



(RESEARCH ARTICLE)



## Temperature and relative humidity in a commercial bread wheat field, recorded by an automated meteorological station and a digital sensor in the Yaqui Valley, Sonora, Mexico

Maria Monserrat Torres-Cruz <sup>1</sup>, Pedro Felix-Valencia <sup>2</sup> and Guillermo Fuentes-Davila <sup>1,\*</sup>

<sup>1</sup> *Wheat Pathology, INIFAP, Norman E. Borlaug Experimental Station, Apdo. Postal 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Cd. Obregon, Sonora, Mexico.*

<sup>2</sup> *Agroclimatology, Norman E. Borlaug Experimental Station, Apdo. Postal 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Cd. Obregon, Sonora, Mexico.*

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### Abstract

Meteorological parameters determine most agronomic events, with temperature being the climatological factor most closely related to the annual productivity of a crop. The objective of this work was to monitor the temperature and relative humidity at different growth stages of a commercial bread wheat field, during the crop season 2017-2018. The work was carried out with data obtained from December 12, 2017 (sowing date) to April 18, 2018, from a mobile OMEGA OM-EL-USB-2 sensor within the field, sown with the bread wheat cultivar Borlaug 100, located in Block 1020, in the Yaqui Valley, Sonora, Mexico, and from the Block 910-CIANO meteorological station, located 8 km away, which is the closest to the field. Calculations were made for the average temperature, relative humidity and cold units (CU). In addition, the data was filtered by day and night time, considering daytime data from 7:00 to 18:00 and nighttime data from 19:00 to 06:00. The CU recorded by the sensor was higher with 384 than the meteorological station, which accumulated a total of 321. The temperature during the day was on average 2.9 °C higher than that recorded by the meteorological station, and 1.6 °C lower at night. The relative humidity recorded by the sensor was 5 % higher than that recorded by the meteorological station.

**Keywords:** Temperature; Digital sensor; Bread wheat; *Triticum aestivum*; Pressurized irrigation

### 1. Introduction

Agriculture is an activity closely related to the climate, therefore it is very sensitive to climate changes and climate variability [1]. Monitoring and recording meteorological data is important, as it allows for timely and pertinent decisions to be made on aspects such as fertilization, sowing and harvesting [2]. In addition, by knowing the precise data on climatic variables, statistical analyses, probable climate scenarios and prediction models of crop phenology, pests and diseases can be carried out [2,3]. The dissemination of meteorological information is of great importance for the agricultural sector, because it is considered a useful tool in decision-making; weather conditions cannot be controlled directly, but by measuring and recording them with sensors and meteorological stations, the farmer can react in time and adjust his crop management practices to protect himself from adverse weather conditions or to take advantage of propitious conditions [4]. There are different electronic tools or instruments where meteorological data can be obtained, such as the sensor/data logger combination (dataloggers), that are inexpensive enough and appear to be accurate enough to be deployed in measurement matrices, to resolve local atmospheric structure over periods of weeks to months [5]. Data can also be obtained from automated meteorological stations, which are electronic devices with autonomous energy, which measure and record weather conditions through the use of electronic sensors [6].

\* Corresponding author: Guillermo Fuentes-Dávila, E-mail: [fuentes.guillermo@inifap.gob.mx](mailto:fuentes.guillermo@inifap.gob.mx)

Temperature is the climatological factor most closely related to the annual productivity of a crop, which controls the development rate of many organisms, that require the accumulation of a certain amount of heat to move from one state to another in their agricultural cycle [7]. According to Félix-Valencia *et al.* [8], wheat development is influenced by meteorological factors such as air temperature and daylight duration, which induce plant development from emergence to flowering and maturity [9], and affects growth processes [10]; high temperatures promote greater metabolic activity in the plant, as well as an acceleration of the physiological processes that determine its growth and development [11]. On the contrary, wheat requires accumulating a total of cold units (CU), to lengthen the biological cycle, and generally a higher grain yield is generated [8]. Regarding relative humidity, wheat requires between 40 and 70%; from the time of heading to harvest is the period with the greatest requirements in this regard, since it requires a relative humidity between 50 and 60 % and a dry climate for its maturation [12]. The objective of this work was to monitor the temperature and relative humidity at different growth stages of a commercial bread wheat field, recorded by an automated meteorological station and a digital sensor.

## 2. Materials and methods

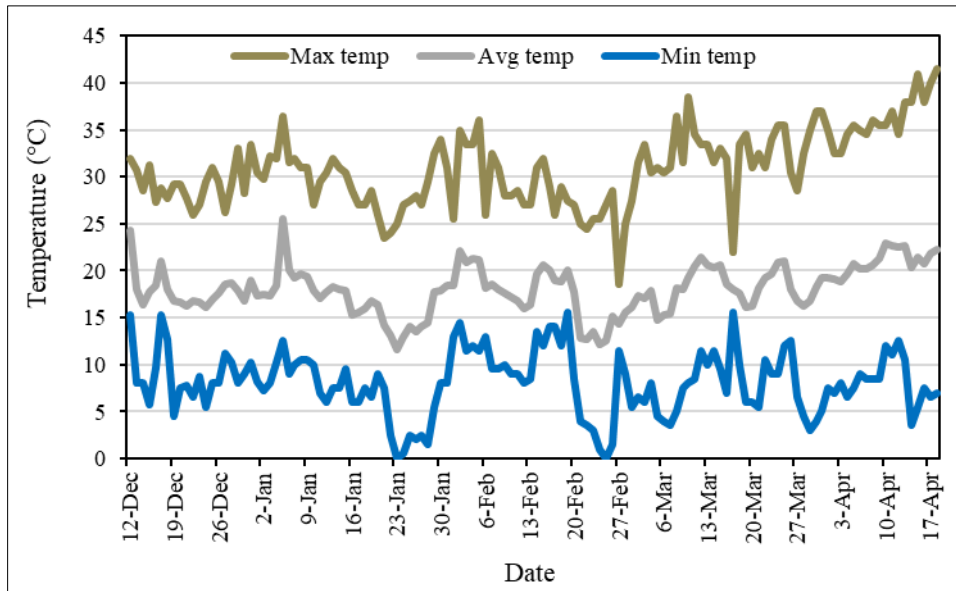
The work was carried out during the crop season 2017-2018 in a commercial field located in Block 1020, lots 11-12 in the Yaqui Valley, Sonora, Mexico, at 27° 20' 50.0640" latitude north, 109° 49' 40.5984" longitude west, at 59 m.a.s.l. (Figure 1). The field has an area of 100 ha and it was sown on December 12, 2017 with the bread wheat cultivar Borlaug 100 [13], with a pressurized front-advance irrigation system. The air temperature and relative humidity within the crop was recorded in an hourly fashion with a mobile sensor (datalogger) OMEGA OM-EL-USB-2, as well as from an automated meteorological station (Figure 1). The station Block 910-CIANO belongs to the automated meteorological station network of Sonora (REMAS), and is located at a distance of 8 km from the wheat field, but it is the closest. This allowed to compare data between the two devices. The data set captured in Excel covers the fall-winter crop season 2017-2018, from December 12, 2017 to April 18, 2018. Calculations were made for the average temperature, relative humidity and cold units. In addition, data was filtered by day and night time, considering daytime data from 7:00 a.m. to 6:00 p.m. and nighttime data from 7:00 p.m. to 6:00 a.m.



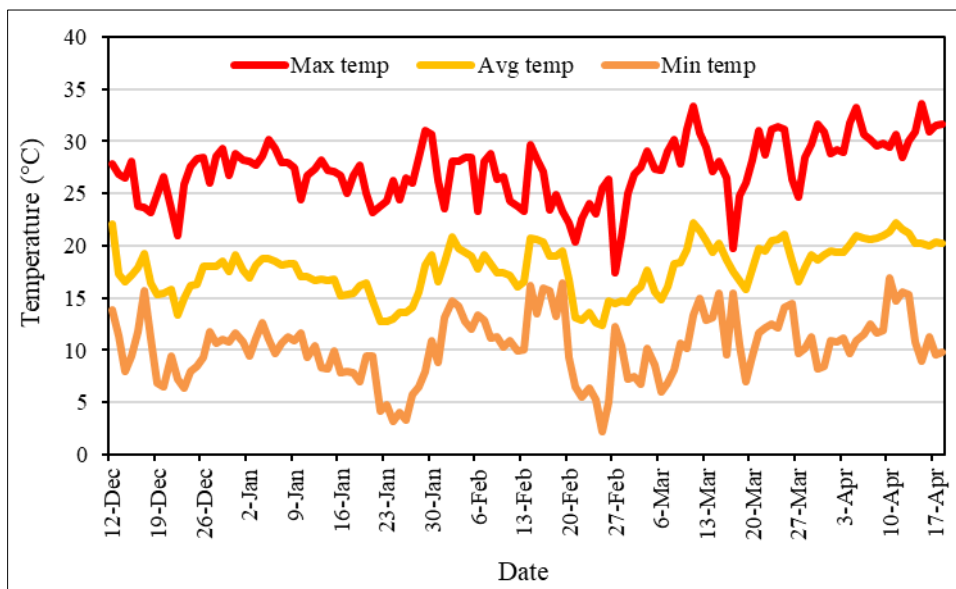
**Figure 1** Location of the commercial wheat field (yellow rectangle) and the closest meteorological station

## 3. Results and discussion

The minimum temperature recorded by the datalogger located inside the wheat field ranged between 0 and 15.5 °C with an average of 8.08 °C (Figure 2), while at the meteorological station, it ranged between 2.16 °C and 16.89 °C with an average minimum temperature of 10.28 °C (Figure 3). Regarding the maximum temperature, the datalogger recorded an average of 30.9 °C, with a temperature range of 18.5 to 41.5 °C, and the meteorological station recorded an average of 27.3 °C, ranging between 17.37 and 33.68 °C. Overall, the average temperature recorded by the datalogger ranged between 11.54 and 25.57 °C (Figure 2) with an average temperature of 18.04 °C, while at the meteorological station, it ranged between 12.41 and 22.18 °C, with an average temperature of 17.74 °C.



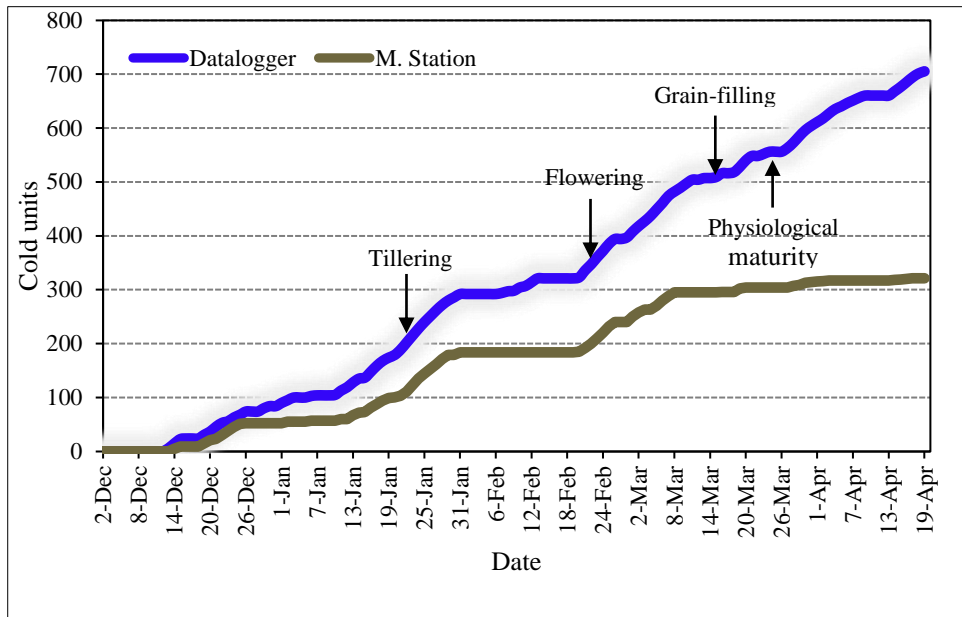
**Figure 2** Maximum, minimum, and average temperature recorded by the datalogger OM-EL-USB-2, from December 12, 2017, to April 18, 2018, within a commercial wheat field sown with cultivar Borlaug 100, in the Yaqui Valley, Sonora, Mexico



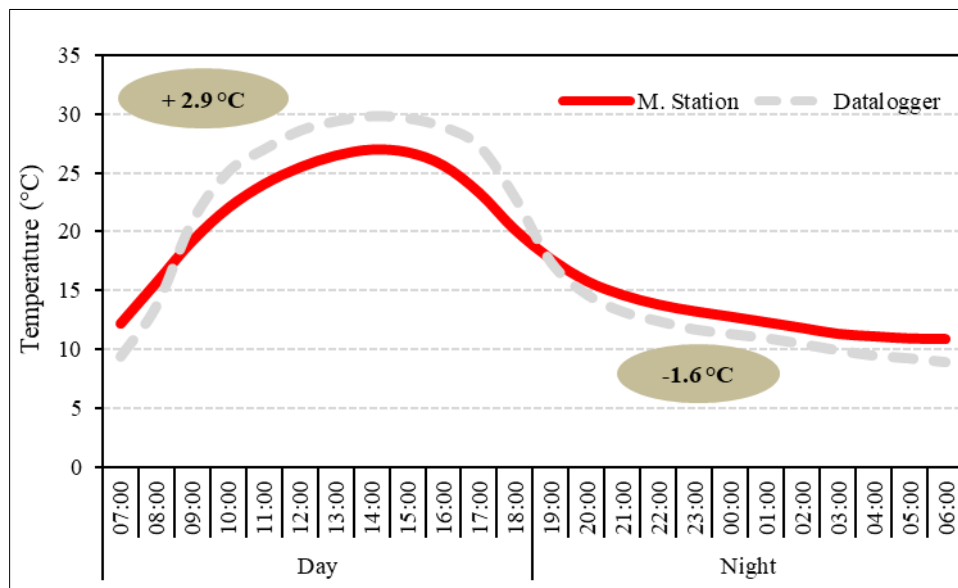
**Figure 3** Maximum, minimum, and average temperature recorded by the automated meteorological station Block 910-CIANO, from December 12, 2017, to April 18, 2018, in the Yaqui Valley, Sonora, Mexico

The number of cold units (CU) recorded by the datalogger in the field during the period of the study was 705, while, the meteorological station recorded a total of 321 CU (Figure 4). The dynamics of CU accumulation recorded by both devices are similar up to March 8, although small differences were detected from December 15; the minimum and maximum differences between December 15 and March 8 were 14 and 187 CU, respectively. Subsequently, the meteorological station recorded a minimum of CU accumulation, in comparison to the datalogger which continued to accumulate CU, even after April 15. Cold conditions lengthen the phenological periods, provide conditions that reduce the speed at which physiological processes take place and consequently slow growth [8]. Depending on the sowing date and climatic conditions, the tillering stage may be extended with greater cold weather, forming more body (higher leaf area index), giving the opportunity for the complete formation of a greater number of tillers; on the other hand, this stage may be shortened by the effects of heat, producing incomplete tillers with less plant body (lower leaf area index). Chilling

requirements at this stage are important to complete optimal growth, particularly those tillers that contribute to potential yield [8]. Figure 4 shows that in the tillering stage, the accumulated CU recorded by the datalogger were 228, 372 at the beginning of flowering, 516 at grain-filling, and 556 at physiological maturity.



**Figure 4** Accumulated cold units recorded by the datalogger OM-EL-USB-2 and the automated meteorological station Block 910-CIANO, from December 12, 2017, to April 18, 2018, in the Yaqui Valley, Sonora, Mexico

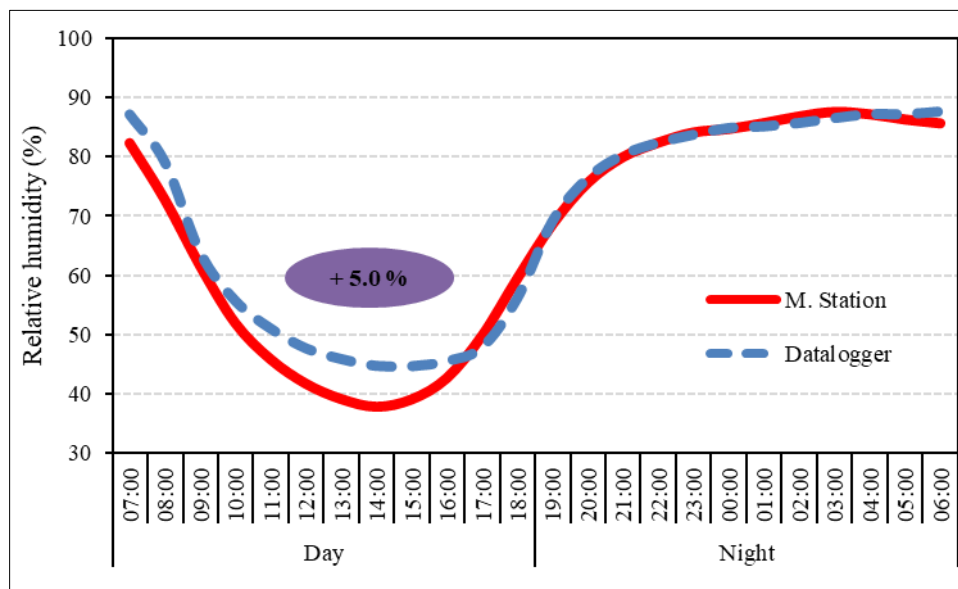


**Figure 5** Hourly average temperature recorded by the datalogger OM-EL-USB-2 and the automated meteorological station Block 910-CIANO, from December 12, 2017, to April 18, 2018, in the Yaqui Valley, Sonora, Mexico

Félix-Valencia *et al.* [8] reported that in a cold season, when the wheat plant reaches the tillering stage, there is a plant cover of 30%, and 150 CU have already accumulated, and Zhao *et al.* [14] reported that approximately 300 CU are needed to ensure good tillering which is directly correlated with grain yield. Félix-Valencia *et al.* [8] concluded that in a warm crop season, the flowering stage begins when around 350 CU have accumulated and 500 CU in a cold season. Stratonovitch and Semenov [15] mentioned that it has been shown that wheat is particularly sensitive to extreme cold and hot temperatures during the reproductive stage, and Madariaga [16] reported that flowering is a stage sensitive to

low temperatures, since it can cause grains of lower weight, sterility or the total loss of the productive capacity of the spike. Regarding the average temperature in hourly format (Figure 5), the meteorological station during the daytime was 2.9 °C lower on average than the datalogger, while at nighttime, the datalogger recorded on average 1.6 °C lower than the meteorological station. Similar results were reported by Torres-Cruz *et al.* [17] in a study inside an experimental station, using the datalogger LCD-520 within a field wheat plot, and the meteorological station Block 910-CIANO located in the same station; the temperature recorded by the meteorological station was 1.89°C in average lower than the datalogger, while at night, the datalogger recorded colder temperatures, an average of -0.98°C lower than the records of the meteorological station.

In December, during the day, the datalogger recorded 2.1 °C greater than the meteorological station, but there were no differences at night. In the months of January and February, the datalogger detected an average of 2.4 °C greater than the meteorological station during the day, while at night it recorded 1 °C and 1.5 °C, respectively. During the month of March, the sensor recorded 3.3 °C greater than the meteorological station during the day and 2.6 °C lower at night. In the first 18 days of April, the datalogger recorded an average of 4.4 °C greater than the meteorological station during the day and 3.0 °C lower at night. In March, heat waves occurred during the stages of grain-filling to physiological maturity; high temperatures can cause different damage depending on the phenological stage; one of the effects that occur during grain-filling, is the inactivation of enzymes responsible for the conversion of sugar into starch, and another is the loss of photosynthates in the respiration process [18]. The location of each of the weather recording instruments used in this work, may be an important factor in causing the difference in data recording, since the datalogger was installed inside the wheat crop, where it can be affected by the irrigation water and tissues of the developing plant, while the meteorological station was located on a cement floor 8 km away; therefore, the absorption properties and heat radiation are different in both scenarios.



**Figure 6** Hourly relative humidity recorded by the datalogger OM-EL-USB-2 and the automated meteorological station Block 910-CIANO, from December 12, 2017, to April 18, 2018, in the Yaqui Valley, Sonora, Mexico

The main system of irrigation of wheat in the Yaqui Valley is by gravity, but there are instances where the front-advance and spray irrigation schemes are used [19], as it was the case in this work. When the front-advance irrigation system is used, about 12 irrigations have to be applied as compared to three by gravity, although with a lower total amount of water, but the effect of water on the soil and plant tissue in relation to the temperature and humidity was not studied. Different studies have been carried out comparing data from sensors with different technologies, which have found highly significant differences, as reported by Sun *et al.* [20] and Torres-Cruz *et al.* [17]. Gattinoni *et al.* [21] compared the quality of temperature and precipitation data during the year 2007, between one conventional and two automated meteorological stations at daily and monthly scales; the statistical parameters, specially the temperature, resulted to be similar between the stations, but the annual cumulative values and extremes of precipitation showed greater differences. Peña Quiñones *et al.* [22] quantified the difference between the air temperature (AT) measured at a standard meteorological station and by installing thermistors and thermocouples within the vine canopy of a six-year-old vineyard, at heights of 0.5 m and 1.2 m above the soil surface and adjacent to the berry clusters. Significant differences were found between the AT measured at the meteorological station. The average daily minimum AT within

the canopy was 1.2°C lower than at the meteorological station, and the average daily maximum AT in the canopy was 2.0°C higher than at the meteorological station. They concluded that models that assume that AT measured at a meteorological station is similar to AT measured in the vineyard canopy, could have greater uncertainty than models that consider the temperature within the canopy. Monitoring different climatic variables in agriculture through the use of new technologies is very important, as it is the case where sensors have been developed for monitoring soil humidity and other variables throughout the crop season [23]. Results of other investigations agree with the usefulness of sensor technology as a tool to economize fertilizer, reduce the environmental impact, and contribute to the cost effectiveness of wheat production [24]. Regarding the average percentage relative humidity provided between the datalogger in the commercial field and the meteorological station, it indicated a differential of 5% greater in the datalogger during the day and 0% during the night (Figure 6). This differential behavior of humidity and temperature between both devices can be used to develop a more precise model for early phytosanitary warnings.

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#### 4. Conclusion

The cold units recorded by an OMEGA OM-EL-USB-2 datalogger, located inside a commercial wheat field and the Block 910-CIANO meteorological station 8 km away from the field, were 705 and 321, respectively.

The temperature recorded during the day by the datalogger was on average 2.9 °C higher than that recorded by the meteorological station, and 1.6 °C lower at night.

The relative humidity recorded by the datalogger was 5 % higher than that recorded by the meteorological station.

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#### Compliance with ethical standards

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##### *Disclosure of conflict of interest*

The authors declare no conflict of interest.

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