Phenology observation of Wheat (*Triticum Aestivum)* of four Indian winter wheat cultivars under different thermal growing conditions

Ashish Gothwal

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Certificate of Examination

This is to certify that the dissertation titled "Phenology observation of Wheat (*Triticum Aestivum)* of Four indian winter wheat cultivars under different thermal growing conditions" submitted by Mr. Ashish Gothwal (Reg. No. MS13076) for the partial fulfilment of BS-MS dual degree programme of the Institute, has been examined by the thesis committee duly appointed by the Institute. The committee finds the work done by the candidate satisfactory and recommends that the report be accepted.

Dr. Baerbel. Sinha (Supervisor)	Dr. V. Sinha	Dr. Ram Yadav

Dated: April, 2019

Declaration

The work presented in this dissertation has been carried out by me under the guidance of Dr. Baerbel Sinha at the Indian Institute of Science Education and Research Mohali.

This work has not been submitted in part or in full for a degree, a diploma, or a fellowship to any other university or institute. Whenever contributions of others are involved, every effort is made to indicate this clearly, with due acknowledgement of collaborative research and discussions. This thesis is a bonafide record of original work done by me and all sources listed within have been detailed in the bibliography.

Ashish Gothwal
(Candidate)

Dated: 24.4. 2019

In my capacity as the supervisor of the candidate's project work, I certify that the above statements by the candidate are true to the best of my knowledge.

Dr. Baerbel Sinha

(Supervisor)

Acknowledgment

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To conclude above all, it was almighty and my family which have been there all these years strongly supporting and guiding me in life.

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Notation (Abbreviations)

SM Soil moisture.

VPD Vapour pressure deficit.

CONTENTS

Abstract

In this study we have explored the phenology of the four different cultivars (GW322, C306, DBW88, Local breed) of *triticum aestivum* during wheat growing season from November 2018 to April 2019. The cultivars GW322, C306 and DBW88 were acquired from breeders while Local breeds were obtained from seed shop were grown for comparison.

To study our objective, wheat was grown in three different plots with variations in growth conditions and time periods. Sowing was done on November 1st for plot 1, November 15th and December 1st for plot 2 and 3 respectively. Different parameters such as temperature, plant phenology, and time period were analysed for all different cultivars of *triticum aestivum.* These analyses were performed to observe their effects on the yield of wheat cultivars.

Most cultivars show a similar thermal sum to reach flag leaf stage for plot 1 and plot 1 but a significantly lower thermal sum for plot 3. This is despite the fact that the temperature at which the thermal sum is conventionally capped was not reached before this growth stage. Plants on plot 3 did not reach tillering growth stage before temperatures, dropped as winter started early. While the plats reach the flag leaf stage fast, heading and flowering is significantly delayed, possibly because the vernalisation was affected by the plats tillering after temperatures rose.

We observe, that there is a decrease in the number of active tillers for plot 2 and even more so for plot 3. Plot 3 also shows shorter heads compared to plot 1 and 2 as the plants were exposed to heat stress at the time of flowering and shortly before. This obviously affected the head length.

Chapter 1

Introduction

1.1 What is Tropospheric ozone?

Ozone is a greenhouse gas that is continually produced and destroying in the atmosphere by chemical reaction. Troposphere ozone is secondary air pollutant and greenhouse gas[1]. In troposphere ozone is a secondary pollutant formed when some anthropogenic gas release from motor vehicles, industrial process, burning of crop residue such as volatile organic compounds, carbon monoxide and nitrogen oxides chemically react to produce ozone. Increasing concentration of tropospheric ozone negatively affects human health, crop yields, plant and ecosystem. It is also known to negatively affect wheat crop yield [1].

1.2 How Tropospheric Ozone formed?

The precursors of ozone are NOx, VOC(volatile organic compound) including CH_4,CO and many other more complex compound in the presence of sunlight by chemical reaction[1].

NO_2 photolyses at wavelengths less than 424 nm to give NO and O singlet D

$$NO_2 + hv \rightarrow NO + O \qquad (R1)$$

This reacts with oxygen to form ozone in the presence of a third body which takes the extra energy and stabilizes the reaction product

$$O_2 + O + M \rightarrow O_3 + M \qquad (R2)$$

However, ozone reacts immediately with NO to reform NO_2 and O_2 so this reaction sequence becomes a null cycle in the absence of other reactions to convert NO to NO_2.

$$O_3 + NO \rightarrow NO_2 + O_2 \qquad (R3)$$

Certain radicals such as RO_2 and HO_2 radicals can convert NO to NO_2.

Initially reaction of VOC and OH radical by oxidation give RO_2 and HO_2 radicals. These radicals further react with NO to give NO_2 and NO_2 by photolysis give NO and O radical and O radical react with O_2 molecule to give ozone[3]. So net production occurs when VOC's are oxidised by OH radicals producing peroxi radicals which can oxidise NO to NO2

Ozone formation by chemical reaction

$$\text{VOC (volatile organic compound)} + \text{OH (radical)} \rightarrow RO_2 \qquad (R4)$$

$$RO_2 + NO \text{ -----}\rightarrow RO + NO_2 \qquad (R5)$$

$$NO_2 + \text{photolysis} \text{ -----}\rightarrow NO + O \qquad (R6)$$

$$O + O_2 \text{ ------}\rightarrow \text{ozone} \qquad (R7)$$

The anthropogenic human activities increase the emission of ozone precursor increase the ozone in the troposphere. Production of the ozone depend upon the level of NOx and VOC's and can be in a VOC limited and NOx limited production regime[2].

1.3 Loss process of Tropospheric Ozone

Deposition process

The main removal process for ozone in the boundary level is deposition to the surface known as dry deposition [1]. Dry deposition refers to removal of a gas from atmosphere to the earth in the absence of rain or water droplets. While particles can deposit due to their own weight under the influence of gravity, gases are transported downwards by winds and can stick to a surface or be destroyed on a surface upon hitting it. The dry deposition rate of ozone is dependent upon the season in particular over vegetated surfaces. The reason is that plants take up gases through their stomata as part of the process of photosynthesis. During this process other gasses such as ozone also enter the plant. The rate of deposition to land surface are greater than rate of deposition to marine surface as surface roughness increases the interaction of winds with the surface and plants take up ozone into their stomata. From the report of Reich and Amundson there is relation between stomatal conductance and potential ozone damage. Plant with higher rate of stomatal conductance are often more negatively affected by ozone than plant with lower rate of stomatal conductance[1]. However, there is also a phytotoxic dose for each species. When the flux per unit area of leaf surface area and time exceeds a certain threshold, the plant's defence system is no longer able to handle the ozone that enters and damage occurs.

The non-stomatal sink for ozone removed by plants can also be important in ozone loss from atmosphere. Processes include here are the reaction of ozone with compounds emitted by plants that have double bonds such as terpenes, the reaction of ozone with leaf surfaces or moisture on top of the leaf surface and the physical destruction of ozone upon collision with surfaces.

Chemical destruction

In the night, absence of sun light the concentration of free radical can become low so fresh ozone formation ceases and some chemical process occurs at the night for ozone loss. Nitrogen oxide react with ozone to give nitrogen dioxide and oxygen molecule[3]. So continued NOx emissions at night can titrate the ozone to zero, although the NO_2 will rapidly photolysis and form fresh ozone at sunrise. The ozonolysis of terpenes can titrate away ozone at night. Moreover, in a NOx rich atmosphere, NO_2 can react with OH during daytime to form HNO_3 (g) which will further react with NH_3 (g) and form particulate matter. This can remove NOx from the system and limit ozone formation.

1.4 How ozone damage plants

When ozone entered into the leaf it react rapidly in apoplast with a number of potential molecule produce other ROS (reactive oxygen species), including hydrogen per oxide, super peroxide radical, hydroxyl radical [1].

Potential damage mechanism-the increased production of ROS during the Environmental stress like drought, high temperature, pathogen attack[4]. It damages the cell by activate the enzyme ethylene, jasmonic acid, salicylic acid. When the level of ROS increase the oxidative stress increased on cell. To avoid oxidative injury the cells attempt to control the level of ROS tightly by producing anti-oxidants. However, an ozone flux exceeding the phytotoxic dose can overwhelm the response system of cells. Excess of ROS is control largely by scavenging and detoxification[4]. Plant evolved both enzymatic and non-enzymatics antioxidant defence such as ascorbic acid, guthine etc. but when the system is overwhelmed damage, yellowing, bronzing or early leaf death can occur.

The effect of ozone decrease the primary metabolism.in fixation of CO_2, change in rubisco content and other component of the photosynthetic machinery and Calvin benzo cycle enzyme including rubisco activase, ATP synthase, the hydrogen evolving subunit of photosystem second[1]. These decrease in primary metabolism and decrease the area of leaf because change in enzyme activity decreases the starch and sucrose level.

Chapter 2

Materials and Methods

2.1 Location and Climate

Figure 1 shows the location of Mohali within India and the location of the wheat field within the campus.

Figure 1: Location of Mohali in the Indian subcontinent, IISER campus and location of Experimental field within the campus.

Mohali district is located in Punjab. On the world map Punjab will be on the north western part of India closer to Pakistan. IISER Mohali campus is located in Mohali district where all experiments related to this study were performed. The Mohali region is a part of Indo-Gangetic alluvial plains. is situated at 30^{o} .67 N latitude and 72^{o} .73 E longitudes with an altitude of 312 km above mean sea level. The location of wheat field is in the south-eastern corner of the residential campus. The soil of this land consists of loam to heavy loam and sand to sandy loam and has very fertile land and this type of soil is highly rich in nutrients which are very suitable for wheat cultivation. Punjab has an area of 35 lakh hectare for wheat cultivation. Wheat production is expected around 180 lakh metric tonnes this time as against 176 lakh metric tonnes of the crop produced during rabi season of 2017 (The Tribune, Punjab ,9 April 2019).

The climate of Mohali district is hot in summer and cold in winter. The temperature may touch in summer to $45^{o}C$ or more in day time, whereas winter temperature may fall as low as 1-$2^{o}C$.

The metrological data of various parameters like temperature, soil moisture, relative humidity (RH), solar radiation, wind speed, wind direction and leaf wetness was taken using Decagon EM50G data logger. Decagon EM50G data logger was setup in the wheat field.

2.2 Agricultural methodologies

Previous Background of field

The wheat had been cultivating since three years. Before this the field was unsown and was covered with weed. Field was used only for the wheat season and set free afterward. Number of plots increased during every season. (i.e. 1, 2, 3 in session 2015-16, 2016-17 and 2018-19 respectively).

Preparation of Field:

For well sowing, uniform irrigation and good yield, firstly with the help of labour the over grow of weed was removed with the help of small sickle. We prepared the field using latest agricultural equipment. Soil was tilled to change its soil structure, to kill weeds and to manage crop residues and break the soil into microscopic level and then the disc harrow was used twice to overturn the soil. Followed by using tiller to get fine structure of the soil and then rotavator was used for preparing the seed bed,

After this we did the irrigation to get required moisture for the sowing and the land set free for 2-3 days then did the needed plot measurement one day before sowing we watered in sprinkle form. Same method was used for other two plots.

Wheat was sown manually using the metallic rod for making the whole (4cm) for planting seeds.

For the growing season 2018-19 we made three plot with the dimension of 25x20 m and each plot comprises of 10 cultivar with three replica.

Outer boundaries of these three plot covered with the buffer of local farmer pedigree and outer layer of plots with buffer covered with net fence which help in prevent the entry of unwanted animals.

Seeds were sown with the following spacing:

Total number of cultivar - 10

- Replicates of each cultivar - 3
- Number of plants of each cultivar in a plot - 30
- Rows of each cultivars in a plot - 3
- Row to row inter cultivar distance in a plot - 23 cm
- Cultivar to cultivar distance in a plot - 44cm
- Plant to plant distance - 15 cm
- Sowing depth - 4 cm

Figure 2: Layout of the field. Plot 1 was sown in 1st of November, Plot 2 was sown on 15th of November and plot 3 was sown on 1st of December

We did three sowing at different dates to get the taste about the phonological observations of the wheat cultivars.

1st sowing – 1st November 2018

2nd sowing- 15th November 2018

3rd sowing -1st December 2018

Same seed sowing plan procedure was adopted in all three plots. We did the hole at the depth of 4cm using the metallic road and put two seeds in each hole and after the complete emergence of wheat unfit plant was single out manually in all three plots.

With the use of water pump we flooded the field after every 2 weeks. At the time of anthesis we irrigated the plots in every 5-7 days.

No chemical was used for controlling the weed. Mostly weed was removed manually after the irrigation with the help of trowel.

Fertilizers such as ammonia phosphate, calcium phosphate, potassium phosphate as plant nutrition were used to avoid the yellowness of leaves. 3 treatments of these fertilizers were given to the every plot before the irrigation. All these fertilizers were given till the flag leaf stage.

2.3 Analytical Details

Agriculture meteorological Station (EM50G data logger):

The agro-meteorological station was fixed in the field to get the accurate measurements. Em50G data logger has various supporting instruments to measure the temperature, pressure, relative humidity, photosynthetic active radiation precipitation, soil moisture, wind direction and wind speed. Below I have quick overview of all these sensors.

- **Temperature and relative humidity sensor:** vp-4 temperature sensor, it is very precise tool for checking vapour pressure, temperature, humidity and atmospheric pressure in soil and air. It required low input voltage and fully calibrated RH and temperature. It has the working temperature range of -40° C to +80° C and the sensor dimension of 5.4x2.0 cm.
- **Photosyntetic active radiation sensor:** QSO-S PAR photon flux sensor is measured at 180 degree with respect to field in $\mu molm^{-2}s^{-1}$ via QSO-S PAR flux sense model. In order to get good spectral response characterised pigment were added to diffusion task. The PYR sensor has the spectral range of 380-1120 nm with the accuracy of ±5%.
- **Soil moisture sensor GS-1:** The operating environmental range is -40° C to +60° C.with accuracy of ±0.03 m^3/ m^3 and minimum measurement duration is 10ms. For the reading the sensor is buried in the soil.
- **Davis cup anemometer-** it has wind speed accuracy ±5.1 and has wind direction accuracy is 7° C with the wind speed resolution of 1 mph (0.45 m/s).the wind direction range is 0-360° .

2.4 Cultivars in this study

The phenological observations of five cultivars were studied which are GW322, C306, DBW88 and the LOCAL Breed during the season. Two of them were taken directly from the local farmers. The details of the cultivars are given below:

GW322:

This variety was developed by GAU vijapur.this is the of wheat sown in rabi season which gives the highest yield in good maintenance in very few less quantity. Crop as ready for harvesting in 115-120 days with irrigation 3to 4 times in season. this wheat variety need very less fertilizer/pesticide because it is resistant to stem rust and leaf rust.

C306:

This variety was developed by HAU (Hissar Agriculture University) and it takes normally 136-140 days to mature and at maturity this attain a height of 110-120 cm.this variety of crop contain 11-12% of protein so it’s very good for chapati. Average yield of this crop is 26-30 quintal/ha.

DBW88:

It is the wheat variety which yields between 20-21 QH/acre. Crop matures in approximately 143 days under irrigated condition when timely sown. Plant grows up to height 80-95 cm. it has seedling resistance against the most prevalent pathotype and yellow and brown rust and tolerance to fungal disease. It has high biomass and high protein content so it used in making bread.

Local seed: (This is also a variety recommended for Punjab)

This is unknown pedigree and directly taken from the farmer. This was cultivated for the comparison. The plant attains the height of 90-95 cm by the maturity time.

Plants observation: For predicting the yield the plant observation is the basic step. These 3 plots were monitored regularly. Mainly emergence, Flag leaf, Heading, and anthesis stages were observed. Details of these stages are written below:

Emergence: After sowing at the different dates all these plots were observed daily to record the emergence data. The emerged plants were counted for each cultivars and the sigmoid function were plotted.

Flag leaf: Flag leaf is the most critical stage for the wheat. It is the last leaf emerged called as flag leaf. The flag leaf was counted for each cultivar and then the sigmoid function plotted against DAS (Days after Sowing) and temperature sum.

Heading: When the 50 percent spikes came out it is counted as the heading stage has emerged. The procedure of making graphs was same as upper stages.

Anthesis: This is the flowering stage of the wheat. It is marked by the bulges out of anthers from the spikelets. The graphs were the same as mentioned in upper stages.

2.5 Data processing of Meteorological data

The data has taken from decagon EM50 data loggar which were installed in the field. All data then procced in Microsoft excel 2013. All record data of four Phenological observations were put in the Microsoft excel 2013 and made the table of calculation of average and fraction emerged. Took the table of fraction (emergence, flag leaf, heading and anthesis) and plotted with Days after sowing(DAS) and Temperature sum. The temperature data taken from decagon EM 50 data logger and took the 24 hrs average of temperature. All the graphs were made in the Igor pro and the graphs were fitted with the sigmoid function in the Igor pro.

Chapter 3

Results and Discussion

3.1 Meteorological conditions during the wheat growing season 2018-19

Weather condition directly affect the wheat production which is almost consistent with date so time of sowing is a key factor which control the production yield of crop. As it regulates optimum time of sowing. By growth exploring factor in appropriate manner, optimum time enhance the efficiently of a crop. As we know optimal planting time vary by cropping system, variety and environmental condition sowing before and after the optimal planting date can negatively influence can reduce the production yield, and quality. Planting before the optimal planting date took more number of days to flowering and there might be a lag phase as crop did not meet the required temperature and other climate necessary. On the other hand, sowing after the optimum time results in a low number of seed grains or less grain filling because of rise in temperature during ripening stage. Hence the optimal date of sowing is a critical factor to obtain high productive yield. [5].

The mean temperature during day was around 14.6 ^{o} C during the wheat season. The minimum temperature was observed 2.4 ^{o} C in the month of November and the maximum temperature of 37.5 degree was observed in the month of April. The relative humidity ranged during the season was 28 percent to 88 percent. The minimum and maximum humidity was seen on the month of November and February, respectively.

Figure 3 shows the temperature, PAR, VPD, soil moisture, Wind speed during the growing season 2018-19. The minimum and the maximum temperature 2.4 degree and

37.5 degree respectively was noticed on 12 December 2018 at 07:30 hours and on 4 April 2019 at 12:50 hours respectively. From November to march the temperature fluctuates between 5-25 degree providing optimum conditions for wheat growth. After it there is continuous increase in temperature. Heat stress inducing temperatures in excess of 32 degree were only observed from the second week of march onwards.

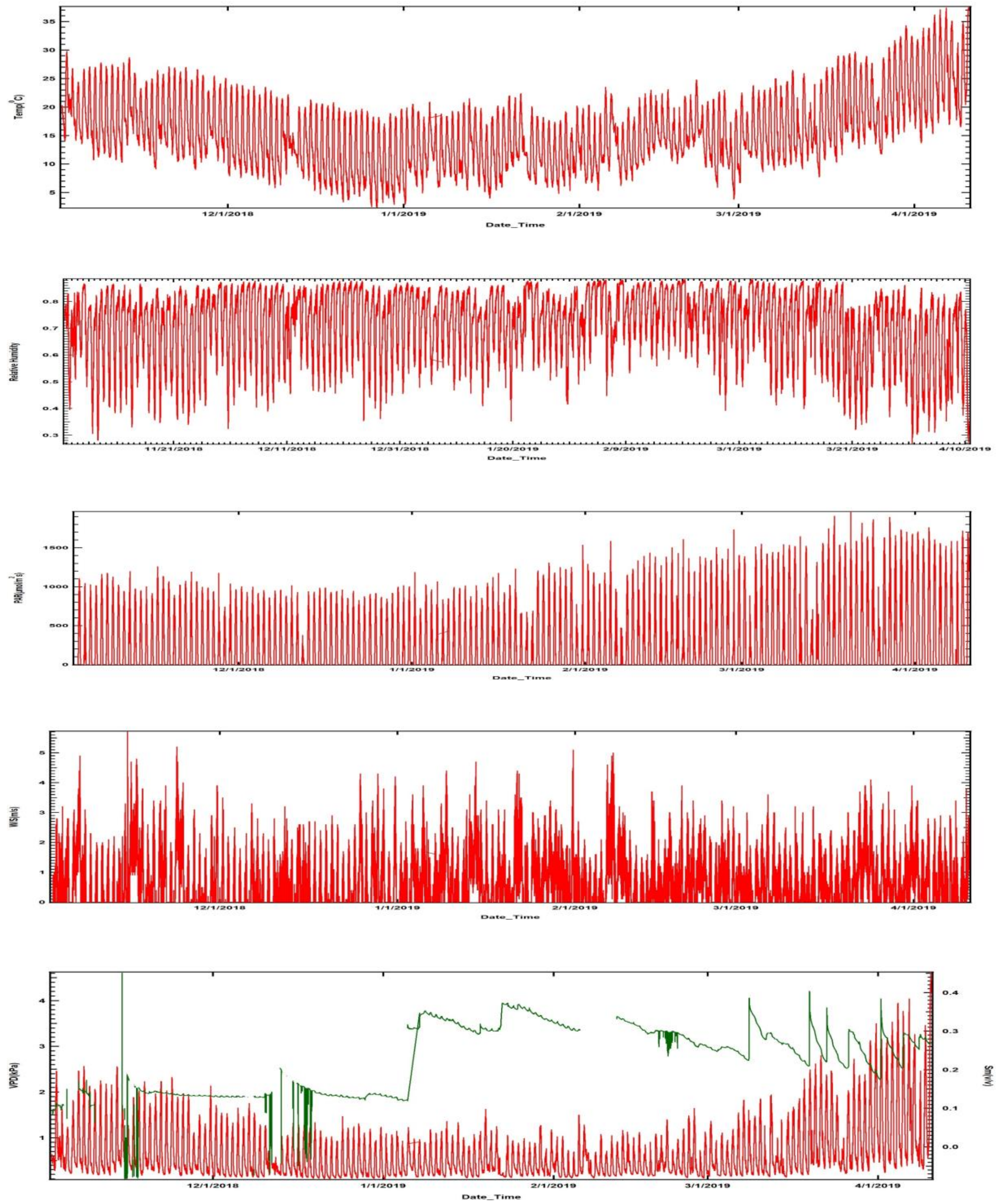

Figure 3: Temperature, Soil moisture, VPD, and PAR for growing season 2018-19.

While may Western Disturbances occurred the maximum wind speed at crop level

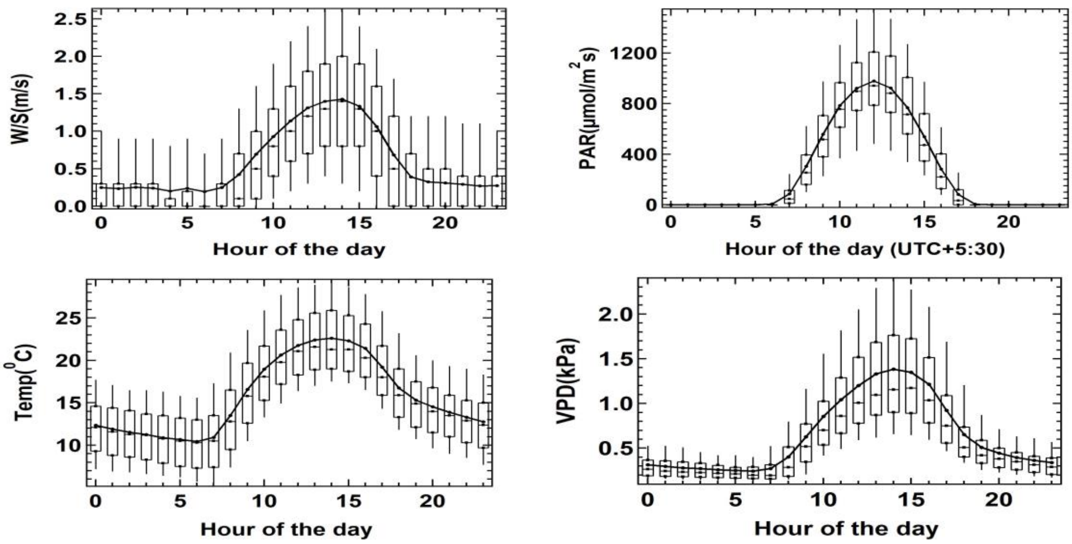

Figure 4: Diel box and whisker plot for PAR, Temperature, VPD and Wind Speed for the growing season 2018-19. All measurements taken during a certain hour of the day during the entire growing season are binned against the start time of the hour. The lower and upper limit of the box represents 75th and 25th percentile and the line in the middle represents the median and the average is marked by a dot. The Whiskers show the 90th and 10th percentile of the data.

generally remained between 1 m/s to 6 m/s resulting in very little lodging except for C306, which is a very tall cultivar that lodges easily. Relative humidity dropped during the day and was higher at night, however, the air was rarely really dry during this wheat growing season. The VPD remained at less than 2.5 kPa and imposed no limitations on plant growth till the second half of March. It increased continuous after March to end of growing season which suggest the drying conditions. Good soil moisture was maintained throughout thanks to regular irrigations. In the beginning the soil moisture sensor had some problems as it had been bitten by dogs, however it was replaced with a new piece in the second half of December.

Figure 4 shows the diel and whisker plots for PAR, temperature, VPD and Wind speed. It is clear from the graphs that everyday sun rises around 7:00 AM and after 1 hour the temperature starts rising. The photosynthetically active radiation is high around 12:00 PM

3.2 Plant growth and development in the three treatments during 2018-19 growing season: Emergence

Table 1 summarizes the emergence data of all the four cultivars both in terms of number of days after sowings it took for the cultivars to emerge and in terms of the thermal sum to emergence. The cultivars GW322, C306 and the local farmers cultivar took a larger number of days to emergence the later they were sown. However in terms of thermal sum, the cultivars sown on 15th November took longest, possibly because the soil was too wet as it had rained heavily the night before.

Table 1: Emergence data for the cultivars GW322(C6), C306(C7), DBW88(C8) and collected from local farmers(C9 & C10).

GW322:

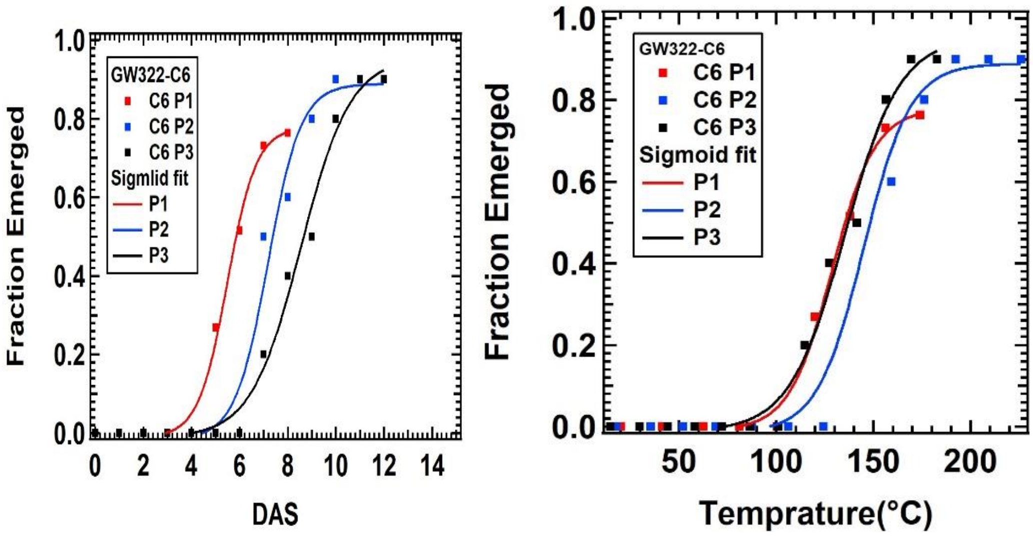

Figure 5: Emergence count of cultivar GW322. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum.

Figure 5 shows the emergence count of cultivar GW322. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum. The y-axis shows the fraction of the 180 seeds that were put which had emerged. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and maroon, respectively. It can be seen from the graph that GW322 has an almost constant thermal sum irrespective of days of sowing.

C306:

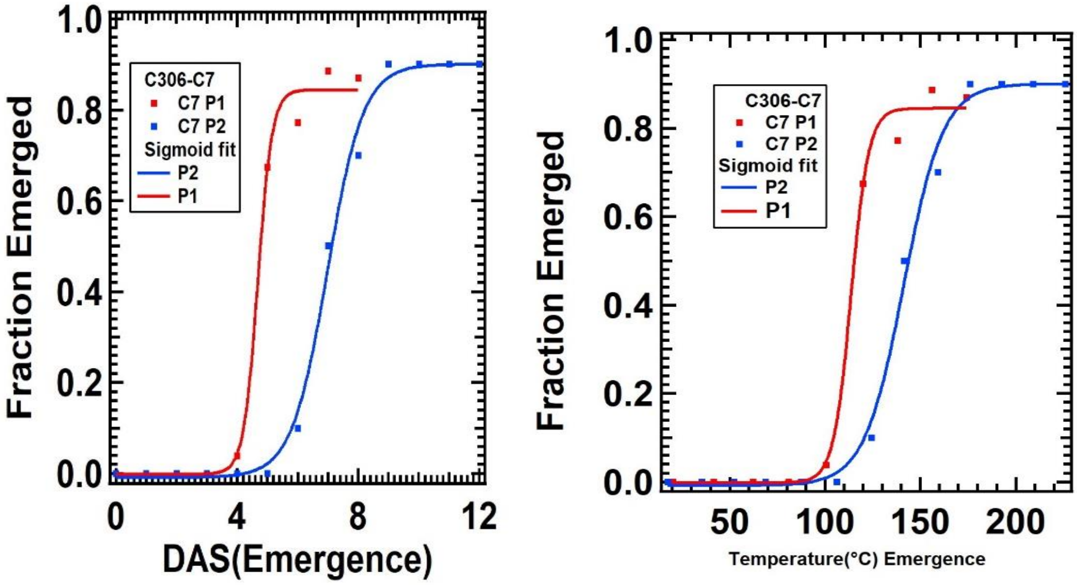

Figure 6: Emergence count of cultivar C306. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum.

Figure 6 shows the emergence count of cultivar C306. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum. The y-axis shows the fraction of the 180 seeds that were put which had emerged. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November and 15th of November) are indicated using the colours red and blue respectively. It can be seen from the graph that C306 has a slightly difference in their thermal sum and days of sowing. The third treatment is not available, because a seed bag was mislabelled and the cultivar sown was not C7. It was significantly shorter.

DBW88:

Figure 7 shows the emergence count of cultivar DBW88. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum. The y-axis shows the fraction of the 180 seeds that were put which had emerged. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that DBW88 emerge after the same number of days when sowin on 15th November and 1st of December despite having a different thermal sum, while plot 1 emerges faster in terms of number of days, although the thermal sum is slightly higher than for plot 3.

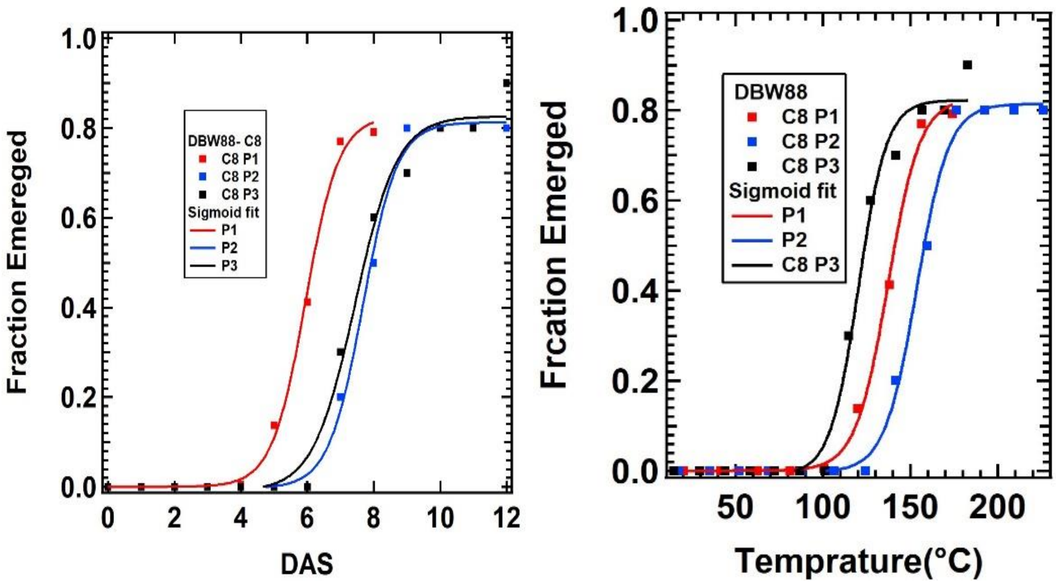

Figure 7: Emergence count of cultivar DBW88. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum.

<u>Local Breed C9 and C10:</u>

Figure 8 and 9 show the emergence count of cultivar Local breed C9 which is identical to C10. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum. The y-axis shows the fraction of the 180 seeds that were put which had emerged. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that Local breed C9 and C10 emerge after the same number of days for plot 2 and 3 while plot 1 emerges faster. The thermal sum is identical for plot 1 & 3 but longer for plot 2 which was sown into very wet and heavy soil.

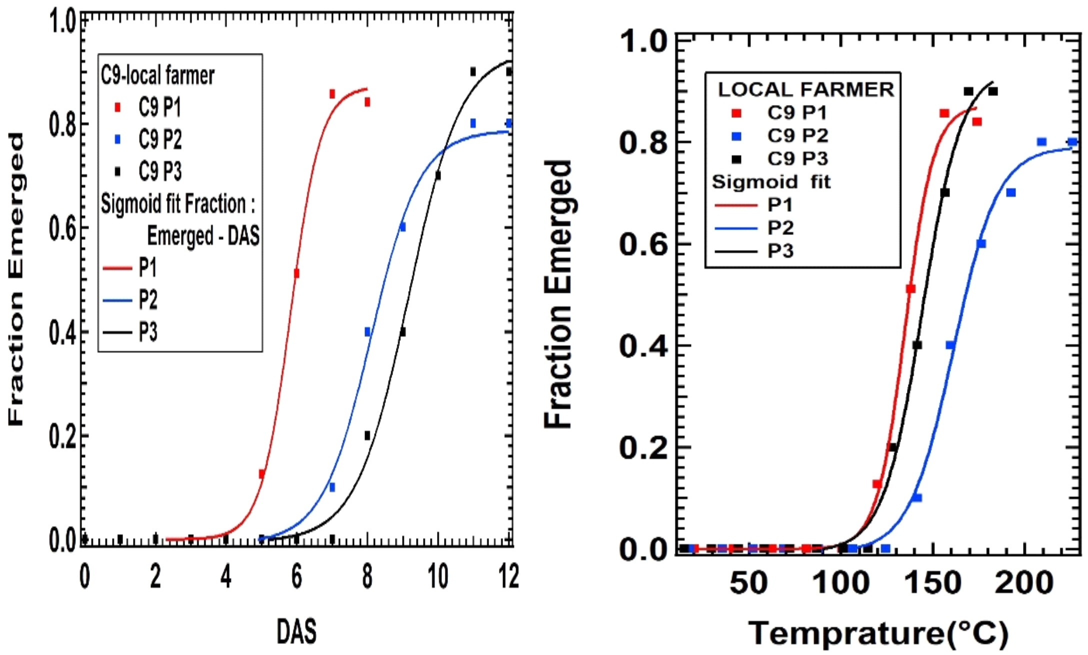

Figure 8: Emergence count of cultivar Local Breed C9. The left hand panel shows the emergence count as a function of days after sowing (DAS). The right hand side shows the emergence count as a function of thermal sum.

3.3 Plant growth and development in the three treatments during 2018-19 growing season: Flag leaf stage

Table 2 shows the flag leaf stage data for the cultivars GW322(C6), C306(C7), DBW88(C8) and collected from local farmers(C9 & C10). It can be seen that the local cultivars C9 & C10 reach flag leaf stage fastest (around 20th of January) when sown early. The number of days required to reach the flag leaf stage reduces for later sowings (from 80 ± 2 to 73 ± 1 days after sowing) hence plot 3 reaches the flag leaf stage already on 11th of February. The thermal sum is lower for the late sowing. In plot one GW322 reaches the flag leaf stage at the same time as the local farmer cultivar, however, in plot 2 and 3 it is two and three days faster to reach the flag leaf stave when compared to the localc farmers cultivar, respectively. It reaches the flag leaf stage more than 10 days faster of a 1st of December sowing compared ot a 1st of November sowing. DBW88 is the second cultivar to reach the flag leaf stage on 26th of January in plot 1. This one too reaches the same growth stage 10 days faster and with a lower thermal sum for a later sowing and flowers no later than 14th of February. For C306 only limited data for plot 1 and two is available.

Table 2: Flag leaf stage data for the cultivars GW322(C6), C306(C7), DBW88(C8) and collected from local farmers(C9 & C10).

GW322:

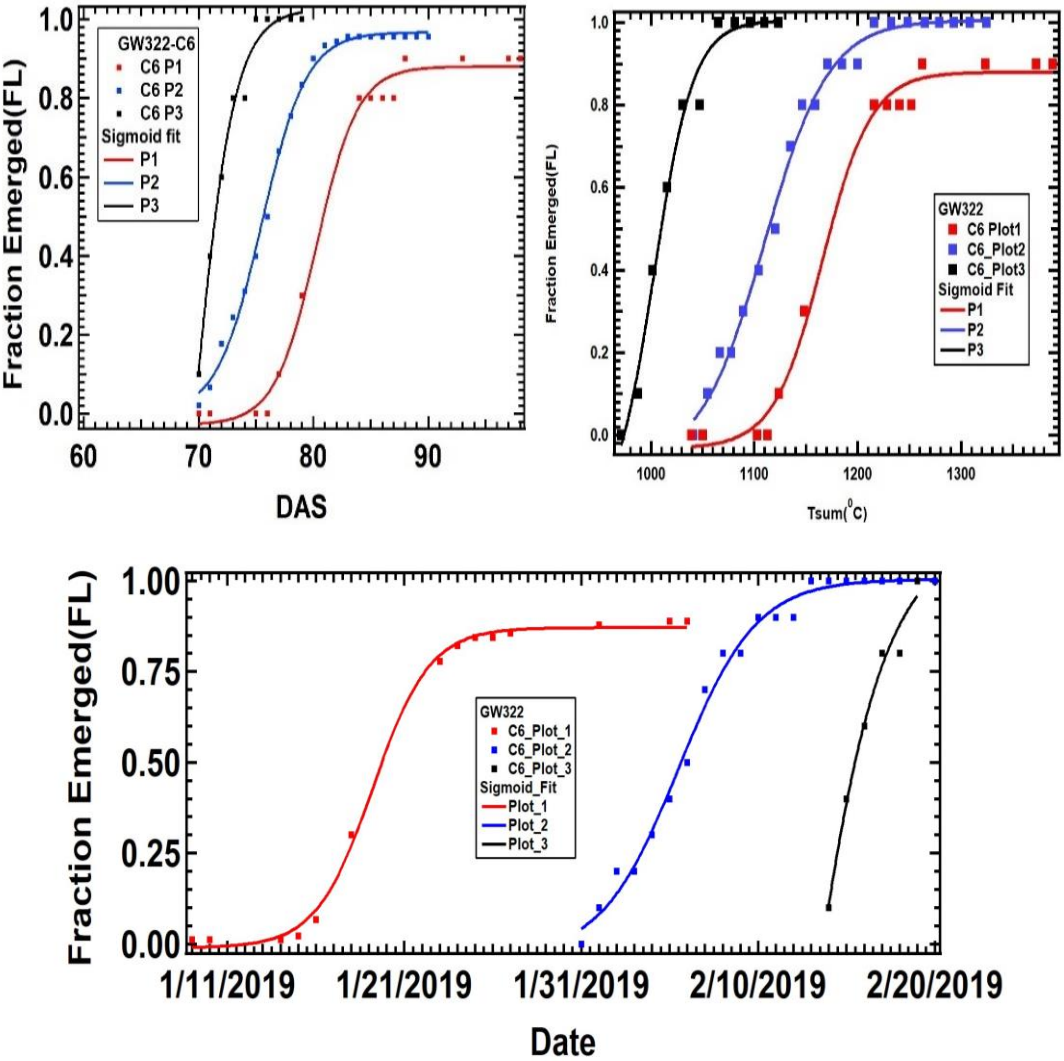

Figure 10: Flag Leaf count of cultivar GW322. The left hand panel shows the Flag Leaf count as a function of days after sowing (DAS). The right hand side shows the Flag Leaf count as a function of thermal sum. The lower graph shows the flag leaf emergence with date-time.

Figure 10 shows the flag leaf count of cultivar GW322. The left hand panel shows the flag leaf count as a function of days after sowing (DAS). The right hand side shows the flag leaf count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a flag leaf. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of

December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that GW322 grow the flag leaf in a shorter time span and with a lower thermal sum if shown later. While plot 3 has been sown 30 days later flag leaf comes only 20 days later compared to the earlier sowing.

C306:

Figure 11 shows the flag leaf count of cultivar C306. The left hand panel shows the flag leaf count as a function of days after sowing (DAS). The right hand side shows the flag leaf count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a flag leaf. The number does

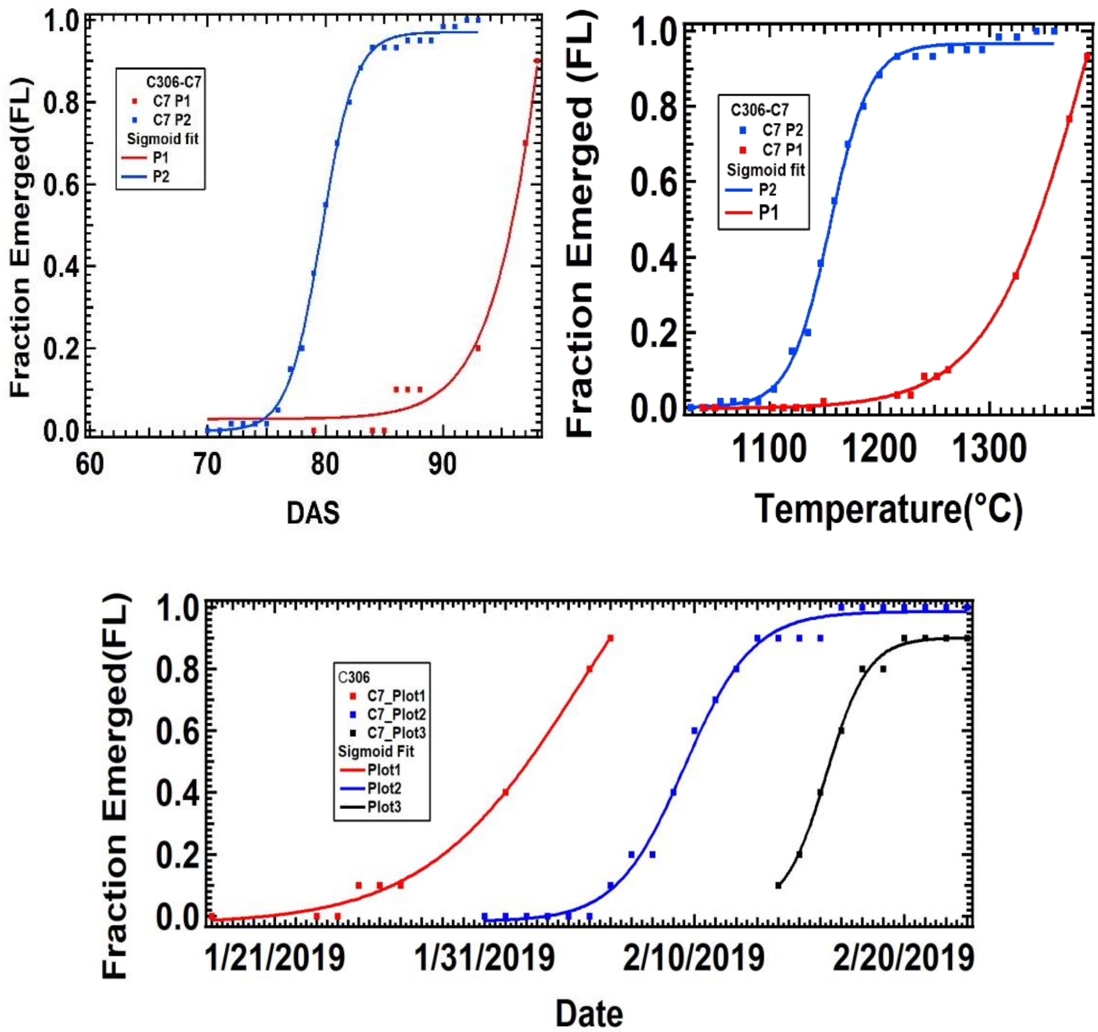

Figure 11: Flag Leaf count of cultivar C306. The left hand panel shows the Flag Leaf count as a function of days after sowing (DAS). The right hand side shows the Flag Leaf count as a function of thermal sum. The lower graphs shows the flag leaf emergence with date and time.

not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November and 15th of November) are indicated using the colours red and blue respectively. On one hand the graph shows a difference (of 15 days) in emergence of flag leaf stage and on the other hand an absolute difference in their temperature sum.

<u>DBW88:</u>

Figure 12 shows the flag leaf count of cultivar DBW88. The left hand panel shows the flag leaf count as a function of days after sowing (DAS). The right hand side shows the flag leaf count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a flag leaf. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right

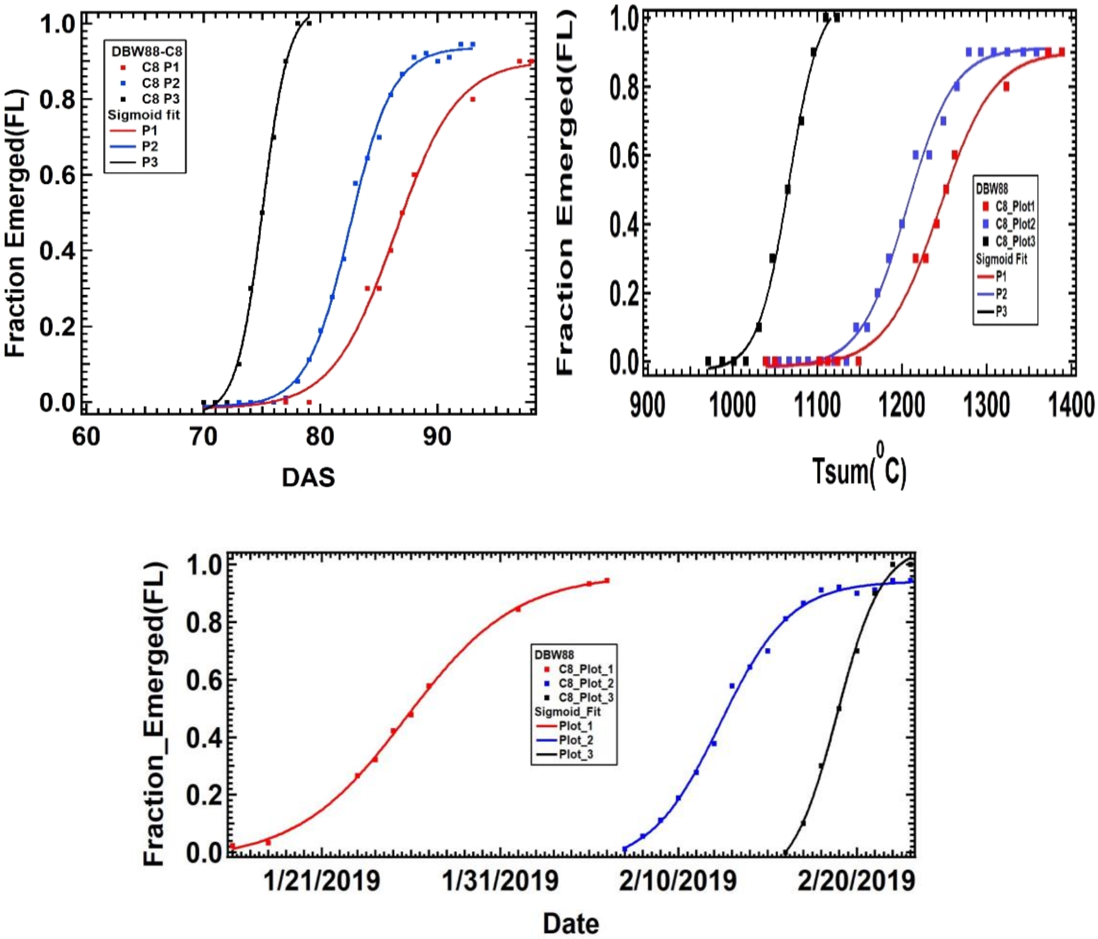

Figure 12: Flag Leaf count of cultivar DBW88. The left hand panel shows the Flag Leaf count as a function of days after sowing (DAS). The right hand side shows the Flag Leaf count as a function of thermal sum. The lower graphs shows the flag leaf emergence with the date-time

hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that DBW88 grow the flag leaf in a shorter time span and with a lower thermal sum if shown later. While plot 3 has been sown 30 days later flag leaf comes only 20 days later compared to the earlier sowing.

Local Farmer C9 and C10:

Figure 13 and 14 show the flag leaf count of cultivar Local breed C9. The left hand panel shows the flag leaf count as a function of days after sowing (DAS). The right hand side shows the flag leaf count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a flag leaf. The number does not reach 1 because on some position both seeds did not emerge. The x- axis

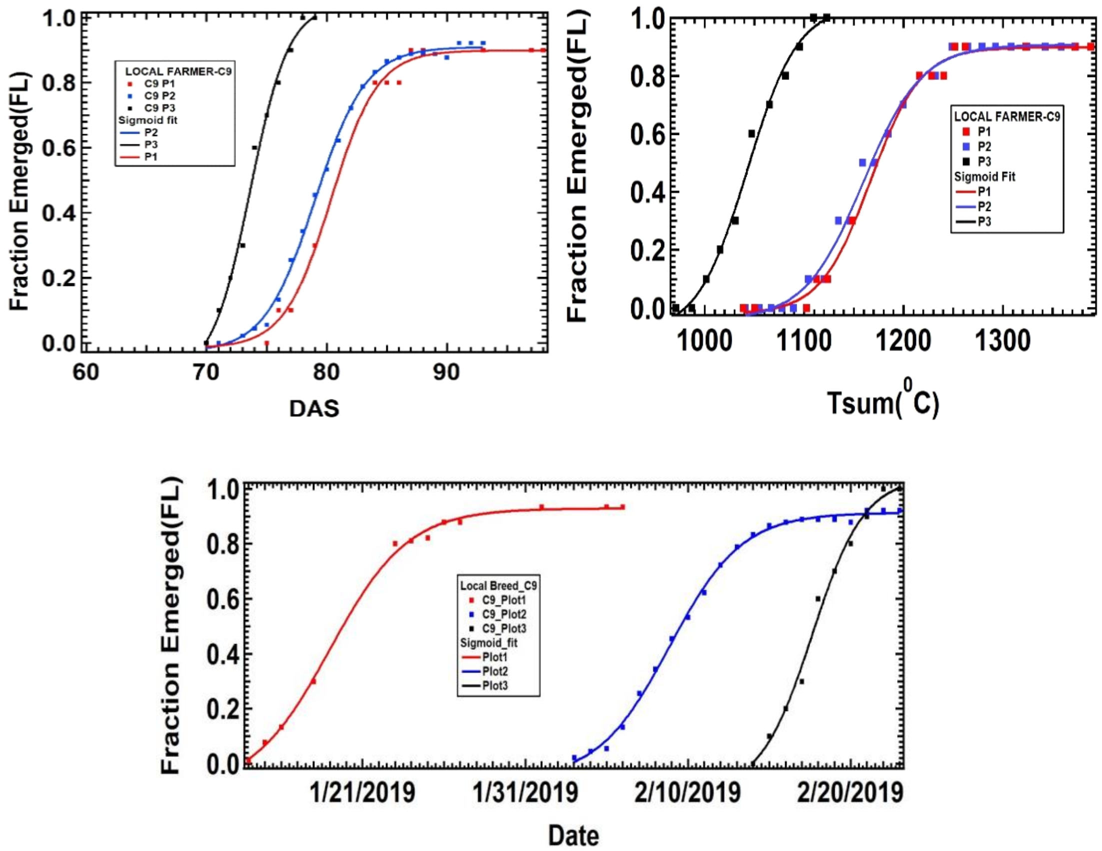

Figure 13: Flag Leaf count of cultivar Local breed C9. The left hand panel shows the Flag Leaf count as a function of days after sowing (DAS). The right hand side shows the Flag Leaf count as a function of thermal sum. The lower graphs shows the flag leaf emergence with date-time

shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that Local breed C9 cultivar on the other hand takes almost the same time and thermal time to the flag leaf stage irrespective of sowing time. It is barely 5 days faster for a very late sowing.

Figure 14 shows the flag leaf count of cultivar Local breed C10 which is the same seeds as C9. The left hand panel shows the flag leaf count as a function of days after sowing (DAS). The right hand side shows the flag leaf count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a flag leaf. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of

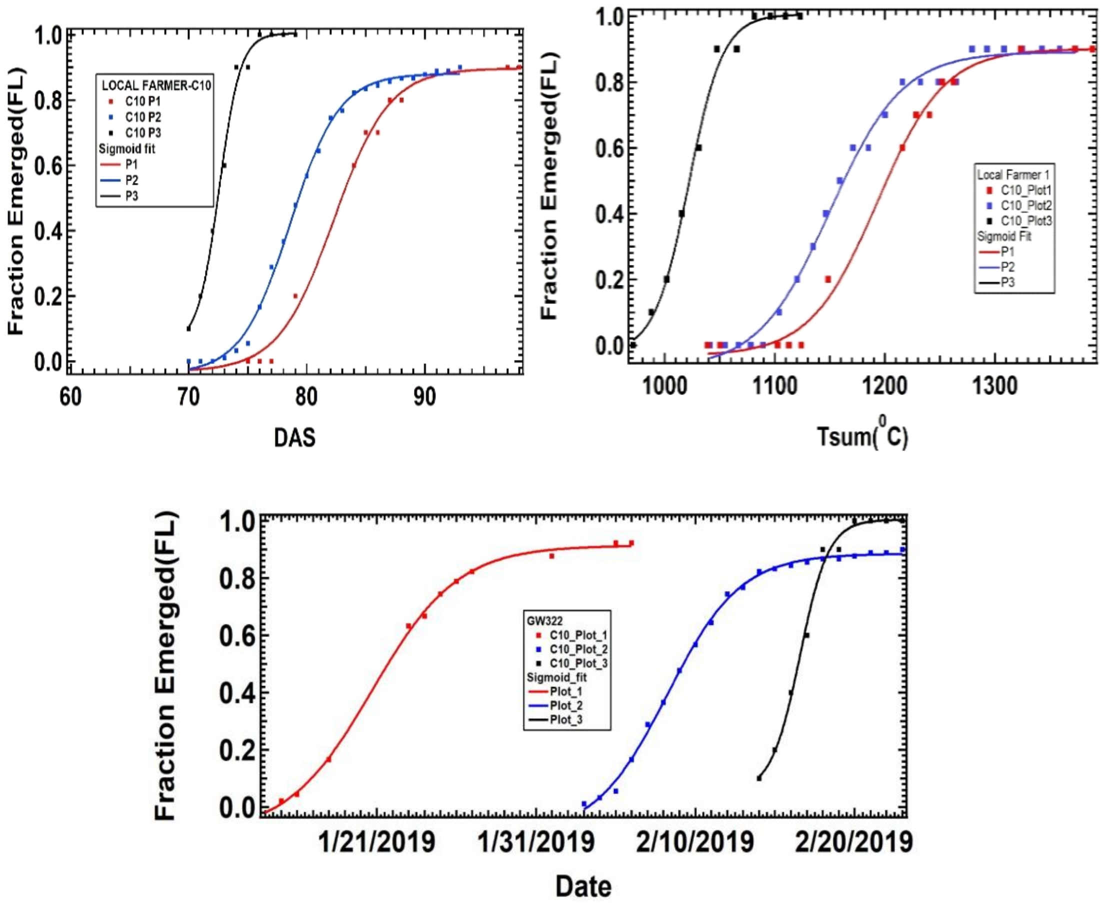

Figure 14: Flag Leaf count of cultivar Local breed C10. The left hand panel shows the Flag Leaf count as a function of days after sowing (DAS). The right hand side shows the Flag Leaf count as a function of thermal sum. The lower graphs shows the flag leaf emergence with date-time.

November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that Local breed C10 cultivar on the other hand takes almost the same time and thermal time to the flag leaf stage irrespective of sowing time. It is barely 5 days faster for a very late sowing.

3.4 Plant growth and development in the three treatments during 2018-19 growing season: Heading

Table 3 summarizes the heading data of all the four cultivars in terms of number of days after sowings it took for the cultivars to grow the head, in terms of the thermal sum to heading and the actual date on which 50% of the plants had heads. GW322 was the first cultivar to grow heads in all three plots. 50% of the plants had heads on 1st of February, 13th of February and 27th of February, respectively in the three treatments. Heads were observed approximately 13-14 days after the flag leaf for plot 1 & 2 but 18 days after the flag leaf in plot 3. The second cultivar to have 50% heads was the local farmers cultivar (C9 & C10) on on 2nd of February, 18th of February and 1st-2nd of March, respectively. Heads were observed approximately 11-14 days after the flag leaf for plot 1, 16 days after the flag leaf for plot 2 and 18 days after the flag leaf in plot 3. The third cultivar to have 50% heads was DBW-88 on on 7tj of February, 20th of February and 3rd of March, respectively. Heads were observed approximately 13-14 days after the flag leaf for plot 1 and 2 and 17 days after the flag leaf in plot 3. C306 showed 50% heads on 11th of February and 18th of February (i.e. only 7 days apart) for plot 1 and 2 respectively. The time difference between 50% Flag leaf and 50% heads was 15 days for plot 2. There is too little data to establish this time difference for other plots.

Overall it seems that the later sowings need a longer time to grow heads for all cultivars, even though they grew flag leaves earlier. Whether this observation can be reproduced remains to be tested in future years, but it is certainly peculiar and possibly related to unmet vernalisation requirements or insufficient vegetative growth (no tillering) before the winter cold set in and means that cultivars sown late fail to escape terminal heat stress.

Table 3: Heading data for the cultivars GW322 (C6), C306 (C7), DBW88 (C8) and collected from local farmers (C9 & C10).

GW322

Figure 13 shows the heading count of cultivar GW322. The left hand panel shows heading count as a function of days after sowing (DAS). The right hand side shows the heading count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that the cultivar shows head growth in a shorter time span and with a lower thermal time if sown late (1^{st} December) as compared to when it is sown earlier (1^{st} November).

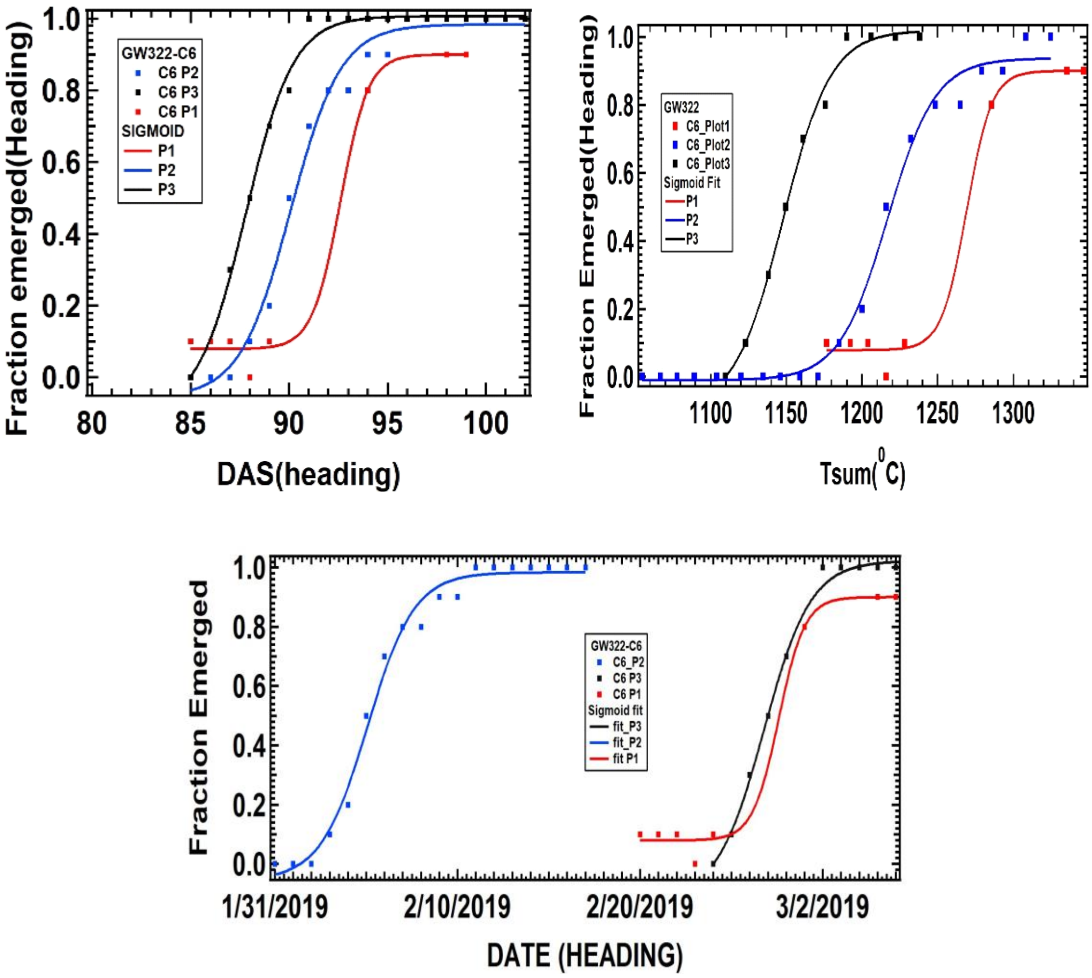

Figure 15: Heading count of cultivar GW322. The left hand panel shows the Heading count as a function of days after sowing (DAS). The right hand side shows the Heading count as a function of thermal sum. The lower graphs shows the heading count as a function of date-time.

<u>C306:</u>

Figure 16 shows the heading count of cultivar C306. The left hand panel shows heading count as a function of days after sowing (DAS). The right hand side shows the heading count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel.

The different sowing dates (1st of November and 15th of November) are indicated using the colours red and blue respectively. It can be seen from the graph that C306 shows that due to late sowing (15th November) the head grows with a shorter time span and with a lower thermal sum as compared to if sown earlier (1st November).

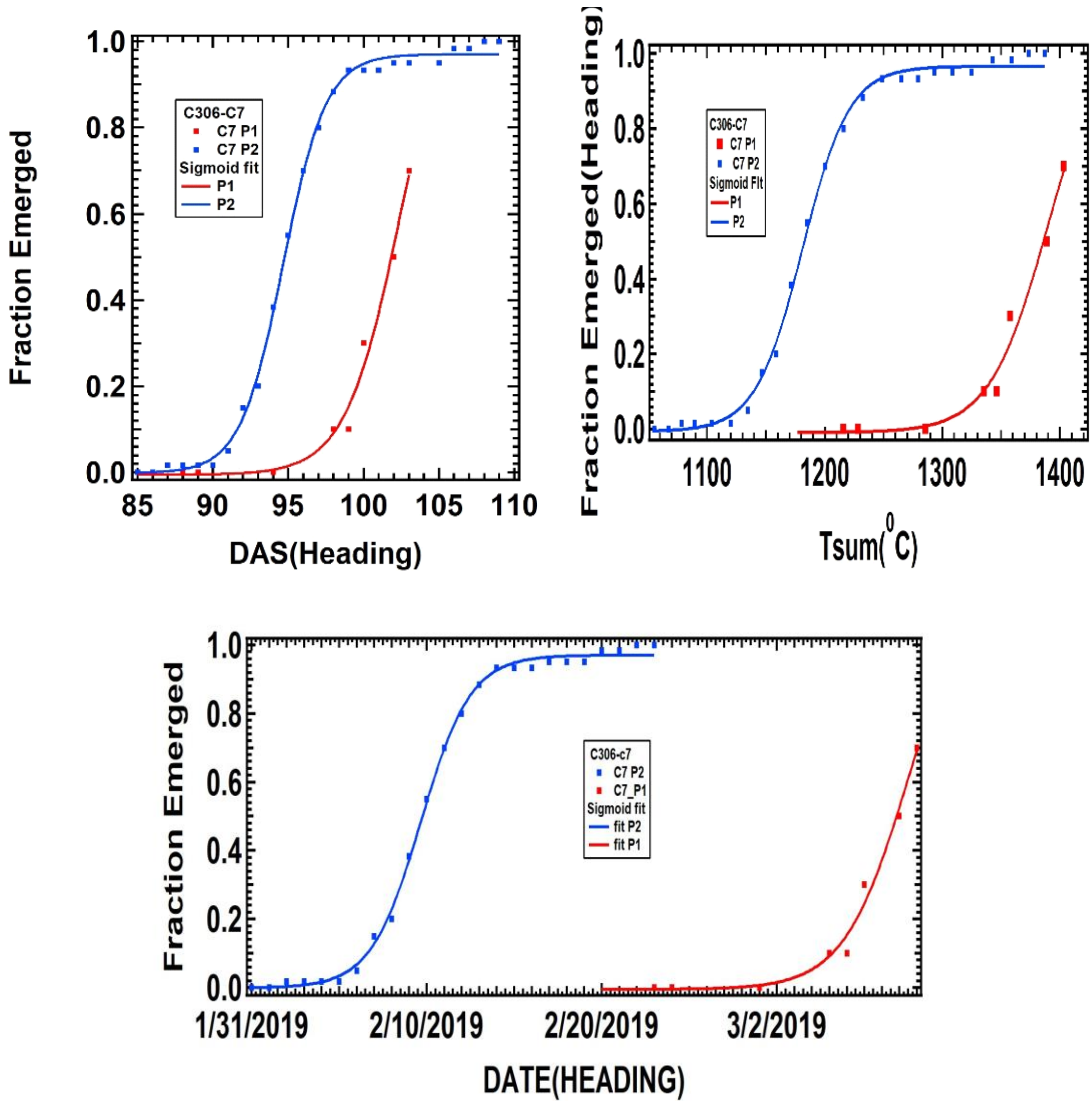

Figure 16: Heading count of cultivar C306. The left hand panel shows the Heading count as a function of days after sowing (DAS). The right hand side shows the Heading count as a function of thermal sum. The lower graphs shows the heading count as function of date-time.

DBW88:

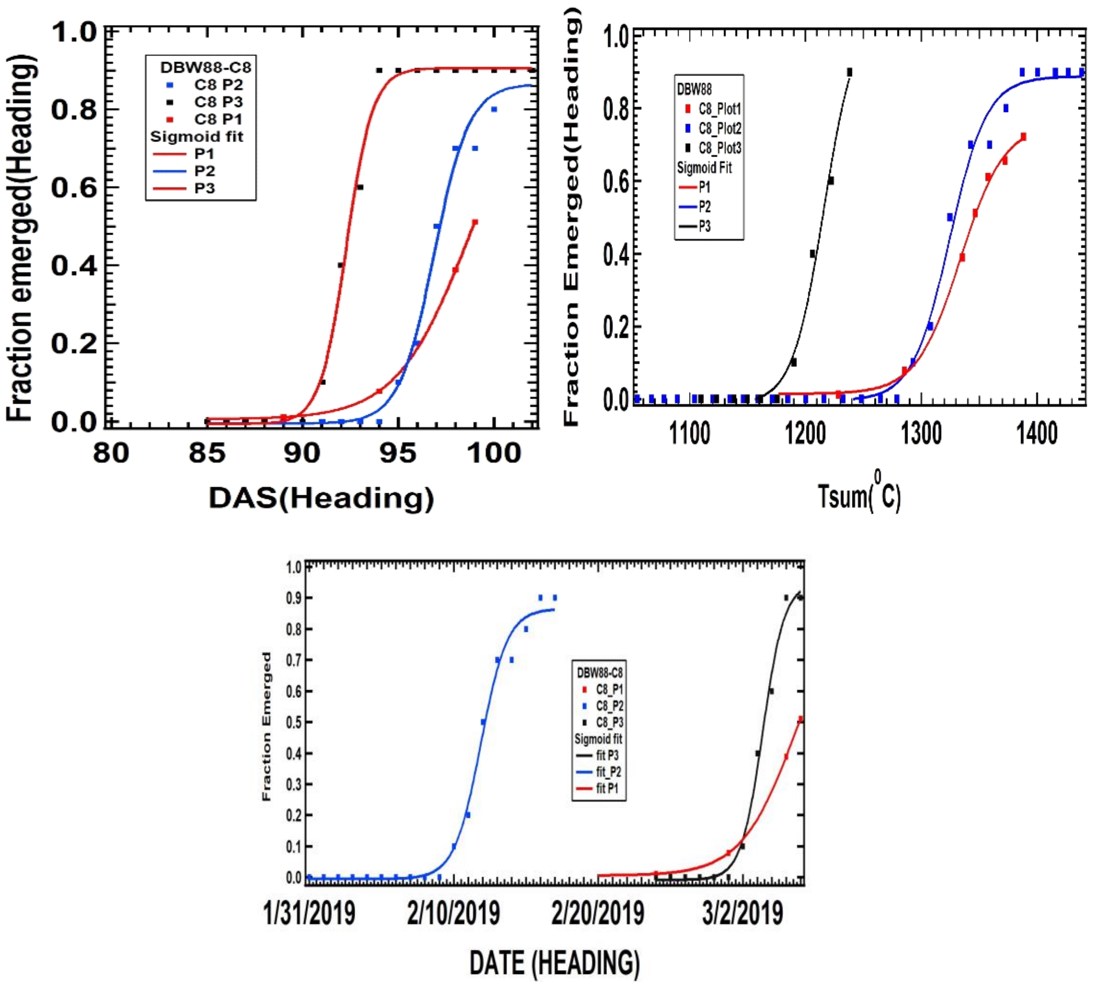

Figure 17: Heading count of cultivar DBW88. The left hand panel shows the Heading count as a function of days after sowing (DAS). The right hand side shows the Heading count as a function of thermal sum. The lower graphs shows the Heading count as a function of date-time.

Figure 17 shows the heading count of cultivar DBW88. The left hand panel shows heading count as a function of days after sowing (DAS). The right hand side shows the heading count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of

December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that the cultivar shows head growth in a shorter time span and with a lower thermal time if sown late (1st December) as compared to when it is sown earlier (1st November). Earlier sowing shifts the reproductive growth to a time with lower temperature and ozone (beginning of February instead of February/beginning of March). Higher yields are expected for earlier sowings.

Local Breed C9 and C10

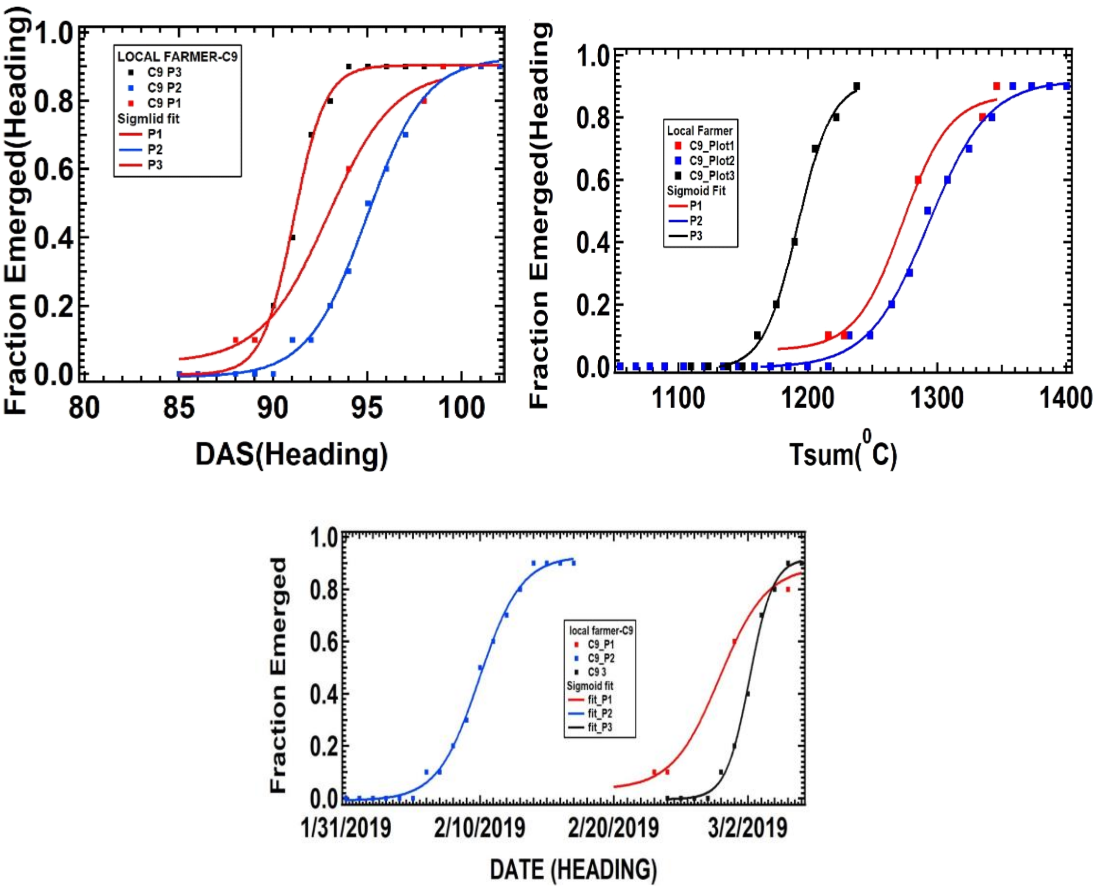

Figure 18: Heading count of cultivar Local Breed C9. The left hand panel shows the Heading count as a function of days after sowing (DAS). The right hand side shows the Heading count as a function of thermal sum. The lower graphs shows the Heading count as a function of date-time.

Figure 18 shows the heading count of cultivar Local breed C9. The left hand panel shows heading count as a function of days after sowing (DAS). The right hand side shows the heading count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that the cultivar shows head growth in a shorter time span and with a lower thermal time if sown late (1st December) as compared to when it is sown earlier (1st November). Earlier sowing shifts the reproductive growth to a time with lower temperature and ozone (beginning of February instead of February/beginning of March). Higher yields are expected for earlier sowings.

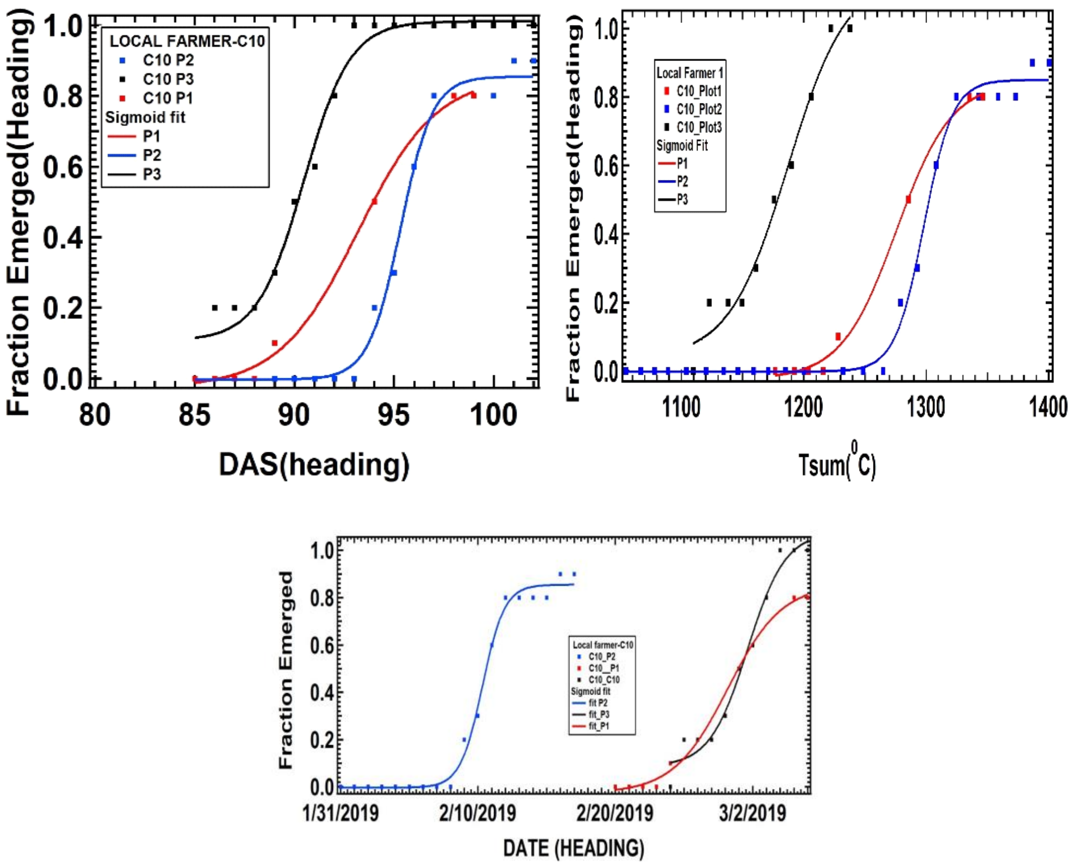

Figure 19: Heading count of cultivar Local Breed C10. The left hand panel shows the Heading count as a function of days after sowing (DAS). The right hand side shows the Heading count as a function of thermal sum. The lower the graph shows the

Figure 19 shows the heading count of cultivar Local breed C10. The left hand panel shows heading count as a function of days after sowing (DAS). The right hand side shows the heading count as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (1st of November, 15th of November and 1st of December) are indicated using the colours red, blue and black respectively. It can be seen from the graph that the cultivar shows head growth in a shorter time span and with a lower thermal time if sown late (1st December) as compared to when it is sown earlier (1st November). Due to earlier sowing the reproductive growth shifts to a time with lower temperatures and ozone and higher yields are expected for earlier sowing.

3.5 Plant growth and development in the three treatments during 2018-19 growing season: Anthesis

Table4 summarizes the anthesis data of all the four cultivars in terms of number of days after sowings it took for the cultivars to reach 50% flowering, in terms of the thermal sum to heading and the actual date on which 50% of the plants had antlers. Only data for plot 2 & 3 was taken. GW322 was the first cultivar to show antlers in both plots. 50% of the plants had antlers on 25th of February and 14th of March, respectively in Plot 2 and 3. Antlers were observed approximately 12 and 15 days after 50% heads had appeared in plot 2 and 3, respectively. The second cultivar to have 50% antlers was the local farmers cultivar (C9 & C10) on on 26th of February and 12th of March, respectively for plot 2 and 3. Antlers were observed approximately 8 and 11 days after the heads for plot 2 and 3, respectively. The third cultivar to have 50% antlers was C306 on 28th of February in plot 2, 11 days after 50% heads were observed. The data for this cultivar cannot be analysed further because there is no data to compare it with. DBW-88 showed 50% antlers on 2nd and 13th of March, respectively. Antlers were observed 10 days after 50% of the heads were out on both plot 2 and plot 3. While there is an up to 5 day lag between the time 50% antlers were reached for the different cultivars in plot 2 all of them reach 50%

antlers within 2 days on plot 3. It is likely that this happened because peak daytime temperatures were close to 30 degree Celsius when the flowering happened on plot 3 and this may have accelerated the process for some of the cultivars that were slower on plot 2 due to heat stress.

Table 4: Anthesis data for the cultivars GW322(C6), C306(C7), DBW88(C8) and collected from local farmers(C9 & C10).

GW322:

Figure 18 shows the anthesis of cultivar GW322. The left hand panel shows anthesis as a function of days after sowing (DAS). The right hand side shows the anthesis as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (15th of November and 1st of December) are indicated using the colours blue and black respectively. The graph indicates that the anthesis occurred within 101 days after sowing for both the plots. This shows that early sowing results in early flowering for the cultivar and less prone to yield loss.

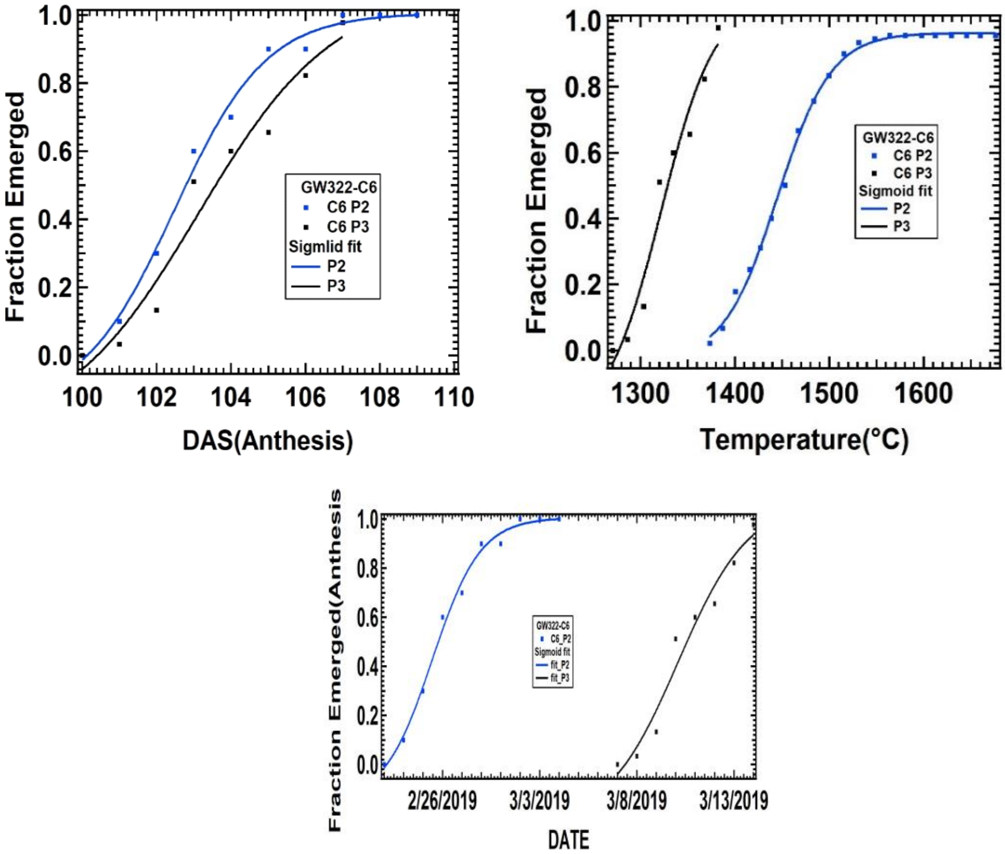

Figure 18: Anthesis count of cultivar GW322. The left hand panel shows the Anthesis count as a function of days after sowing (DAS). The right hand side shows the Anthesis count as a function of thermal sum. The lower graphs shows the Anthesis

C306:

Figure 19 shows the anthesis of cultivar C306. The left hand panel shows anthesis as a function of days after sowing (DAS). The right hand side shows the anthesis as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (15th of November) are indicated using the colours blue respectively. The graph indicates that the anthesis occurred within 105 days after sowing for the plot. Unfortunately, no data was collected on plot 1 which makes interpretation difficult.

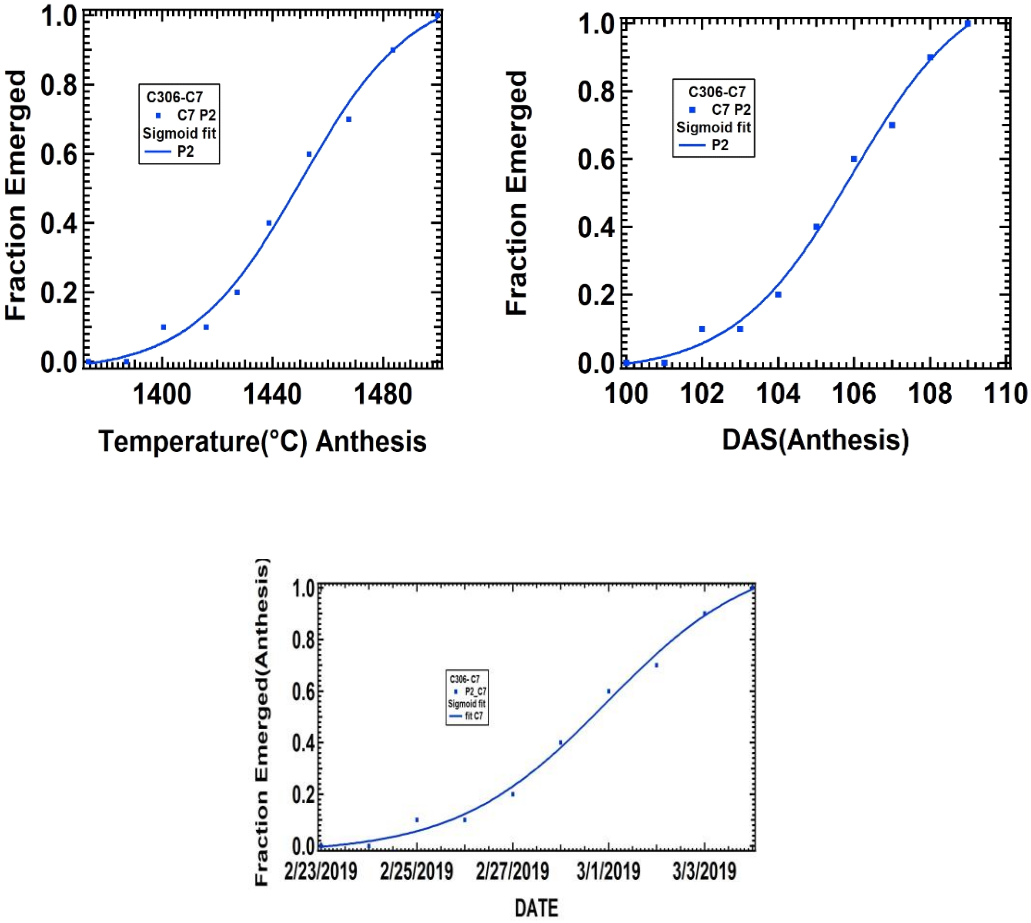

Figure 19: Anthesis count of cultivar C306. The left hand panel shows the Anthesis count as a function of days after sowing (DAS). The right hand side shows the Anthesis count as a function of thermal sum. The lower graph show the Anthesis

<u>DBW88:</u>

Figure 20 shows the anthesis of cultivar DBW88. The left hand panel shows anthesis as a function of days after sowing (DAS). The right hand side shows the anthesis as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (15th of November and 1st of December) are indicated using the colours blue and black respectively. The graph indicates that the anthesis occurred within 101 days after sowing for both the plots. The cultivar needs almost the same number of days but a lower thermal sum to reach anthesis.

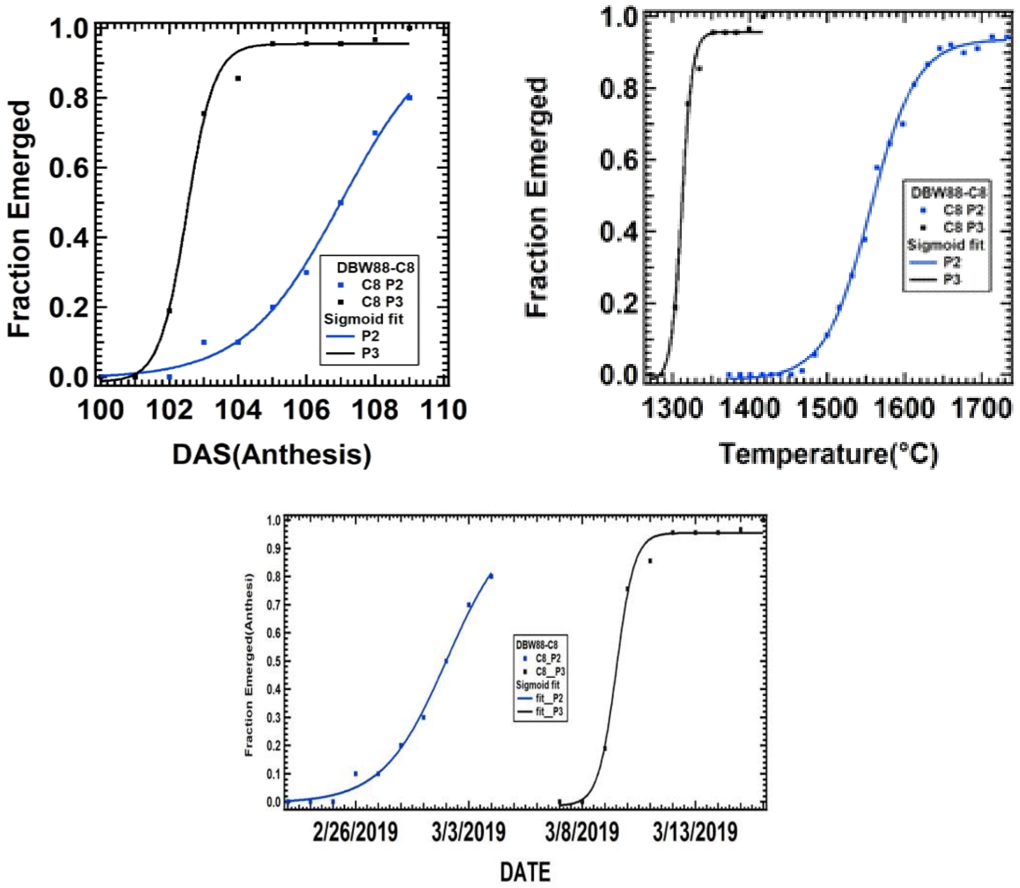

Figure 20: Anthesis count of cultivar DBW88. The left hand panel shows the Anthesis count as a function of days after sowing (DAS). The right hand side shows the Anthesis count as a function of thermal sum. The lower graph show the Anthesis count as a function of date-time

LOCAL FARMER C9 and C10:

Figure 21 shows the anthesis of cultivar Local breed C9. The left hand panel shows anthesis as a function of days after sowing (DAS). The right hand side shows the anthesis as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (15th of November and 1st of December) are indicated using the colours blue and black respectively. The graph indicates that the anthesis occurred within 101 days after sowing for both the plots. The cultivar needs almost the same number of days but a lower thermal sum to reach anthesis.

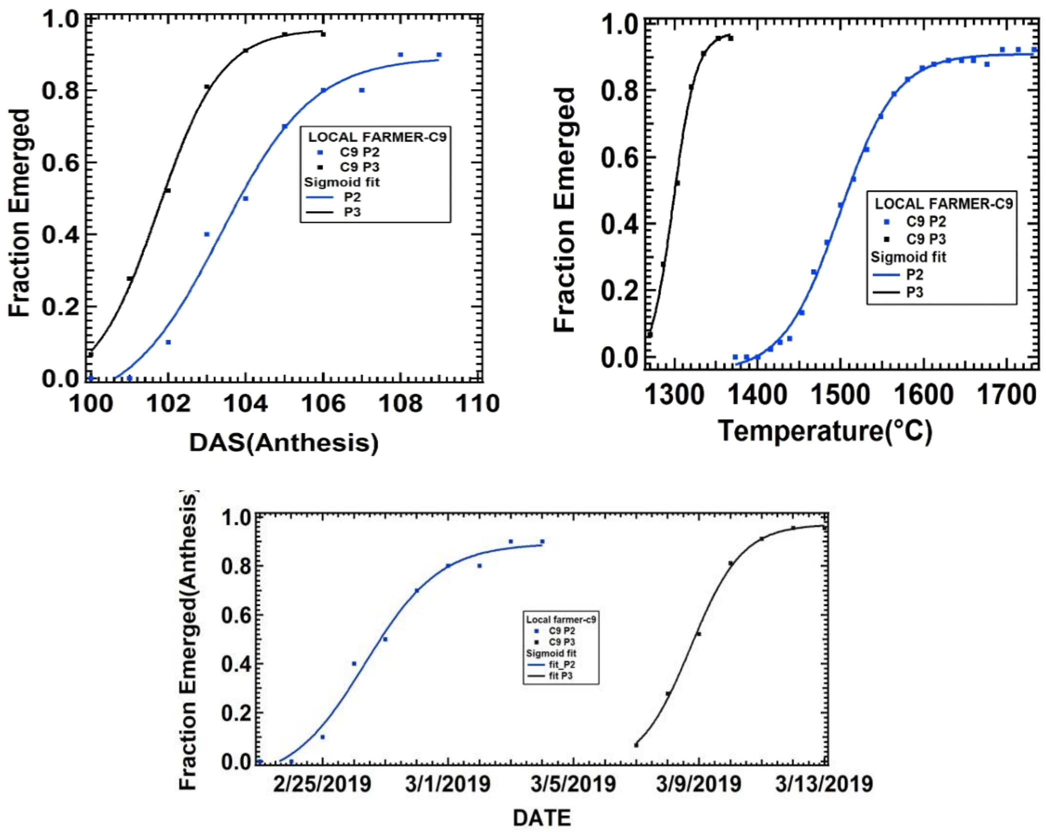

Figure 21: Anthesis count of cultivar LOCAL FARMER C9. The left hand panel shows the Anthesis count as a function of days after sowing (DAS). The right hand side shows the Anthesis count as a function of thermal sum. The lower graph show the Anthesis count as a function of date-time

Figure 22 shows the anthesis of cultivar Local breed C10. The left hand panel shows anthesis as a function of days after sowing (DAS). The right hand side shows the anthesis as a function of thermal sum. The y-axis shows the fraction of the 90 plants which should have emerged and were retained which had a heading. The number does not reach 1 because on some position both seeds did not emerge. The x- axis shows the number of days after sowing for the left hand panel and the thermal time on the right hand panel. The different sowing dates (15th of November and 1st of December) are indicated using the colours blue and black respectively. The graph indicates that the anthesis occurred within same days after sowing for both the plots. The cultivar needs almost the same number of days but a lower thermal sum to reach anthesis.

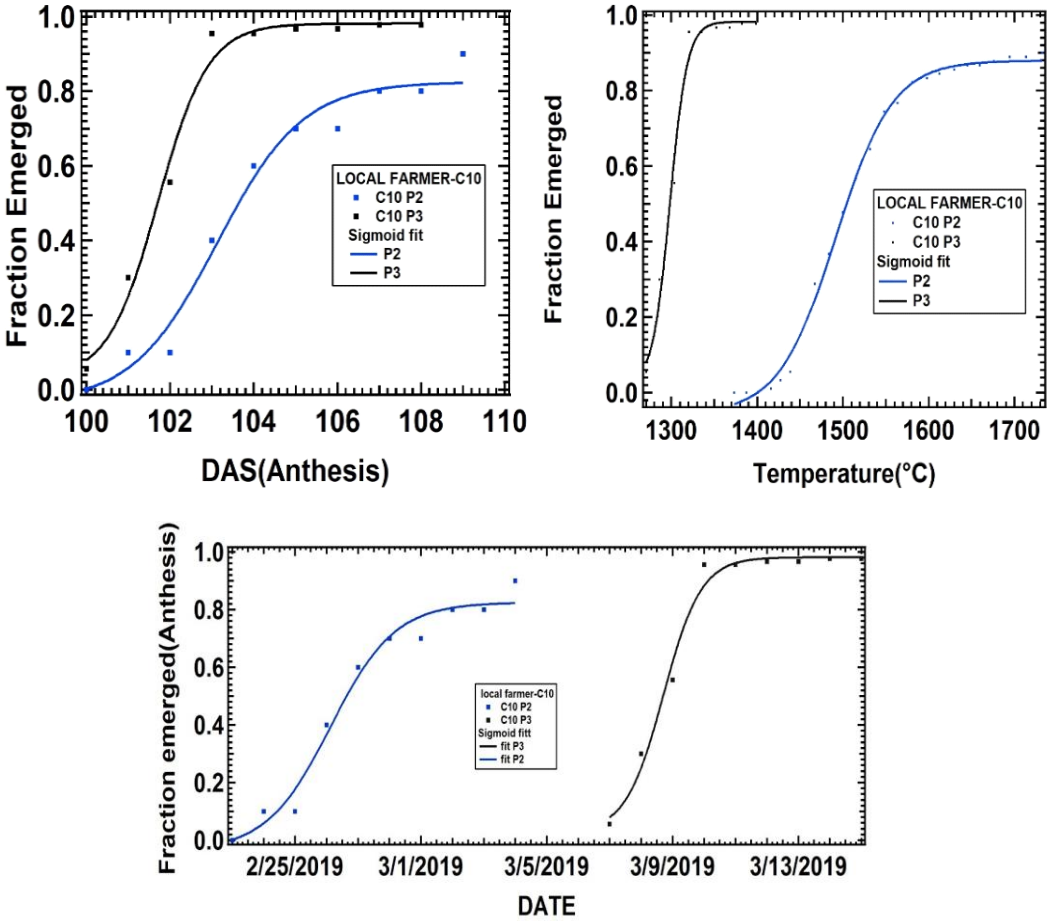

Figure 22: Anthesis count of cultivar LOCAL FARMER C10. The left hand panel shows the Anthesis count as a function of days after sowing (DAS). The right hand side shows the Anthesis count as a function of thermal sum. The lower graph shows the function as a function of date-time.

3.6 Yield parameters during 2018-19 growing season:

While detailed yield data will be analysed by future students, some proxy for yield can be recorded quickly. These are the average number of active tillers for the three treatments and the average head length for the three treatments. Table 5 shows the average count of active tiller per plant and average head length for the cultivars GW322(C6), C306(C7), DBW88(C8) and collected from local farmers (C9 & C10). It can be seen that the average number of active tillers decreases for later sowing dates across all cultivars. The effect is most pronounced for GW322 which develops very rapidly and is the first to flower and less pronounced for DBW-88 one of the later flowering cultivars. The number of active tillers is very high for C7. This has to be cross checked at harvest since the plant is very tall and partially lodged and it is difficult to count the tillers accurately without damaging the plant further. The average head length, too, decreases for later sowing. There is no significant difference between plot 1 and plot 2 for all cultivars. GW322, DBW88 and C9 show a significantly shorter head for plot 3.

Table 5: Average count of active tiller per plant and average head length for the cultivars GW322(C6), C306(C7), DBW88(C8) and collected from local farmers(C9 & C10).

Chapter 4

Conclusions

In this study we show the field measurements of plant phenology from four different cultivars sown in Mohali, Punjab in the NW-IGP during winter 2018-19. The cultivars were GW322, C306, DBW88, Local breed. The cultivars GW322, C306 and DBW88 were acquired from breeders while Local breeds were obtained from seed shop were grown for comparison.

The phenological observation was taken at different stages of plant and different interval of time is used to get optimum window for sowing, favourable environmental conditions for growth and good yield. For each cutivars the number of active tillers and average head length varies from 9-30 and 10-14 cm respectively. The earliest sowing had the highest number of active tillers. If the grains are well filled, this indicates that an experiment to test how early wheat can be sown for optimum yield should consider earlier sowing times as well. The newly developed Happy Seeder makes such early sowings for the short duration parmal paddy varieties possible.

Our study shows that sowing dates is playing very crucial role in determining plant phenology. if the sowing is done on 1st November, we can get better yield as compared to other sowing dates. The yield loss is due to the heat waves, unfavourable environmental conditions at the time of anthesis and grain filling stage for plot 3.

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