Mean monthly Anuual Rainfall(mm) of Tandojam during Rabi season

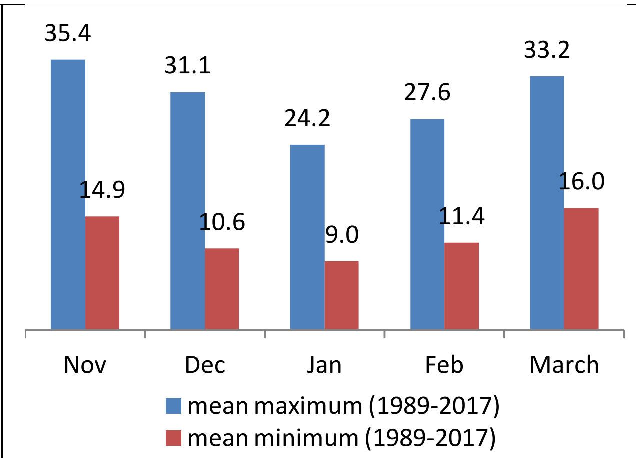

Figure 1.3: Mean daily maximum and minimum temperature (°C) of Tandojam during Rabi season

1.2Scope 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 patternresulting 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. Thiscould 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 Tandojam region.
- To develop the relationship between weather parameters, crops life cycle and yield obtained.

1.4 Review of Agriculture Production in Pakistan

Pakistan is an agrarian country whose population and economy (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 while 43% of the labor force is engaged in this sector. [4] The crops are the 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 andlower 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 [2]. 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 [8].

The fertile land of the province of Sindh occupies southeastern parts of the country, which is famous for the production of cotton, wheat, rice, sugarcane, mango, banana, vegetables and other orchards. Sindh can be compared with Egypt since for the last 1000 years; both have received the gift of alluvium deposited by the rivers Indus and Nile, respectively. Well-drained loams and clay loams of Sindh is considered as ideal soil for wheat production. This is the main reason for the domination of fertile land of Sindh in per hector yield among all the agricultural plains of the country [9].

Chapter 2

Materials and Method

This study is based upon field observations of recommended variety Imdad of wheat crop planted in the experimental field of plant physiology section of Sindh Agriculture Research Institute Tandojam in lower Sindh during Rabi season 2016-17.

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 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

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 best determined by crop growth or Phenological stage rather than calendar date [10].

Table 2.2: Phenological Stages of Wheat Crop 2016-17

	Phenological stage	Date
1.	Sowing	**08-11-2016.**
2.	Germination	**10-11-2016 to 14-11-2016**
3.	Emergence	**15-11-2016 to 19-11-2016**
4.	Third Leaf	**20-11-2016 to 30-11-2016**
5.	Tillering	**01-12-2016 to 19-12-2016**
6.	Shooting	**20-12-2016 to 08-01-2017**
7.	Heading	**09-01-2017 to 20-01-2017**
8.	Flowering	**21-01-2017 to 11-02-2017**
9.	Milk Maturity	**12-02-2017 to 19-02-2017**
10.	Wax Maturity	**20-02-2017 to 08-03-2017**
11.	Full Maturity	**09-03-2017 to 18-03-2017**

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 then 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

The methodology applied for the particular study is to compare the Meteorological data of the

Rabi season with the normal values derived from 29 years i.e. 1989- 2017 data of Rabi season of the study area. The effects of various Meteorological parameters over the Phenological stages and non meteorological parameters like time of sowing, fertilizer intake, amount and variety of seed cultivated, irrigation schedule and pest/ weed attacks on the crop are studies too and discussed in the next chapter.

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 100-122 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	½ Acre
2	Crop variety	Imdad
3	Date of Sowing	08-11-2016
4	Information about any disease/pest attack,	Nil
5	Pesticides and weedicides details	Nil
6	Quantity of seed per acre	50 Kg / acre
7	Row spacing	23cm
8	Schedule and quantity of supplied dose of fertilizer	• 2 Bag S.S.P, pre sowing • 1 bag Sona urea at 1st Irrigation • 1 bag Urea at 2nd Irrigation • 1 bag Urea at 3rd Irrigation.
9	Type of irrigation	Tube well irrigation
10	Irrigation schedule	• 1st 17/11/2016 • 2nd 17/12/2016 • 3rd 07/01/2017 • 4th 07/02/2017 • 5th 27/02/2017
11	Heat units consumed from sowing to full maturity	2090
12	Total days taken by the crop from sowing to full maturity	129
13	Date of harvesting	19-03-2017
14	Actual/ Potential yield	750 Kg $acre^{-1}$/1200 Kg $acre^{-1}$

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. [11]

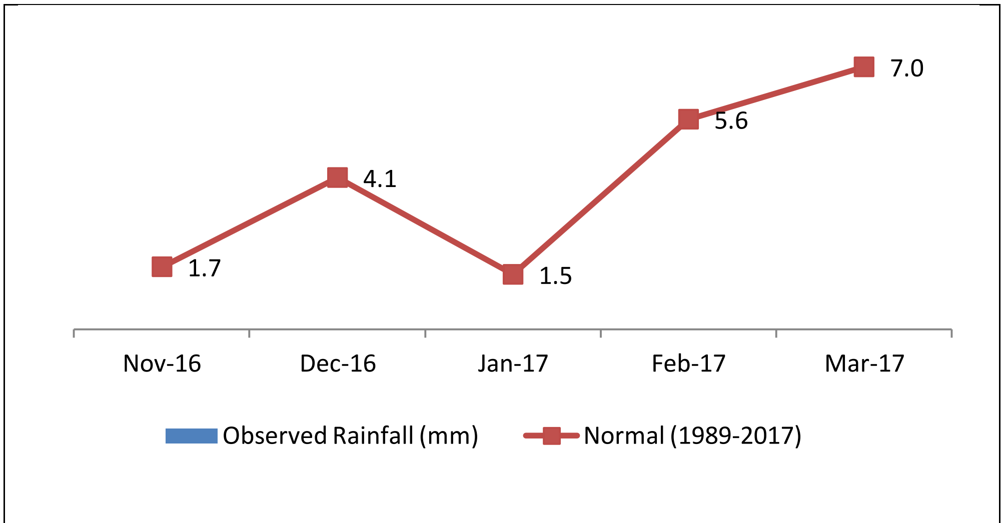

Figure 3.1: Comparison of Monthly observed rainfall with Normal (1989-2017) at Tandojam during Rabi season 2016-17.

During the crop season 2016–17: Figure 3.1 shows that there was no rainfall recorded in the crop life cycle.

3.2 Irrigation during Crop Growth

The wheat crop was irrigated five times during the entire season before full maturity. Crop was first irrigated at emergence phase. During the Tillering, shooting, flowering and Wax maturity stages it was irrigated second, third, fourth and fifth time respectively.

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 [12].

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.

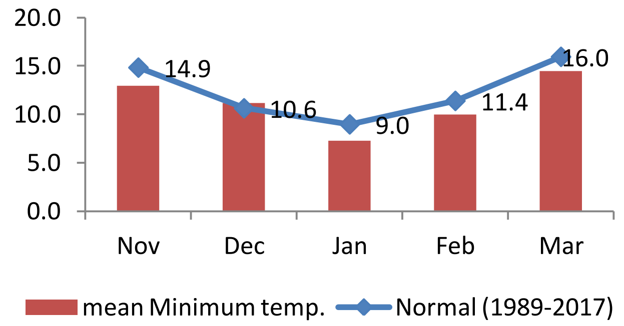

Figure 3.2: Comparison of Mean minimum temperature with Normal (1989-2017) at Tandojam during Rabi season 2016-17.

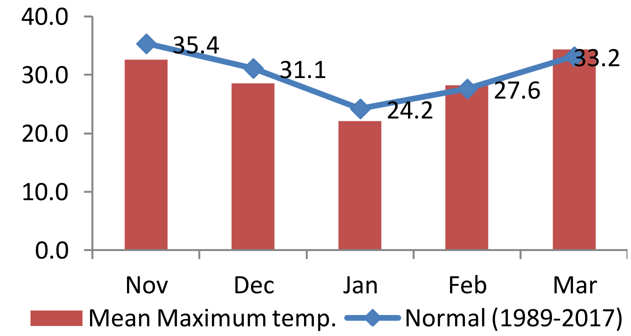

Figure 3.3: Comparison of Mean maximum temperature with Normal (1989-2017) at Tandojam during Rabi season 2016-17.

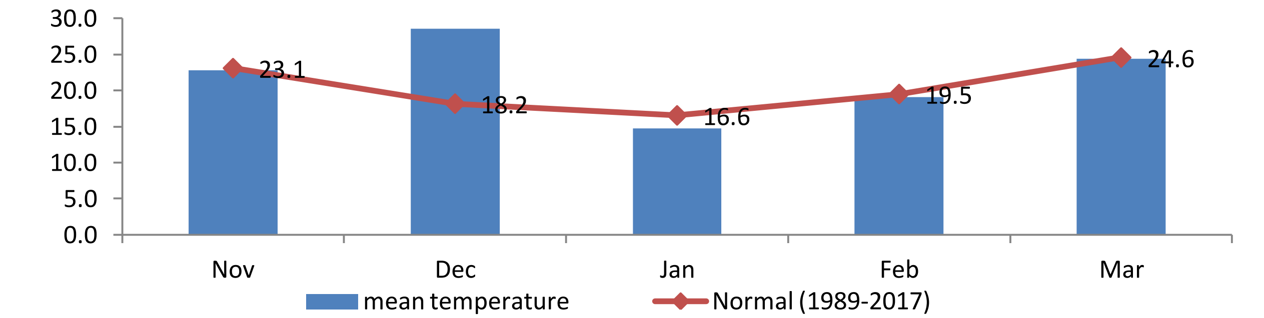

Figure 3.4: Comparison of Monthly Mean temperature with Normal (1989-2017) at Tandojam during Rabi season 2016-17.

During the crop season of 2016-17, an abnormal rise in day time temperature occurred during the month February and December. The rise in December did not affect the crop because the RH was high in the air at the stage and secondly the crop was in growing stages i.e. vegetative stages. And in these stages the temperature didn't reached its optimal value at which the crop stops growing. But the rise of temperature in the month of February, negatively affected the crop yield by shrinking the seed size. It was because the temperature raised and the RH was low in air this time and the crop was in its maturity stages, as a result the evoptranspiration occurred.

Table3.2: Mean Monthly Temperature during Rabi Season 2016-17

Month	Mean Monthly (°C)	Monthly Mean Max.(°C)	Monthly Mean Min(°C)	Absolute Max. (°C)	Absolute Min. (°C)
Nov-2016	22.8 (23.1)	32.6 (35.4)	12.9 (14.9)	37.0 (35.0)	9.5 (10.3)
Dec-2016	19.9 (18.2)	28.5 (31.1)	11.2 (10.6)	35.5 (30.8)	8.0 (6.1)
Jan-2017	14.7 (16.6)	22.1 (24.2)	7.3 (9.0)	29.5 (29.2)	4.5 (4.7)
Feb-2017	19.1 (19.5)	28.2 (27.6)	10.0 (11.4)	34.5 (33.1)	5.5 (6.3)
Mar-2017	24.4 (24.6)	34.4 (33.2)	14.5 (16.0)	42.0 (38.8)	6.5 (10.6)

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 [13].

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.

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

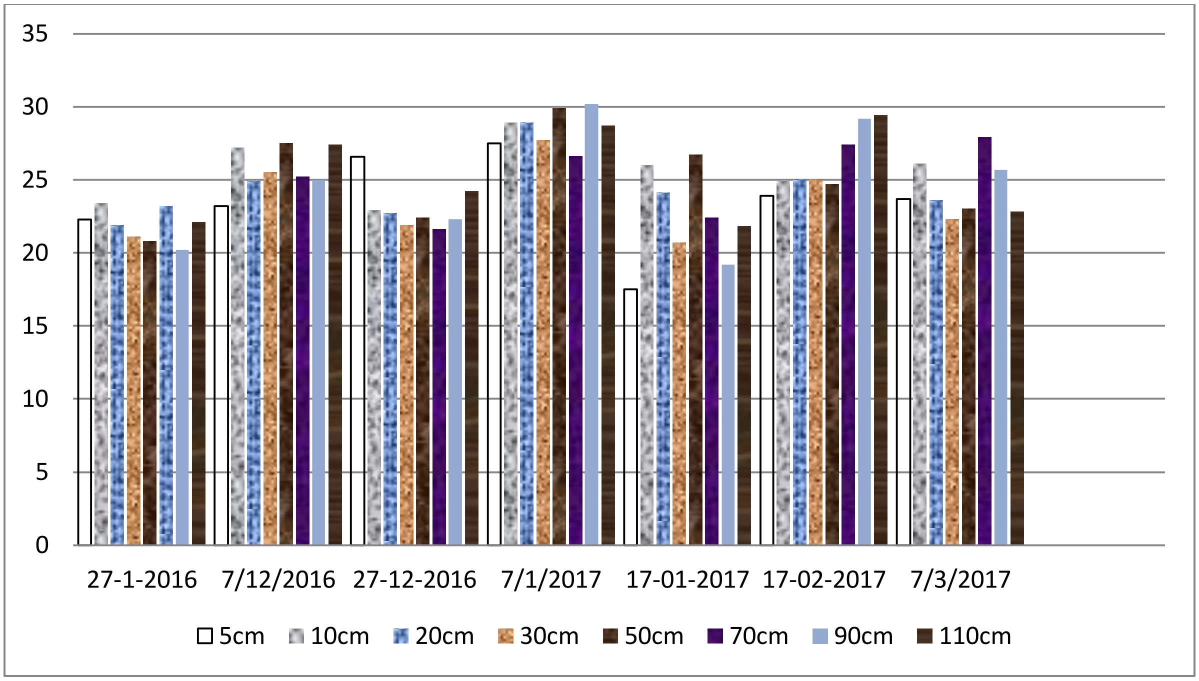

Figure3.6: Soil moisture at different depths during wheat crop 2016-17

During the crop season 2016-17, the soil moisture remained satisfactory all over the stages of the crop.

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 30°C and is further lower than that for the shoots. [12]

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. 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 (°C) were observed and then recorded three times a day at 0300, 0900 and 1200 UTC. The depth at which the soil temperatures were observed on daily basis includes 5, 10, 20, 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 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.

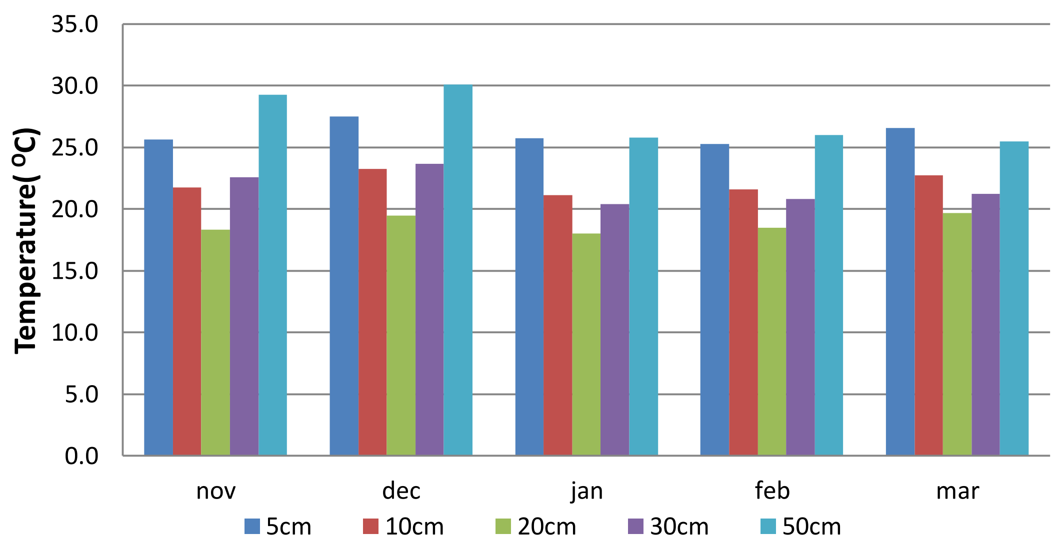

Figure 3.7: Soil temperature during Rabi crop Tandojam 2016-17.

During the crop season 2016-17, soil temperature was observed mostly normal at all depths and remained below 30 °C all the stages, which indicates normal plant and root growth during the crop cycle.

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

Therefore heat unit consumption decides full maturity/ harvesting or completion of a particular phase of the crop. Heat units thus provides an authentic guess to predict the Phenological phase appearance and hence the maturity of the crop. As we all know, there are large variations in temperature from day to day and season to season. The use of thermal time or heat units rather than calendar time takes this variability into consideration and provides an explanation for differences in crop maturity when observations from different years are compared.

But sometimes drought, pest and disease, and variation of nitrogen and phosphorous in the soil may vary heat units requirement of the same variety season to season.

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

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

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

  $H.U = 0:$

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

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

Heat units with effective method are calculated as under:

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

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

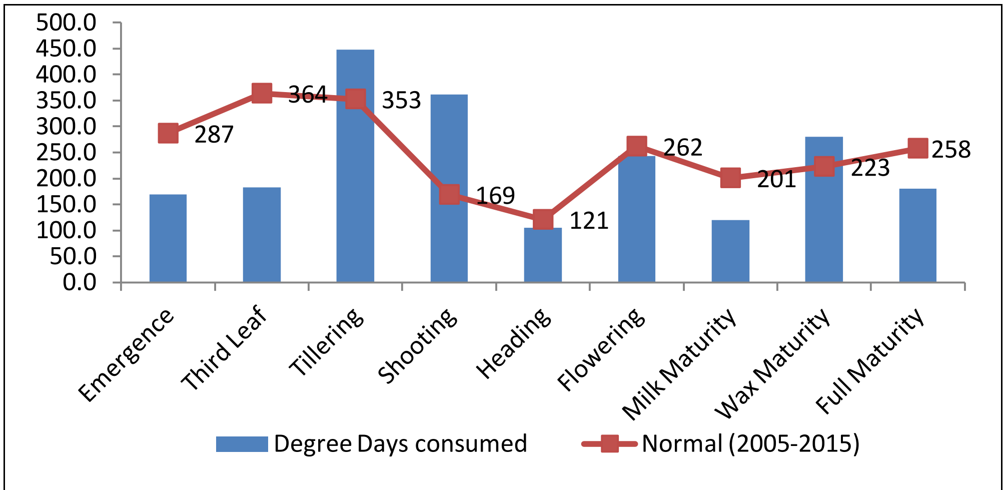

Figure 3.8: Heat units consumed at different phonological stages by the Rabi crop during 2016-17 at Tandojam.

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

S. No.	Inter Phase	Period	No. of Days Taken	Degree Days (T-5℃)	No. of Days Taken	Normal Degree Days
2.	**Emergence**	**10-11-2016 19-11-2016**	**10**	169.0	14	287
3.	**Third leaf**	**20-11-2016 30-11-2016**	**11**	183.3	21	364
4.	**Tillering**	**01-12-2016 19-12-2016**	**19**	447.5	23	353
5.	**Shooting**	**20-12-2016 08-01-2017**	**20**	361.3	11	169
6.	**Heading**	**09-01-2017 20-01-2017**	**12**	105.5	8	121
7.	**Flowering**	**21-01-2017 11-02-2017**	**22**	243.0	14	262
8.	**Milk maturity**	**12-02-2017 19-02-2017**	**08**	120.0	11	201
9.	**Wax maturity**	**20-02-2017 08-03-2017**	**17**	280.3	10	223
10.	**Full maturity**	**09-03-2017 18-03-2017**	**10**	180.0	11	258
11	**Emergence to Maturity**		129	2089.8	122	2238

During the crop season 2016-17, the interphase period of the wheat variety Imdad and corresponding heat units at Tandojam observed at different Phenological stages varies from phase to phase. Total heat units consumed by the crop were 2090 accumulated from sowing to full maturity in 129 days. According to Table 3.4, Interphase duration of the crop period is little longer(129) than normal duration of 122 days, which is due to normal/ slightly below normal mean daily temperature observed during crop life (Figure 3.8). Normally in the early maturity stages crop needs high RH, so that the grain can gai n its full size. During early maturity stages, the daily temperature started rising and the RH remained low in February. The crop dry matter formation or crop seed formation to its original size remained incomplete due to high rate of ETo. And resulted shrived grain size and unsatisfactory actual yield by the variety.

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.

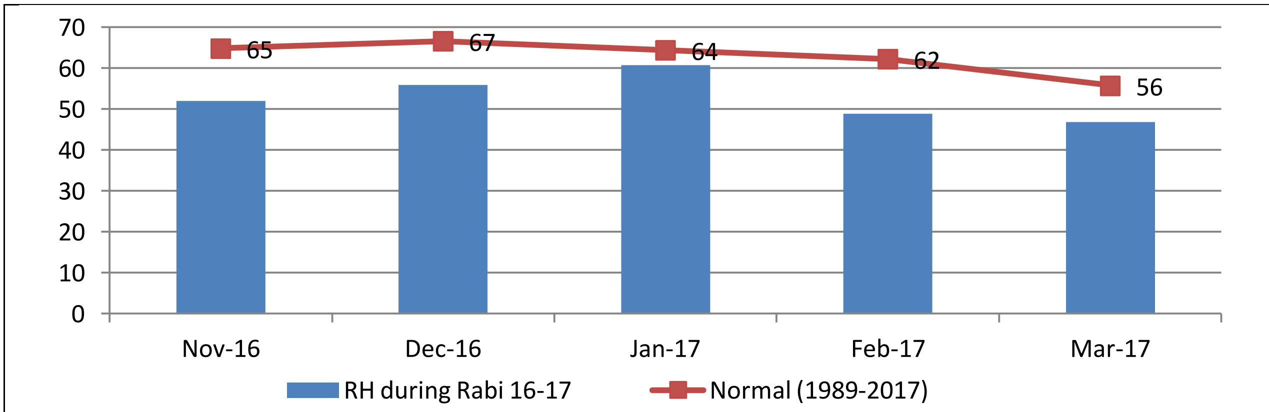

Figure 3.9: Observed relative humidity in Rabi season during 2016-17 at Tandojam.

During the crop season 2016-17, the relative humidity remained low during the early maturity stages (during February and March), which adversely affected the yield by reducing the grain size. The temperature remained high these months and the RH was low in the early maturity stages, in results the evapotranspiration increased and hence reducing the grain size.

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.

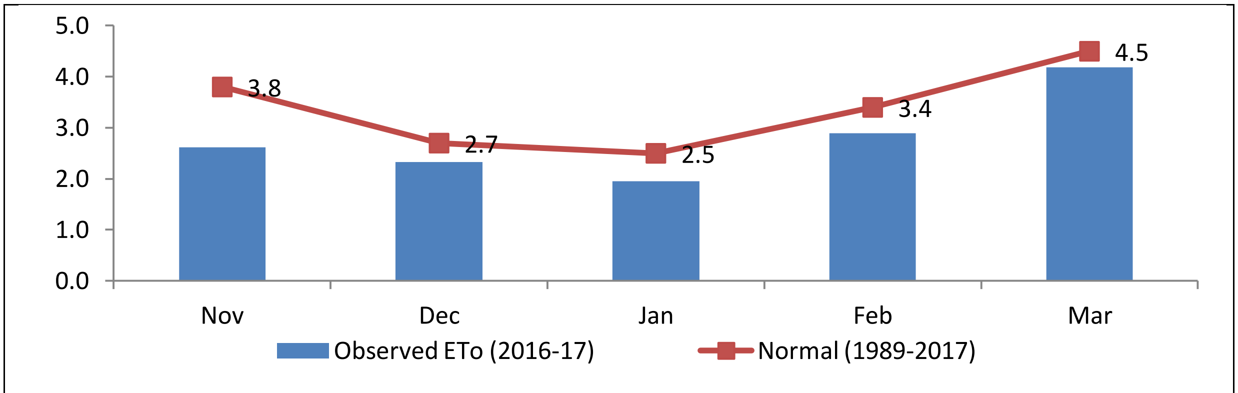

Figure 3.10: Observed ETo by Rabi crop during 2016-17 at Tandojam.

During the crop season 2016-17, relative humidity and ETo both remained below normal during most of the growing period. It might be due to the below normal temperature throughout the season. But during the early maturity stages, the ETo and the temperature remained high as relative to the rest of stages, and that time the relative humidity decreased, and resulted reduced grain size, hence effecting the crop yield.

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.

Table 3.4: Summary of some Meteorological Parameters during Rabi Season 2016-17

Month	Wind speed (km/hr)	RH(%)	Days with mean RH ≥80%	ETo (mm/day)
Nov-16	1.4(3.1)	52(65)	0	2.6(3.8)
Dec-16	2.5(3.3)	56 (67)	0	2.3(2.7)
Jan-17	2.0(3.5)	61(64)	3	1.9(2.5)
Feb-17	1.9(3.8)	49(62)	0	2.9(3.4)
Mar-17	2.2(4.5)	47(56)	0	4.2(4.5)

- Values in ( ) shows Normals based upon 1989-2017.

During the Rabi crop period 2016-17, no such bad weather event was observed. Wind speed was observed mostly below normal and any significant wind speed accompanied by any severe weather event was not observed throughout the period

3.9 Crop Water Requirement (CWR)

The crop water requirement 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 [14].

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 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 3.11.

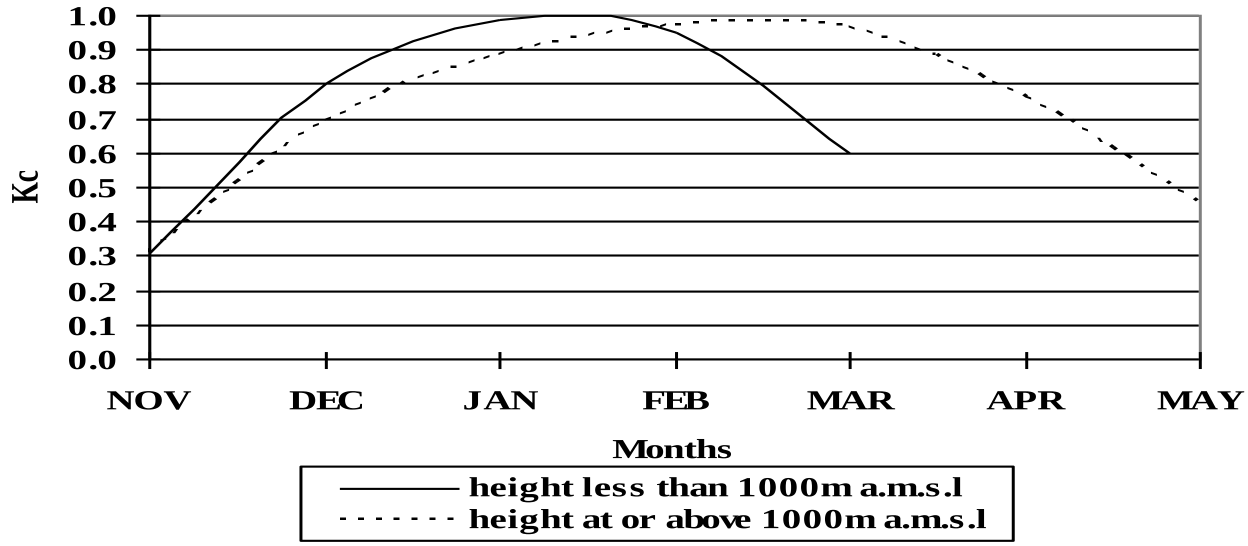

Figure 3.11: March of Crop Coefficient (Kc) for normal duration of Wheat growing season (Emergence to Maturity).

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

10 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 [15].

Table 3.5: 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
1.	**Germination**	**10-11-2016 14-11-2016**	10	26.2	46.1	12.6	28.1
2.	**Third Leaf**	**20-11-2016 30-11-2016**	**11**	26.2	68.7	18.3	60.7
3.	**Tillring**	**01-12-2016 19-12-2016**	**20**	45.8	67.7	40.3	66.0
4.	**Shooting**	**20-12-2016 08-01-2017**	**19**	39.5	41.7	38.7	40.8
5.	**Heading**	**09-01-2017 20-01-2017**	**12**	23.1	24.6	23.1	23.2
6.	**Flowering**	**21-01-2017 11-02-2017**	**19**	54.1	48.7	49.8	43.0
7.	**Milk Maturity**	**12-02-2017 19-02-2017**	**08**	23.8	40.1	19.3	29.5
8.	**Wax Maturity**	**20-02-2017 08-03-2017**	**16**	53.5	41.8	34.2	25.6
9.	**Full Maturity**	**09-03-2017 18-03-2017**	**10**	38.4	46.1	15.4	25.7

*Normals based upon 2005-2016.

During the Rabi Season 2016-17 in Tandojam, water requirement of wheat crop was observed normal to below normal throughout the season except the Flowering and wax maturity phase (Table 3.5). Crop was irrigated during these phases to meet the requirement. During the wax maturity phase, the temperature increased. And the appearance of crop showed the need of irrigation, so the crop was irrigated.

3.11 Agro Meteorological Summary of Crop Cycle

Different meteorological parameters were recorded at various phases of wheat crop during 2016-17. The impact of these parameters at different phenological stages of wheat crop is discussed as under

SOWING

Wheat crop was sown around the second week of November which is the normal time of wheat crop sowing. At the time of sowing the mean temperature was 25°C, which is suitable temperature for wheat crop. Dry weather recorded after the seed sowing while soil temperature and moisture were satisfactory.

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 48% at the time of emergence. Mean air temperature during emergence was found to be 21.9°C. However, optimum ranges vary generally for all varieties of wheat crop. The crop was irrigated for the first time to complete its water requirement because no rainfall was recorded during the season.

THIRD LEAF

In third leaf phase, with 75% occurrence, mean relative humidity was about 56% and mean air temperature was 21.7 °C recorded.

TILLERING

This stage of crop growth started on 01-12-2016 and 75% occurrence was completed on 19-12-2016. The mean air temperature and mean relative humidity were 28.6°Cand 56% respectively. ETo was high in this stage, it might be due to the wind which reached about 3 km/hr this phase. The crop was irrigated to make the conditions favorable for the crop.

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 was 23.1°C while the relative humidity remained 61%. The RH started increasing this stage and the ETo decreased, which favored the crop for normal growth. But the crop appearance showed the need of irrigation so the crop was irrigated at this stage.

HEADING

It is the initiation of reproductive stage of wheat crop. Heading stage started on 09-01-2017 and was completed 20-01-2017. The mean air temperature was 13.8°C and mean relative humidity was 58%. Crop was in good condition this stage.

FLOWERING

Flowering started in the last week of January and completed till second week of February. As this stage needs more water, relative to the other stages, so the crop was irrigated.

The Mean air temperature was recorded 16.0°C while mean relative humidity was 53%. The crop showed normal growth because the condition were satisfactory for normal growth.

MILK MATURITY

Wheat has varying requirements for temperature and soil moisture during seed formation. Crop needs high relative humidity in this stage, so that the seed can gain its size. This phase started on 12-02-2017 and ended on third week of February. Mean air temperature was recorded 20.0°C and mean relative humidity was 47%. The relative humidity decreased this stage which adversely affected the crop seed formation. The rate of ETo increased and as a result the grain did not get its full volume and affected the crop final yield.

WAX MATURITY

This started on 20-02-2017 and ended on 08-03-2017.The mean air temperature was 21.5°C. The mean relative humidity during this phase was 48%. Again the same conditions were faced by the crop at this stage as in Wax maturity stage. The relative humidity was not satisfactory for seed formation in air and as a result the ETo increased. So, the crop water requirement increased. So, the crop was irrigated. But still the seed formation needs high humidity in air. So, the meteorological parameters were not in the favor of full volume seed formation.

FULL MATURITY

Wheat requires high temperature at this stage. The mean relative humidity at this stage was 45%, mean air temperature recorded was 23.0°C. Temperature recorded at this stage was 42°C. This stage the seed needs hot and dry weather. So, the conditions were in favor of crop. The crop was harvested on 19-03-2017. But as discussed above that the early maturity stages affected the grain size, that’s why the crop yield was not satisfactory as relative to the actual yield of the variety.

Chapter 4

REVIEW OF CROP SEASON

The crop variety Imdad was cultivated in the experimental field of Agriculture Research Institute Tandojam. The sowing time of wheat and the meteorological parameters plays an important role in the quality and quantity of yield obtained.

The crop was sown at normal time. Amount of seed cultivated per acre was 50 kg which is considered sufficient for the crop cultivated in November. Fertilizer was applied on proper time to the crop. Dry season was reported during the whole crop period and field has been irrigated 5 times, which mostly fulfilled the water requirement. Day and night time temperatures and RH both were observed with in slightly below normal to normal range. However ETo remained slightly below normal during most of the crop's growth period except the early maturity stages. Air and soil temperature regime remained normal to slightly below normal for most of the crop's period, which also favored the crop growth at all stages. Total heat units consumed by the wheat crop were 2090 accumulated from germination to full maturity in 129 days. On average 16.2 heat units were consumed by the crop per day. Normally these heat units are consumed in 122 days at the rate of 18.3 heat units per day, which shows that the crop reached to full maturity in slightly above normal time span. Wheat crop needs high humidity during the early maturity stages but in February 2017, the humidity decreased in air and the temperature increased. Accordingly, the evapotranspiration increased, so affected the crop yield by shriving the grain size.

4.1 Conclusions

During the Rabi season 2016-17, the temperature increased in February 2017, when crop was in its early maturity stages. The sudden change in temperatures along with the decrease in the relative humidity, and increased ETo, adversely affected the crop yield. Due to which, the variety produced a relatively lower yield as compared to its potential yield. Hence, it is concluded that RH, ETo and temperature plays a vital role in the formation of seed during the maturity stages.

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, sowing of wheat should be completed up to the first week of November in the irrigated planes of Sindh.

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 rain fed 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.

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