World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

PRODUCTIVITY OF TWO COMMERCIAL BREAD WHEAT CULTIVARS IN THE YAQUI VALLEY, SONORA, MEXICO, DURING THE 2024-2025 CROP SEASON

Ivón Alejandra Rosas-Jáuregui [1], Guillermo Fuentes-Dávila [2,*], José Luis Félix-Fuentes [1], María Monserrat Torres-Cruz [2], Xochilt Militza Ochoa-Espinoza [3] and Pedro Félix-Valencia [4]

[1] INIFAP, Wheat Biotechnology, Norman E. Borlaug Experimental Station, P.O. Box 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Obregon City, Sonora, Mexico.
[2] Wheat Pathology, Norman E. Borlaug Experimental Station, P.O. Box 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Obregon City, Sonora, Mexico.
[3] Annual oilseed crops, Norman E. Borlaug Experimental Station, P.O. Box 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Obregon City, Sonora, Mexico.
[4] Agroclimatology, Norman E. Borlaug Experimental Station, P.O. Box 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Obregon City, Sonora, Mexico.
* Corresponding Author
ORCID Details
Ivón Alejandra Rosas-Jáuregui: https://orcid.org/0000-0003-3678-5543
Guillermo Fuentes-Dávila: https://orcid.org/0000-0001-8342-5554
José Luis Félix-Fuentes: https://orcid.org/0000-0002-5479-1827
María Monserrat Torres-Cruz: https://orcid.org/0000-0002-0827-9937
Xochilt Militza Ochoa-Espinoza: https://orcid.org/0000-0002-5135-2271
Pedro Félix-Valencia: https://orcid.org/0000-0003-3563-5527

World Journal of Advanced Research and Reviews, 2026, 31(03), 464–473

Publication history: Received on 31 July 2026; revised on 07 September 2026; accepted on 09 September 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.31.3.2331

ABSTRACT

In Mexico, wheat is an essential cereal in the population diet, due to its nutritional contribution and low cost; wheat production is carried out under irrigated and rainfed conditions, and almost 90 % of the production is concentrated in the states of Sonora, Guanajuato, Sinaloa, Baja California, Jalisco, and Chihuahua. In this work, grain yield potential of the most recently released bread wheat commercial cultivar CIANO C2018 was evaluated, as well as the check Borlaug 100 F2014, during the crop season 2024-2025. Sowing was carried out on December 06, 2024, at the Norman E. Borlaug Experimental Station, in the Yaqui Valley, Sonora, Mexico. Experimental plots consisted of two beds 3 m long with two rows and with 0.80 m of separation, and with three replications. Seed density was 100 kg ha^{-1}, and fertilization consisted of 150 kg ha^{-1} of urea applied before sowing; an irrigation was applied for seed germination and three other complementary irrigations were applied during the season. Before the first complementary irrigation, 100 kg ha^{-1} of urea and phosphorus were applied, and 100 kg ha^{-1} of urea before the second complementary irrigation. Average thousand grain weight of Borlaug 100 F2014 was 35 g, 5.14 % superior than CIANO M2018, and 11.9 % superior in grain yield (avg yield for Borlaug 100 F2014 was 4.2 ha^{-1}). Both cultivars showed similar avg grain length (0.7 cm) and grain weight (0.04 g). Cultivar Borlaug 100 F2014 continues being an excellent option for wheat producers in southern

Sonora. The average hourly temperature was 18.0 °C with a maximum of 37.8 °C and a minimum of 2.9 °C, the average relative humidity was 50.4 %, there were 0.1 mm of precipitation, and the number of heat and cold units were 322 and 702, respectively.

Keywords: Bread wheat, *Triticum aestivum*, CIANO M2018, Borlaug 100 F2014, Grain yield.

1 INTRODUCTION

Wheat (*Triticum* spp.) is one of the three most important staple cereals worldwide. Along with rice (*Oryza sativa* L.) and maize (*Zea mays* L.), it constitutes a fundamental component of the human diet and contributes approximately one-fifth of global caloric intake [1]. Wheat is also the most extensively cultivated cereal crop, occupying approximately 220 million worldwide. The leading wheat-producing countries include China, India, Russia, and the United States [2]. Mexico ranks 29th globally in wheat production, with an estimated total production of 3,862,914 tons. In Mexico, wheat is regarded as an essential staple grain because of its high nutritional value and relatively low cost, which makes it accessible to low-income populations in both rural and urban areas [3]. Wheat production in the country is carried out under both irrigated and rain-fed conditions, with approximately 90 % of total production concentrated in the states of Sonora, Guanajuato, Sinaloa, Baja California, Jalisco, and Chihuahua [4]. The national supply and demand dynamics differ substantially between bread wheat and durum wheat. While durum wheat production exceeds domestic demand, resulting in substantial surpluses that are exported, bread wheat production is insufficient to meet domestic requirements, leading to a dependence on imports [5]. During the 2020–2021 fall-winter crop season, Mexico produced approximately 1.4 million tons of bread wheat, a key raw material for the national industrial baking sector. However, approximately 4.793 million tons were imported during the same period, and imports increased to approximately 5.181 million tons over the subsequent two years [6]. One factor contributing to the rising dependence on bread wheat imports, is the quarantine status of some irrigated wheat-growing areas in northwestern Mexico due to the presence of Karnal bunt (*Tilletia indica* Mitra). Although the disease can affect durum wheat, bread wheat cultivars generally exhibit greater susceptibility to infection [7]. Preferences regarding the cultivated wheat species vary by region; durum wheat predominates in the northwest due to its high yields, disease resistance, and acceptance in the international market [8]. Soft milling wheat is preferred in El Bajío region [9], whereas bread wheat is preferred in the North [10]. Borlaug 100 F2014 [11] (Figure 1) has been the predominant bread wheat cultivar grown in the Yaqui Valley, with a cultivated area ranging from 9,309 to 44,381 ha between the 2018-2019 and 2023-2024 crop seasons [12-17]. This cultivar occupied 95.9 % of the area grown with bread wheat in the Yaqui Valley during the 2024-2025 crop season [18]. Borlaug 100 F2014 has demonstrated yield stability; it is moderately susceptible to Karnal bunt and resistant to leaf rust (*Puccinia triticina* Eriks.) and stripe or yellow rust (*Puccinia striiformis* Westend. f. sp. *tritici* Eriks.) [11]. During the 2021–2022 fall-winter crop season, the percentage of the area sown with other bread wheat cultivars in southern Sonora was: Onavas F2009 [19] 3.03 %, RSM Norman F2008 [20] 2.26 %, Tacupeto F2001 [21] 0.63 %, CIANO M2018 0.37 % [22], and Roelfs F2007 [23] 0.01 %. Although CIANO M2018 (Figure 2) was released in 2018, and demonstrated superior grain yield compared to Borlaug 100 F2014 in experimental trials conducted during the 2017-2018 to 2019-2020 growing seasons, outperforming it by 1.58 % and 6.27 % with two and four complementary irrigations, respectively [22], its adoption by wheat producers in Sonora has remained limited, with commercial cultivation covering no more than 125 ha.

Figure 1: Phenotype of bread wheat cultivar Borlaug 100 F2014

Figure 2: Seed samples of cultivars CIANO M2018 (left) and Borlaug 100 F2014 (right)

This limited adoption not only restricts the contribution of CIANO M2018 to broadening the region´s genetic diversity for rust, but also hinders efforts to increase domestic bread wheat production and reduce Mexico´s dependence on imports. This issue is particularly relevant considering the country´s average annual per capita wheat consumption of 61.4 kg [24]. Therefore, the objective of this study was to compare the grain yield and other components of the two most important commercial bread wheat cultivars in southern Sonora, during the 2024-2025 crop season.

2 MATERIAL AND METHODS

The evaluation was conducted during the 2024-2025 fall-winter crop season at the Norman E. Borlaug Experimental Station (CENEB), part of Mexico's National Institute for Forestry, Agriculture, and Livestock Research (INIFAP). The experimental site is located in Block 910 of the Yaqui Valley in the state of Sonora, Mexico (27°22′3.01″ N, 109°55′40.22″ W; 37 m above sea level). According to the Köppen climate classification modified by García [25], the region of southern Sonora is characterized by a hot, dry climate (BW(h)) and extreme heat (BSo). The bread wheat cultivars CIANO M2018 and Borlaug 100 F2014 were evaluated to determine the following yield components: grain length (cm), grain weight (g), thousand-grain weight (g), and grain yield (t ha^{-1}). The pedigree and selection history of the cultivars are shown in Table 1.

Table 1: Commercial bread wheat cultivars evaluated at the Norman E. Borlaug Experimental Station during the 2024–2025 fall-winter crop season in the Yaqui Valley, Sonora, Mexico

Cultivar	Pedigree and selection history
CIANO M2018	STLN/MUNAL#1//2*BORL14 CMSS12B00828T-099TOPY-099M-0SY-42M-0WGY-300Y.
Borlaug 100 F2014	ROELFS07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/ TUKURU//FRET2 CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B

The sowing date was December 6, 2024; plots consisted of two 3-m-long beds spaced 0.80 m apart, each with two rows, arranged in a randomized design with three replicates, and the seeding rate was 100 kg ha^{-1}. Fertilization consisted of 150 kg ha^{-1} of urea applied prior to sowing. One irrigation was applied for seed germination, followed by three complementary irrigations during the growing season; 100 kg ha^{-1} of urea and phosphorus were applied before the first complementary irrigation, and 100 kg ha^{-1} of urea before the second. During crop development, herbicides were used for broad-leaf weed control: Full-mina 4 [26] and Starane Ultra (300 mL ha^{-1}) [27] were applied at the tillering stage (stage 24, Zadoks) [28], while Axial XL (400 mL ha^{-1}) [29] was used for narrow-leaf weed control at the stem elongation stage (stage 35, Zadoks). Control of the foliage aphid (*Schizaphis graminum* Rondani) was carried out using the insecticide Muralla Max (200 mL ha^{-1}) [30] upon entry into the flowering stage (Zadoks stage 65). Harvesting was performed manually using a sickle, and threshing was carried out using a Pullman stationary thresher. Length and grain weight were determined on 50 grains per replication after plots were harvested. The thousand-grain weight was determined by counting and weighing the grains, while grain yield per plot and the corresponded yield per ha, was recorded after harvesting 0.8 m^2 from each plot. Data of temperature, relative humidity, cold (CU) and heat units (HU) from December 1, 2024, to April 30, 2025, were recorded in hourly format from the CIANO-910 weather station, located at CENEB, which is part of the automated weather station network of Sonora [31]. CU were calculated as the temperature > 0.1 °C to < 10 °C that occurs in a given hour, and HU as the number of hours with temperature above 30 °C [32].

3 RESULTS AND DISCUSSION

The average temperature during the 2024-2025 crop season was 18.0 °C, a maximum of 37.8 and a minimum of 2.9 °C. The average temperature was 16.8 °C in December 2024, subsequently dropping in January and rising a few degrees in February, and March 2025 (14.92 °C, 17.89 °C, and 18.82 °C, respectively) (Figure 3). The average monthly minimum temperature ranged from 2.88 to 5.49 °C, while the maximum ranged from 30.9 to 37.87 °C. The total number of CU was 702; since the first week of December with the occurrence of 22 CU, to the accumulation of 188 during the month, then the count increased to 231 in January, and gradually decreased in February, March, and April (Figure 4).

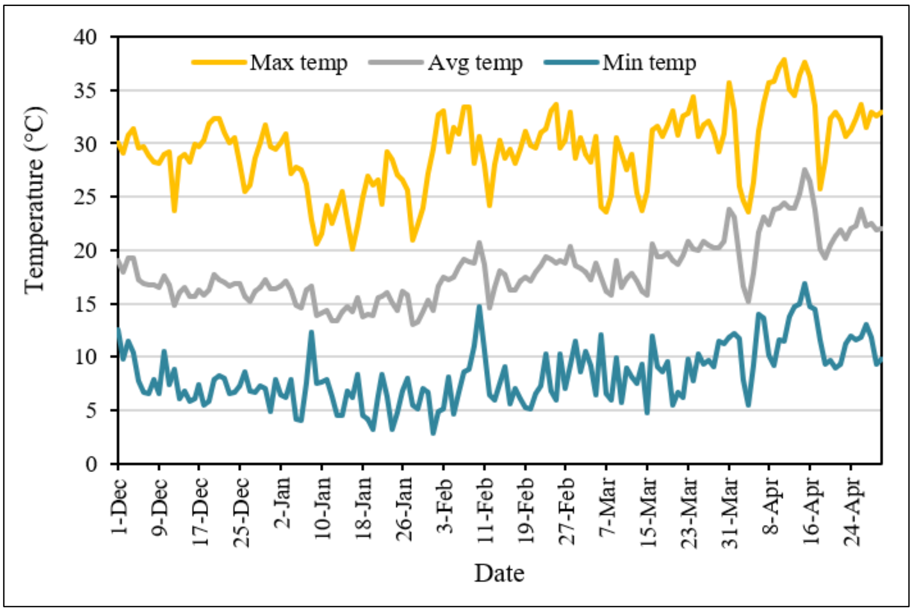

Figure 3: Average, maximum, and minimum temperatures recorded by the CIANO-910 weather station, at the Norman E. Borlaug Experimental Station, during the 2024–2025 fall-winter crop season

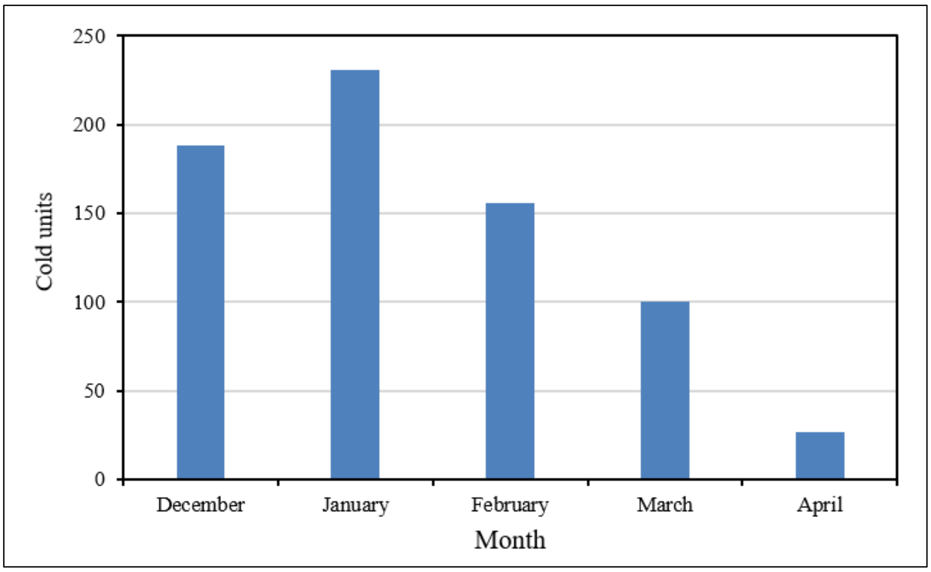

Figure 4: Monthly cold units recorded by the CIANO-910 weather station, at the Norman E. Borlaug Experimental Station, during the 2024–2025 fall-winter crop season

Similar to 2020-2021 and 2023-2024 crop seasons, the maximum number of CU was recorded in January [33,34]. The accumulation of CU may promote adequate tillering and normal crop development. As the accumulation of CU increase, physiological processes in the plant slow down, thereby extending the growth period, which generally contributes to greater grain yield [32]. However, consistent occurrences of temperatures above 30 °C were observed from March 16 to April 30, during which 72.7 % of the total accumulated HU (322) were recorded (Figure 5). However, other events reaching 30 °C for one to several hours were also detected earlier in the season, specifically on December 1 (1 h), 3 (2), 4 (3), 18 (1), 19 (3), 20 (4), 21 (2), 22 (3), 23 (1), 24 (2), 29 (1), 30 (2), January 2 (1), 3 (3), February 2 (4), 3 (5), 5 (4), 6 (4), 7 (5), 8 (4), 10 (2), 14 (2), 19 (3), 22 (2), 23 (3), 24 (5), 25 (5), 27 (2), 28 (5), March 2 (1), 5 (2), and 9 (1).

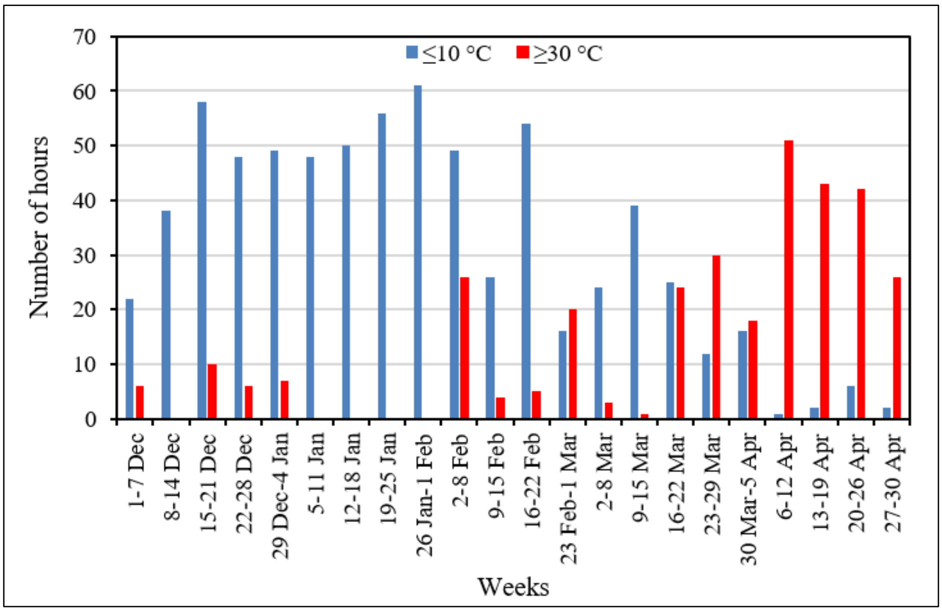

Figure 5: Number of cold and heat units accumulated from December 1, 2024 to April 30, 2025, recorded from the weather station CIANO-910, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

CIANO M2018 is later-maturing cultivar which reaches flowering at 80 days compared to 74 days for Borlaug100 F2014, and reaching physiological maturity at 123 and 118 days, respectively, while its test weight is 81.9 kg hL^{-1} (versus 81.4 kg hL^{-1} for Borlaug100 F2014) and grain protein content is 12.4 % (versus 12.3 %) [22]. The average spike length reported for CIANO M2018 was 9.74 cm with a range of 8.1–11.6 cm, whereas Borlaug 100 F2014 showed an average of 9.73 cm, with a range of 7.1–12.5 cm. The average spike weight of the first cultivar was 3.27 g, with a range of 1.53–5.58 g, while the second showed an average of 3.40 g, with a range of 2.05–5.94 g [35]. Regarding the number of grains per spike, both cultivars showed the same average value of 51, and in our study, average grain length was 0.7 cm and grain weight was 0.04 g for both cultivars. Grain number is closely associated with yield and is largely influenced by agronomic practices, whereas grain weight is more strongly affected by climatic conditions during grain filling, and is closely related to grain size. Therefore, the weight of a standard number or volume of grains is a practical and informative measure of grain characteristics [36]. An increase in grain number does not necessarily result in a proportional increase in yield, partly because greater grain numbers intensify competition for assimilates, often resulting in smaller grains. Additionally, high spike populations may increase the proportion of grains developing in the distal regions of the spike, which are generally smaller than those produced in the central region, and therefore, contribute less to grain weight [37]. Grain size and morphology are important traits that impact yield and milling quality [38,39]; size also contributes to germination vigor [36]. The average thousand-grain weight (TGW) of CIANO M2018 had a range of 31.6-34.0 g, and it was lower 39.5 % and 32.1 % than in the 2021-2022 and 2023-2024 crop seasons (Figure 6). The average TGW for Borlaug 100 F2014 had a range of 33.6 – 35.9 g, and it was lower 45.1 % and 24.1 % than in the crop seasons mentioned. It has been reported that TGW is an important component of wheat grain yield and represents the mean individual grain weight, which varies according to grain position within the spike and spikelet. Together with hectolitre weight, TGW is widely used because it can be measured rapidly and with relatively low error [40]. However, neither parameter captures the variability among individual grains within a sample [36]. Regarding grain yield, Chávez *et al*. [22] not only reported that CIANO M2018 outperformed Borlaug 100 F2014 under two and four complementary irrigations, over three years of evaluation at the Norman E. Borlaug Experimental Station in the Yaqui Valley, but also, that under full irrigation, CIANO M2018 exceeded the yield of Borlaug 100 F2014 by 7.19 %, 3.25 %, and 4.90 % in the states of Sonora, Sinaloa, and Baja California, respectively.

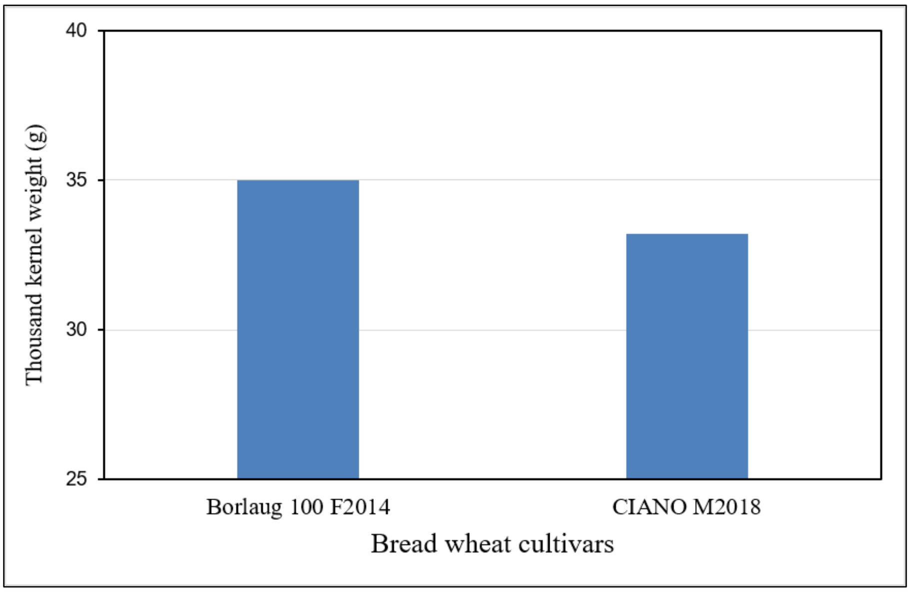

Figure 6: Thousand grain weight of commercial bread wheat cultivars evaluated during the 2024-2025 crop season in the Valle del Yaqui, Sonora, Mexico

However, in the present study, as it was the case with thousand-grain weight, Borlaug 100 F2014 outperformed CIANO M2018 by 0.500 t ha^{-1} (Figure 7). The average grain yield for Borlaug 100 F2014 which had a range of 4.03 – 4.30 t ha^{-1}, was lower 55.0 % and 35.3 % than in the 2021-2022 and 2023-2024 crop seasons, while CIANO M2018 had a range of 3.29 – 3.93 t ha^{-1}, and it was lower 52.9 % and 45.9 % than in the crop seasons mentioned. Two simultaneous processes occur during the crop season: growth and development. Growth involves an increase in biomass, whereas development refers to the succession of morphological or physiological stages that occur during the crop's life cycle. Both processes are genetically regulated and influenced by the environment. Consequently, the growth pattern and the succession of developmental stages (phenology) may differ between cultivars and, within them, depending on environmental conditions [41]. On the other hand, García [37] considers that wheat yield is determined by the number of grains per unit area and grain weight. The number of grains achieved is closely linked to yield and is highly dependent on agronomic practices, whereas grain weight depends more on climatic conditions during grain formation.

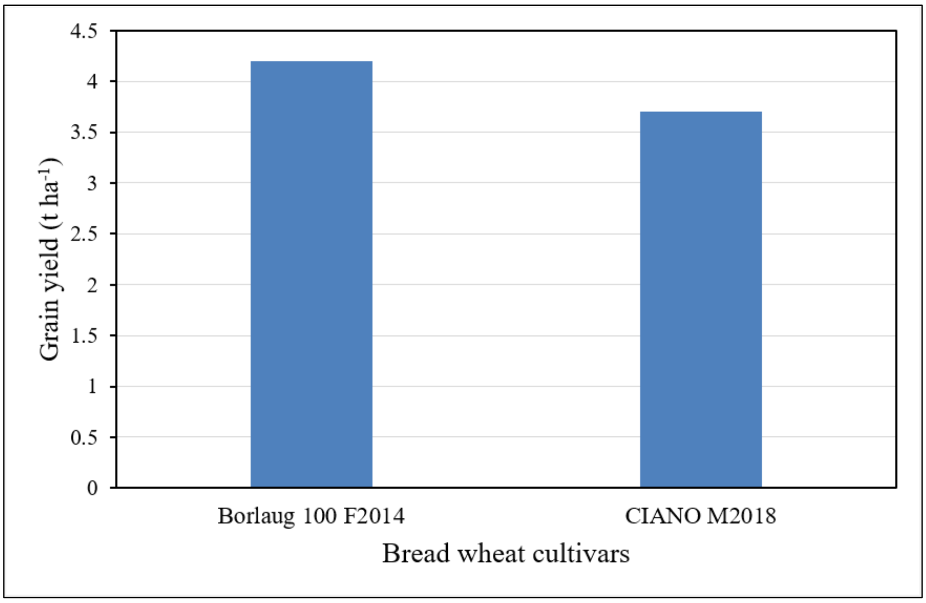

Figure 7: Grain yield of commercial bread wheat cultivars evaluated during the 2024-2025 crop season in the Yaqui Valley, Sonora, Mexico

As a result of the HU occurrence (more than 16) during the periods of December 18-24, 29 and January 2 and 3, seedling development was affected despite the number of CU already accumulated (approximately 215). Also, the exposure of plants to heat stress during flowering [Zadoks stage 65] between February 14 to 25, a high number (more than 20) of HU accumulated which affected the overall plant development and grain yield. Plants under heat stress undergo a variety of physiological and morphological changes. It lowers cell turgor and water-use efficiency, inhibits seed germination and seedling growth, and interferes with cellular functions by producing too many reactive oxygen species (ROS), which causes oxidative stress. Heat stress also hinders assimilate transfer, speeds up leaf senescence, and damages chloroplasts and inactivates photosynthetic enzymes. As a result, the rate and duration of grain growth decrease, producing fewer grains [42].

Félix-Fuentes *et al*. [43] reported that Borlaug 100 F2014 possesses valuable genetic attributes that make it a promising source for the introgression of heritable traits into new wheat germplasm, including disease resistance, high industrial quality, favorable plant architecture, and desirable phenotypic characteristics. The average hourly temperature was 18.0 °C with a maximum of 37.8 °C and a minimum of 2.9 °C, the average relative humidity was 50.4 %, there were 0.1 mm of precipitation, and the number of heat and cold units were 322 and 702, respectively.

4 CONCLUSION

- Bread wheat cultivar Borlaug 100 F2014 outperformed CIANO M2018 in thousand-grain weight and grain yield per plot.
- Borlaug 100 F2014 produced an average grain yield of 4.2 t ha^{-1}, exceeding that of CIANO M2018 by 0.50 t ha^{-1}.
- Borlaug 100 F2014 cultivar continues to be a good bread wheat option for producers in southern Sonora, Mexico.
- A limitation of the evaluation of the two cultivars was that the work was conducted at only one location in southern Sonora; therefore, the number of locations in the region should be increased to enhance the impact of the comparison.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

The authors express their gratitude to the Mexican National Institute for Forestry, Agriculture, and Livestock Research (INIFAP) and to "Patronato" – Farmers´Union for Agricultural Research and Experimentation of the state of Sonora, Inc., for providing the facilities to carry out the research

Funding Source

This research was financially supported by the Mexican National Institute for Forestry, Agriculture, and Livestock Research (INIFAP).

Disclosure of conflict of interest

The authors declare that No conflict of interest.

REFERENCES

[1] Reynolds MP, Pask AJD, Mullan DM, and Chávez DPN. (Eds.). 2013. Physiological Plant Breeding I: Interdisciplinary Approaches to Improving Crop Adaptation. CIMMYT. Mexico. 174 p. Available at: http://hdl.handle.net/10883/3207.

[2] FAO (Food and Agriculture Organization of the United Nations). 2021. Crop Prospects and Food Situation #4, December 2020.. https://doi.org/10.4060/cb2334es.

[3] Morales V, Martínez E, and Fajardo DSG. 2014. Flour and dough quality of rainfed bread wheat. In: Agricultural Sciences Handbook T-II: Interdisciplinary Congress of Academic Groups (pp. 70-80). ECORFAN. Valle de Santiago, Guanajuato, Mexico. Available at: https://www.ecorfan.org/handbooks/ Ciencia%20Agropecuarias%20T-II/Articulo_8.pdf.

[4] SIAP (Agri-Food and Fisheries Information Service). 2022. Agri-food and Fisheries Production. https://www.gob.mx/siap/. Accessed on July 15, 2023.

[5] Villaseñor-Mir HE, Limón-Ortega A, Rodríguez-García MF, Martínez-Cruz E, Santa-Rosa RH, and Mariscal-Amaro LA. 2011. Evaluation under rainfed conditions of durum wheat varieties developed for irrigation. Revista Mexicana de Ciencias Agrícolas 2(5):759-764. Available at: https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-09342011000500010.

[6] SIAP (Agri-Food and Fisheries Information Service). 2023. Monthly outlook for agri-food products. https://www.gob.mx/siap/. Accessed on September 28, 2023.

[7] Fuentes-Davila G, Rajaram S, Pfeiffer WH, Abdalla O, Van-Ginkel M, Mujeeb-Kazi A, and Rodríguez-Ramos R. 1993. Results of artificial inoculations from the 5th selection nursery for resistance to Tilletia indica Mitra. Revista Mexicana de Micología 9:57-65.

[8] Fuentes-Dávila G, Figueroa-López P, Camacho-Casas MA, Chávez-Villalba G, and Félix-Fuentes, JL. 2014. Quetchehueca Oro C2013, new durum wheat variety for northwest Mexico. Revista Fitotecnia Mexicana 37(4):399-401. Disponible en: Chromeextension://efaidnbmnnnibpcajpcglclefindmkaj/https://revistafitotecniamexicana.org/documentos/37-4/11a.pdf.

[9] Solís Moya E, Huerta Espino J, Ireta Moreno J, Sánchez de la Cruz R, Villaseñor Mir HE, Espitia Rangel E, and Ramírez Ramírez A. 2009. Josecha F2007, new bread wheat variety for El Bajío region and irrigated areas of northern Mexico. Agricultura Técnica en México 35(4):475-479.

[10] Huerta-Espino J, Villaseñor-Mir HE, Espitia-Rangel E, Solis-Moya E, and van Ginkel, M. 2011. The history of wheat breeding in Mexico. In: The World Wheat Book. A History of Wheat Breeding. Vol. 2. A.P. Bonjean, W.J. Angus, and M. van Ginkel (eds.). Editions Tec & Doc. Paris, France. pp: 277-308.

[11] Camacho-Casas MA, Chávez-Villalba G, Fuentes-Dávila G, Figueroa-López P, Huerta-Espino J, Villaseñor-Mir HE, and Ortiz-Monasterio JI. 2017. Borlaug 100: Bread wheat variety for northwest Mexico. Technical Brochure No. 100. Norman E. Borlaug Experimental Station, INIFAP. Obregón City, Sonora, Mexico. 32 p.

[12] CESAVESON (Plant Health Committee of the State of Sonora). 2019. Area with planting permit by variety. Available at: https://osiap.org.mx/senasica/quienes-estado/sonora/Agricola.

[13] CESAVESON (Plant Health Committee of the State of Sonora). 2020. Area with planting permit by variety. Available at: https://osiap.org.mx/senasica/quienes-estado/sonora/Agricola.

[14] CESAVESON (Plant Health Committee of the State of Sonora). 2021. Area with planting permit by variety. Available at: https://osiap.org.mx/senasica/quienes-estado/sonora/Agricola.

[15] CESAVESON (Plant Health Committee of the State of Sonora). 2022. Area with planting permit by variety. Available at: https://osiap.org.mx/senasica/quienes-estado/sonora/Agricola.

[16] CESAVESON (Plant Health Committee of the State of Sonora). 2023. Area with planting permit by variety. Available at: https://osiap.org.mx/senasica/quienes-estado/sonora/Agricola.

[17] CESAVESON (Plant Health Committee of the State of Sonora). 2024. Area with planting permit by variety. Available at: https://osiap.org.mx/senasica/quienes-estado/sonora/Agricola.

[18] CESAVESON (Plant Health Committee of the State of Sonora). 2025. Area with planting permit by variety. Available at: https://osiap.org.mx/senasica/quienes-estado/sonora/Agricola.

[19] Figueroa-López P, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, and Mendoza-Lugo JA. 2013. Ónavas F2009, bread wheat variety for northwest Mexico. Revista Mexicana de Ciencias Agrícolas 4(1):175-179.

[20] RSI (Resource Seeds International). 2023. RSM Norman F2008. High-yielding bread wheat (Triticum aestivum) variety. Available at: http://resourceseedsinternational.com.mx/products.html.

[21] Camacho-Casas MA, Singh RP, Figueroa-López P, Huerta-Espino J, Fuentes-Dávila G, and Ortiz-Monasterio Rosas I. 2003. Tacupeto F2001: New bread wheat variety for northwestern Mexico. Technical Bulletin Number 50, National Institute for Forestry, Agriculture, and Livestock Research, Northwest Regional Research Center, Yaqui Valley Experimental Station. Obregon City, Sonora, Mexico. 20 p.

[22] Chávez-Villalba G, Borbón-Gracia A, Díaz-Cisneros HL, Alvarado-Padilla JI, Huerta-Espino J, García-León E, and Fuentes-Dávila G. 2021. CIANO M2018: New bread wheat variety for northwest Mexico. Revista Fitotecnia Mexicana, 44 (3): 477-479. DOI: https://doi.org/10.35196/rfm.2021.3.477.

[23] Figueroa-López P, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, and Mendoza-Lugo JA. 2011. Roelfs F2007, new bread wheat variety for northwest Mexico. Revista Fitotecnia Mexicana 34(3):221-223. Available at: https://revfitotecnia.mx/index.php/RFM/article/view/565/531.

[24] SADER (Secretariat of Agriculture and Rural Development). 2023. Agriculture rolls out programs and actions to boost wheat production—the second most consumed cereal in Mexico. https://www.gob.mx/agricultura/prensa/despliega-agricultura-programas-y-acciones-para-impulsar-la-produccion-de-trigo-segundo-cereal-mas-consumido-en-mexico?idiom=es.

[25] García E. 2004. Modifications to the Köppen climate classification system. Institute of Geography of the National Autonomous University of Mexico. Book Series number 6. México, D.F. 90 p. Available at: http://www.publicaciones.igg.unam.mx/index. php/ig/catalog/view/83/82/251-1.

[26] Corteva Agriscience México. 2021a. Full-Mina 4. Safety data sheet. https://www. corteva.mx/content/dam/dpagco/corteva/la/mesoandean/mx/es/products/files/FULLMINA4%20ETIQUETA %20WEB.pdf. Accessed on October 9, 2024.

[27] Corteva Agriscience México. 2021b. Safety data sheet. https://www.corteva.mx/ productos-y-soluciones/proteccion-de-cultivos/starane-ultra.html. Accessed on October 10, 2024.

[28] Zadoks J, Chang T, and Konzak C. 1974. A decimal code for the growth stages of cereals. Weed Research 14:415-421. doi.org/10.1111/j.13653180.1974.tb01084.x.

[29] SYNGENTA México. 2021. Axial XL. Safety data sheet. https://www.syngenta. com.mx/sites/g/files/zhg501/f/media/2019/09/07/axial_xl.pdf?token=1567883834. Accessed on October 10, 2024.

[30] Bayer de México, S.A. DE C.V. 2021. Muralla Max 300 OD. Safety data sheet.https://www.quimagro.com.mx/web/content/14582/Muralla-Max-Ficha-tecnica.pdf. Accessed on October 10, 2024.

[31] REMAS (Network of Automatic Meteorological Stations of Sonora). 2025. Download data. http://www.siafeson.com/remas/. Accessed on July 24, 2025.

[32] Félix-Valencia P, Ortíz-Enríquez JE, Fuentes-Dávila G, Quintana-Quiróz JG, and Grageda-Grageda J. 2009. Cold hours in relation to wheat yield: production areas of the state of Sonora. INIFAP, Northwest Regional Research Center, Yaqui Valley Experimental Station. Technical Brochure No. 63. Cd. Obregón, Sonora, México. 40 p. ISBN 978-607-425-159-3.

[33] Torres-Cruz MM, Félix-Valencia P, and Fuentes-Dávila G. 2022. Leaf area index and grain yield of durum wheat in southern Sonora, Mexico, during the season 2020-2021. International Journal of Agriculture, Environment and Bioresearch 7(6):253-268. https://doi.org/10.35410/IJAEB.2022.5788.

[34] Rosas-Jáuregui IA, Fuentes-Dávila G, Félix-Fuentes JL, Torres-Cruz MM, Ortiz-Avalos AA, and Cortés-Jiménez JM. 2025. Grain yield of bread wheat cultivars Borlaug 100 F2014 and CIANO M2018 during the 2023-2024 crop season in experimental plots. Open Access Research Journal of Science and Technology 15(02):001-008. DOI: https://doi.org/10.53022/oarjst.2025.15.2.0127.

[35] Rosas-Jáuregui IA, Fuentes-Dávila G, Félix-Fuentes JL, Ortiz-Avalos AA, Cortés-Jiménez JM, and Torres-Cruz MM. 2023. Productivity of two commercial bread wheat varieties in the Yaqui Valley, during the 2021-2022 agricultural cycle. Brazilian Journal of Animal and Environmental Research 6(4):3195-3207. DOI: 10.34188/bjaerv6n4-010.

[36] Whan AP, Smith AB, Cavanagh CR, Ral JPF, Shaw LM, Howitt CA, and Bischof L. 2014. GrainScan: a low cost; fast method for grain size and colour measurements. Plant Methods 10(23):1-10. DOI:10.1186/1746-4811-10-23.

[37] García A. 2017. Sowing density in wheat. Revista INIA 6(49):17-22. Available at: http://www.ainfo.inia.uy/digital/bitstream/item/6965/1/revista-INIA-49.p17-22.pdf.

[38] Williams K, Munkvold J, and Sorrells ME. 2012. Comparison of digital image analysis using elliptic Fourier descriptors and major dimensions to phenotype seed shape in hexaploid wheat (Triticum aestivum L.). Euphytica 190(1):99-116. DOI:10.1007/s10681-012-0783-0.

[39] Williams K, and Sorrells ME. 2014. Three-dimensional seed size and shape QTL in hexaploid wheat (Triticum aestivum L.) populations. Crop Science Society of America 54:98-110. https://doi.org/10.2135/cropsci2012.10.0609.

[40] Baillot N, Girousse C, Allard V, Piquet-Pissaloux A, Le Gouis J. 2018. Different grain-filling rates explain grain-weight differences along the wheat ear. PLOS ONE 13(12):e0209597. https://doi.org/10.1371/journal.pone.0209597.

[41] Abbate P, and Divito, G. 2017. How the wheat crop grows and develops. In: G. Divito, and F. García, Wheat Cultivation Manual (pp. 22-32). International Plant Nutrition Institute. Buenos Aires, Argentina.

[42] Akter N, and Rafiqui IM. 2017. Heat stress effects and management in wheat. A review. Agronomy for Sustainable Development 37:37(1-17). DOI: 10.1007/s13593-017-0443.9.

[43] Félix-Fuentes JL, Fuentes-Dávila G, Rosas-Jáuregui IA, Cortes-Jiménez JM, Ortiz-Avalos AA, and Ortiz-Enríquez JE. 2022. Phenotypic and molecular characterization of the bread wheat variety Borlaug 100. Atena. Desemvolvimento da paquisa científica, tecnología e inovacao na agronomía 3. 12 p. DOI: https://doi.org/10.22533/at.ed. 7772223061.