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(RESEARCH ARTICLE)

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Yield potential of elite advanced bread wheat (*Triticum aestivum* L.) lines during the crop season 2019-2020

Huizar Leonardo Díaz-Ceniceros [1], Alberto Borbón-Gracia [1], Guillermo Fuentes-Dávila [2,*], María Monserrat Torres-Cruz [2], Gabriela Chávez-Villalba [3] and Yerica Renata Valdez-Rodríguez [4]

[1] *Wheat Breeding, INIFAP, Norman E. Borlaug Experimental Station, P.O. Box 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Cd. Obregón, Sonora, Mexico 85200.*
[2] *Wheat Pathology, INIFAP, Norman E. Borlaug Experimental Station, P.O. Box 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Cd. Obregón, Sonora, Mexico 85200.*
[3] *Wheat Quality, INIFAP, Norman E. Borlaug Experimental Station, P.O. Box 155, km 12 Norman E. Borlaug between 800 and 900 Yaqui Valley, Cd. Obregón, Sonora, Mexico 85200.*
[4] *PREGEP-Genetics, COLPOS, Federal Highway México-Texcoco, km 36.5, Texcoco de Mora, State of Mexico 56264.*

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Abstract

The objective of this work was to identify bread wheat lines with grain yield potential under two and four complementary irrigation regimes. Twenty two advanced lines from the 1st Preliminary Bread Wheat Yield Trial of the Norman E. Borlaug-INIFAP breeding program, and two check cultivars were sown on December 16, 2019, in beds 5 m long with 0.80 m separation, under an alpha lattice experimental design with three replications. The variables evaluated were: days to flowering, days to physiological maturity, plant height, reaction to leaf rust, and grain yield. The analysis of variance was performed with the statistical package SAS 9.4, and mean comparison by Tukey´s test ($p < 0.05$). Cultivar CIANO M2018 showed the highest grain yield under two and four complementary irrigations with 7,361 and 7,929 kg ha^{-1}, respectively. Ten lines overcame the average grain yield of regional check cultivar Borlaug 100, but they were not statistically different. Lines with the highest grain yield under four complementary irrigations were sister line BECARD/FRNCLN//2*BORL14 (CMSS14B01371T-099TOPY-099M-0SY-46M-0WGY) with 7,911 kg ha^{-1}, BAJ#1/ KISKADEE#1/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/KURUKU with 7,825, WBLL1*2/BRAMBLING//TAM200/ TUI/3/VILLAJUAREZF2009/4/2*BORL14 with 7,781, and KINDE*2/4/T.DICOCCONPI94625/AE.SQUARROSA(372) //TUI/CLMS/3/2*PASTOR/5/PFAU/MILAN//TROST/3/PBW65/2*SERI.1B*2/4/ MUNAL#1 with 7,717; while with two irrigations BORL14*2//KACHU/KIRITATI with 7,112, SWSR22T.B.//TACUPETOF2001*2/BRAMBLING/3/2* TACUPETOF2001*2/BRAMBLING/4/BORL14 with 6,983, and WBLL1*2/BRAMBLING//TAM200/TUI/3/ VILLAJUAREZF2009/4/2*BORL14 with 6,978. The average temperature during the study period was 19.0 °C with a maximum of 36.3 °C and a minimum of 1.0 °C; the average relative humidity was 69.0 %; there were 17.0 mm of precipitation, and the number of heat and cold units was 229 and 350, respectively. There was no presence of leaf rust in any of the lines evaluated.

Keywords: *Triticum aestivum*; Bread wheat; Limited irrigation; Normal irrigation; Grain yield

1. Introduction

Wheat (*Triticum* spp.) is one of the most important cereal grains worldwide, which along with rice (*Oryza sativa* L.) and maize (*Zea mays* L.) make up part of the human diet, contributing with about one fifth of the total caloric intake as well as proteins [1,2]. Wheat is cultivated in approximately 220 million ha, being China, India, Russia, and the United States

* Corresponding author: Guillermo Fuentes-Dávila

the main producers [3]. In Mexico, wheat is an essential cereal in the population diet, due to its nutritional contribution and low cost, available to low income people in rural and urban areas [4]; wheat production is carried out under irrigated and rainfed conditions, and almost 95.4 % of the production under irrigation is concentrated in the states of Sonora, Guanajuato, Sinaloa, Baja California, Michoacán, and Jalisco, while production under rainfed conditions is concentrated in the states of Tlaxcala, Zacatecas, Oaxaca, and Guanajuato [5]. During the 2019-2020 fall-winter crop season, the area sown with wheat nationwide under irrigated conditions was 463,668 ha with an average grain yield of 6.02 t ha^{-1} and a production volume of 2,793,113 t [5]. In the state of Sonora, 230,082 ha were harvested with an average grain yield of 6.66 t ha^{-1} and a production of 1,532,662 t, which represented 54.8 % of the total national production. Southern Sonora is the most important wheat-producing region in Mexico with 43.9 % of the national production and 79.2 % of the production in the state of Sonora, where the counties of Cajeme, Etchojoa, Navojoa, Huatabampo, Benito Juárez and Bácum stand out, with an average of 6.70 t ha^{-1}. The demand for bread wheat and durum wheat grain in the country is contrasting, while durum wheat has an overproduction and its surplus is exported, there is a high deficit of bread wheat, so it is necessary to import this cereal [6]. One explanation for the increase in imports of bread wheat is that in the northwest region, part of the irrigated areas where wheat is grown are quarantined due to the presence of karnal bunt (*Tilletia indica* Mitra), although it does affect seriously durum wheat, bread wheat shows greater susceptibility [7]. In the 2019-2020 fall-winter crop season, 94,865.61 ha of bread wheat were established in the state of Sonora, of which 88.9 % of the area was sown with commercial cultivar Borlaug 100 [8]. This cultivar has shown stability in yield, it is moderately susceptible to karnal bunt (*Tilletia indica* Mitra), resistant to leaf rust (*Puccinia triticina* Eriks.) and to yellow or stripe rust (*Puccinia striiformis* Westend. f. sp. *tritici* Eriks.) [9]. Commercial bread wheat cultivar CIANO M2018 was released in 2018 and was reported to have outperformed Borlaug 100 in grain yield by 1.58 % and 6.27 % in experimental trials during the 2017-2018 to 2019-2020 agricultural crop seasons with two and four complementary irrigations, respectively [10], however, this cultivar began to be sown commercially until the 2021-2022 crop seasons occupying only 125 ha [11]. In southern Sonora, agricultural production depends on water from dams to ensure crop irrigation. Water supply is often the most expensive input for irrigated crops and is a critical factor limiting crop growth and yield [12], therefore, it is necessary to generate wheat cultivars that make efficient use of water for grain production. The objective of this work was to identify advanced lines from the 1st preliminary bread wheat yield trial, with grain yield potential under two irrigation regimes.

2. Material and methods

This work was carried out at the Norman E. Borlaug Experimental Station (CENEB) which belongs to the National Institute for Forestry, Agriculture and Livestock Research (INIFAP), located in block 910 in the Yaqui Valley, Sonora, Mexico (27º 22' latitude north and 109º 55' longitude west, at 37 masl), during the crop season fall-winter 2019-2020. The bread wheat yield trial comprised 22 experimental lines, including two sister lines, and the check cultivars Borlaug 100 [9] and CIANO M2018 [10] (Table 1), which were evaluated under an alpha lattice experimental design with three replications.

Table 1 Advanced bread wheat lines evaluated for grain yield potential under two irrigation regimes, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico, during the crop season fall-winter 2019-2020

No.	Pedigree and selection history
1	CIANO M2018 CMSS12B00828T-099TOPY-099M-0SY-42M-0WGY
2	WBLL1*2/BRAMBLING//TAM200/TUI/3/VILLAJUAREZF2009/4/2*BORL14 CMSS13B01705T-099TOPY-099M-099NJ-099NJ-16Y-0WGY
3	BECARD/FRNCLN//2*BORL14 CMSS14B01371T-099TOPY-099M-0SY-46M-0WGY
4	BORL14*2//KACHU/KIRITATI CMSS14Y01431T-099TOPM-099Y-099M-0SY-17M-0WGY
5	BECARD/FRNCLN//2*BORL14 CMSS14B01371T-099TOPY-099M-0SY-21M-0WGY
6	WBLL1*2/BRAMBLING*2//BAVIS*2/3/KACHU CMSS14Y01744T-099TOPM-099Y-099M-0SY-1M-0WGY

7	KINDE*2/4/T.DICOCCONPI94625/AE.SQUARROSA(372)//TUI/CLMS/3/2*PASTOR/5/PFAU/MILAN//TROST/3/PBW65/2*SERI.1B*2/4/MUNAL#1 CMSS14Y00980S-099Y-099M-099Y-2M-0RGY
8	SWSR22T.B.//TACUPETOF2001*2/BRAMBLING/3/2*TACUPETOF2001*2/ BRAMBLING/4/BORL14 CMSS14B00380S-099M-0SY-5M-0WGY
9	KACHU/DANPHE//BORL14 CMSS13B00104S-099M-099NJ-099NJ-40Y-0WGY
10	BORL14*2/UCDP 160 CMSS14B01302T-099TOPY-099M-0SY-29M-0RGY
11	KACHU/DANPHE/3/SWSR22T.B./KACHU//2*KACHU CMSS13B00113S-099M-099NJ-099NJ-10Y-0WGY
12	BORLAUG 100 CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B
13	PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI*2/5/CHONTE/7/SERI.1B*2/3/KAUZ*2/BOW//KAUZ/5/CNO79//PF70354/MUS/3/PASTOR/4/BAV92/6/ND643/2*WBLL1/8/PRL/2*PASTOR//KACHU CMSS14Y01656T-099TOPM-099Y-099M-0SY-7M-0WGY
14	BORL14*2/7/SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/KRONSTADF2004/5/MUNAL/6/MUNAL#1 CMSS14B01298T-099TOPY-099M-0SY-34M-0WGY
15	SIRVAN/4/PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI/5/PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA CMSS14Y02192T-099TOPM-099Y-099M-0SY-6M-0WGY
16	PRL/2*PASTOR//KACHU/3/2*BORL14 CMSS14B01633T-099TOPY-099M-0SY-14M-0WGY
17	MUTUS*2/HARIL#1*2/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/KURUKU CMSS14B01582T-099TOPY-099M-0SY-57M-0WGY
18	SOKOLL//W15.92/WBLL1/3/BAVIS/4/2*BORL14 CMSS14B01613T-099TOPY-099M-0SY-12M-0WGY
19	KENYASUNBIRD/KACHU//2*BORL14 CMSS14B01431T-099TOPY-099M-0SY-5M-0WGY
20	TOH#1//MUTUS*2/TECUE#1 CMSS14B00807S-099M-0SY-75M-0WGY
21	PBW343*2/KUKUNA//PBW343*2/KUKUNA/3/WBLL1*2/SHAMA//KACHU/4/2*BORL14 CMSS14B01640T-099TOPY-099M-0SY-21M-0WGY
22	WAXWING*2/TUKURU//2*FRNCLN/3/BORL14 CMSS14Y00407S-099Y-099M-0SY-27M-0WGY
23	BAJ#1/KISKADEE#1/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/KURUKU CMSS13B00220S-099M-099NJ-099NJ-9Y-0WGY
24	TOW/PEW//DGA/3/PISP/4/MUTUS*2/MUU/5/MUCUY CMWS14B00067T-099TOPY-099M-0SY-24M-0RGY

The experimental unit consisted of two beds 5 m long with 0.80 m separation; the beds had two rows with a 30 cm separation. Sowing was carried out on December 16, 2019, in dry soil, and after an irrigation for seed germination, plots

were subjected to two irrigation regimes: reduced (2) and normal irrigation (4). For the first regime, complementary irrigations were applied, one after 50 days after sowing (d) and the second 85 d. For the second regime, four complementary irrigations were applied, the first 40 d, the second 72 d, the third 92 d, and the fourth 104 d. Regarding the agronomic management, fertilization was 276-52-00, of which 103 units of N and all of the P were applied pre-sowing, subsequently, before the first complementary irrigation, 138 units of N were applied, and the rest of the N was incorporated before the second complementary irrigation. For control of broad leaf weeds, Situi XP (Metsulfuron methyl + Thifensulfuron methyl) [13] was used at the rate of 30 g of commercial product ha^{-1}, and for narrow leaf weeds, Axial XL (Pinoxaden + Cloquintocet-mexyl) at the rate of 1 L ha^{-1} [14]; Muralla Max (Imidacloprid + Betacyfluthrin) was used at the rate of 250 mL ha^{-1} [15] for control of the green aphid (*Schizaphis graminum* Rondani). A 650 L cylinder-type Yukon sprayer with 14 ADIA-01 nozzles was used with a volume of 300 L ha^{-1}, for application of the agrochemicals. The entire experimental plots were harvested with a wintersteiger type Nr:1540-46 classic cereal thresher. The daily average temperature (°C), the maximum and minimum, relative humidity, the number of cold and heat units, and precipitation were recorded from December 25, 2019 to May 15, 2020 by the weather station CIANO-910, located in block 910 in the Yaqui Valley [16]; this station belongs to the automated weather station network of Sonora [17]. Cold units were calculated as the temperature > 0.1 °C to < 10 °C that occurs in a given hour, and the heat units as the number of hours with temperature above 30°C [18]. The variables recorded during development of the crop were: days to flowering, days to physiological maturity, plant height, reaction to leaf rust, and grain yield. An analysis of variance was performed with the statistical package SAS 9.4 [19], and the mean comparison by Tukey´s test ($p < 0.05$).

3. Results and discussion

The range of the average temperature during the period of evaluation was 10.3-27.0 °C (Figure 1), while for the maximum temperature it was 16.9-36.3 °C and 1.0-18.1 °C for the minimum temperature.

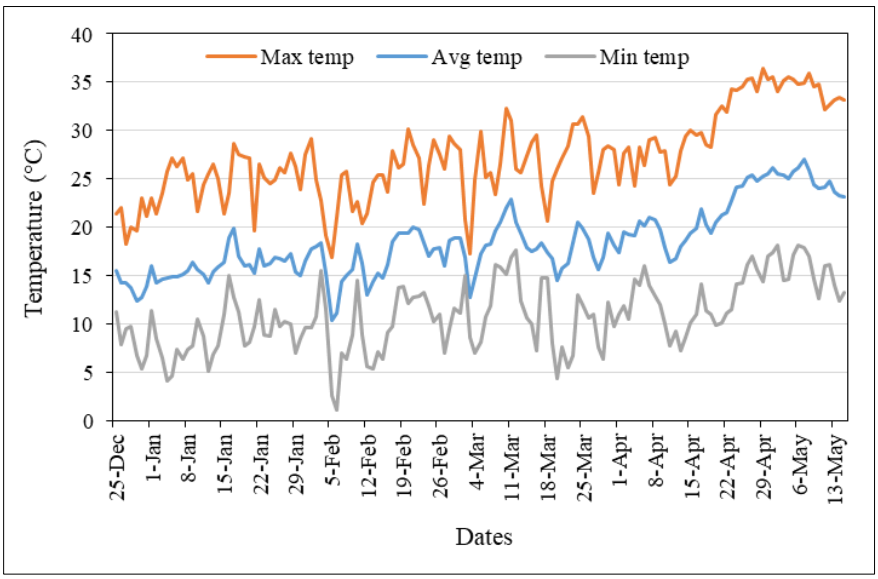

Figure 1 Average temperatures from December 25, 2019 to May 15, 2020, recorded from the weather station CIANO-910, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico, during the crop season 2019-2020

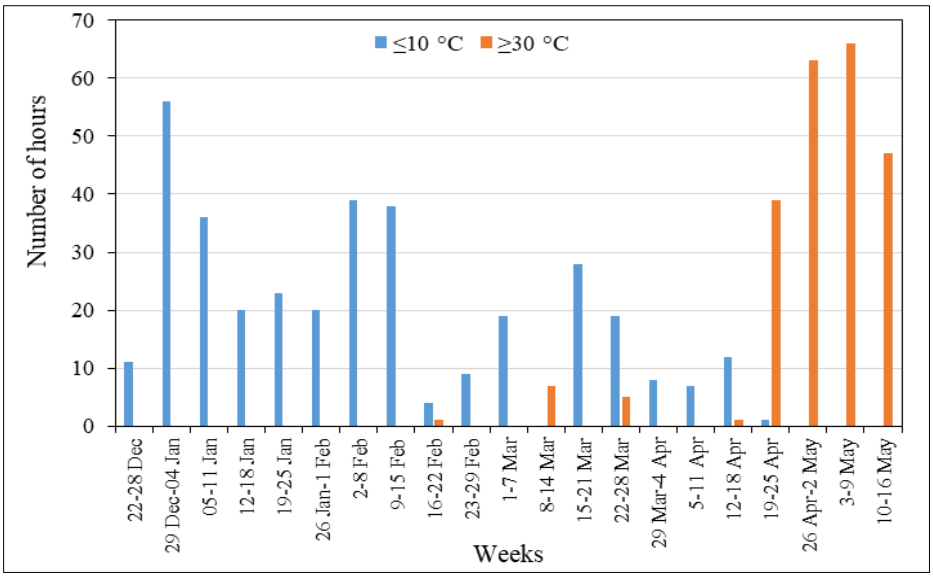

Figure 2 Number of cold and heat units accumulated from December 25, 2019 to May 15, 2020, recorded from the weather station CIANO-910, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico, during the crop season 2019-2020

The occurrence of temperatures above 30 °C were more consistent from April 20 (Figure 2) to May 15, where 93.8 % of the accumulated heat units (229) were recorded during the period of the study, although there were some days where the temperature reached 30 °C for 1 or several hours, like February 20 (1 hour), March 10 (3), 11 (4), 23 (1), 24 (2), 25 (2), and April 15 (1). However, it did not affect development of plants since the maximum average grain yield for two irrigation was 6,707 kg ha^{-1} and 7,469 for four irrigations (Figure 3).

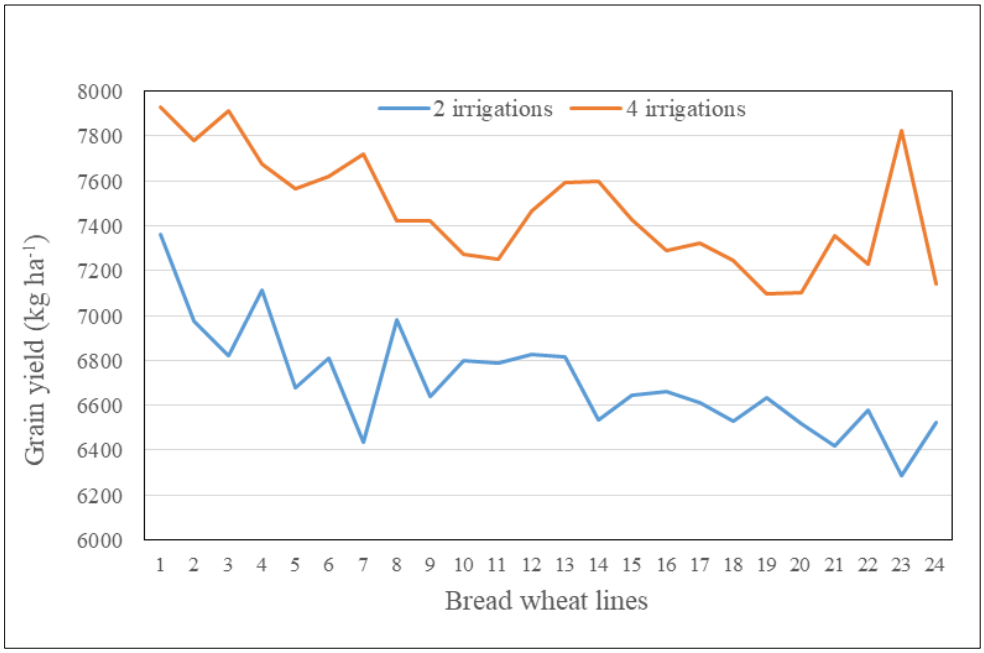

Figure 3 Grain yield per plot of bread wheat cultivars CIANO M2018 (No. 1) and Borlaug 100 (No. 12), and 22 advanced bread wheat lines, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico, during the crop season 2019-2020

The accumulation of cold units (CU) started from December 26, 2019 up to April 14, 2020, with a total of 350. The accumulation of CU was more consistent after December 26, 2019; during the week of December 22-28 there were 11 CU, 56 in December 29-January 4, 36 in January 5-11, 20 in January 12-18, 23 in January 19-25, 20 in January 26-February 1, 39 in February 2-8, 38 in February 9-15, 4 in February 16-22, 9 in February 23-29, 19 in March 1-7, 28 in

March 15-21, 19 in March 22-28, 8 in March 29-April 4, 7 in April 5-11, 12 in April 12-18, and 1 in April 19-25 (Figure 2). The wheat plant as well as many other crops, is sensitive to changes of temperature during all the growth stages; high temperatures favor a greater metabolic activity of the plant, as well as the speed up of the physiologic processes that determine its growth and development [20]. The wheat plant also requires the accumulation of cold units, to prolong its biological cycle, which generally leads to a higher grain yield [18]. Friend [21] reported that in wheat, the production of tillers is associated with increased supply of photosynthates and more tillers are present at heading when plants grow in cooler than in warmer temperatures. In southern Sonora, wheat sowing is recommended between November 15 to December 15; sowing in later dates will cause plants not to tiller properly and will be exposed to heat stress [22]. The average number of days to flowering for the group of advanced lines and commercial cultivars Borlaug 100 and CIANO M2018 with two complementary irrigations was 78.8 with a range of 77 to 82, while for four complementary irrigations was 79.3 with a range of 77 to 83 (Figure 4); the most contrasting difference was shown by the line WBLL1*2/BRAMBLING//TAM200/TUI/3/VILLAJUAREZF2009/4/2*BORL14 (No. 3) with a two day difference.

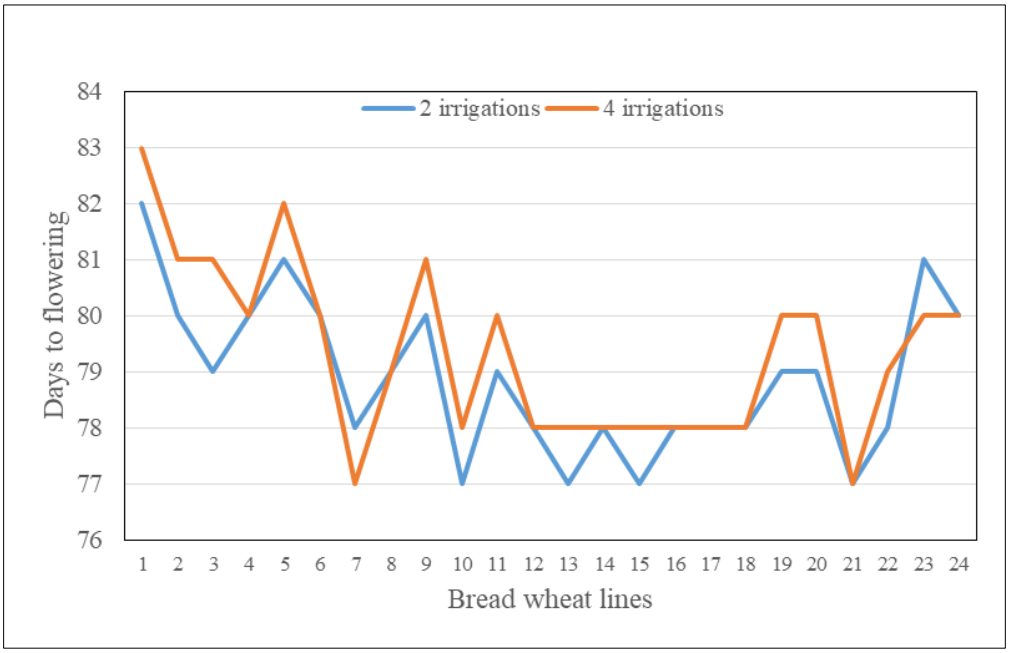

Figure 4 Days to flowering of bread wheat cultivars CIANO M2018 (No. 1) and Borlaug 100 (No. 12), and 22 advanced bread wheat lines, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

The average plant height of the group with two complementary irrigations was 91.9 cm and 91.6 with four complementary irrigations, while the range was similar for both with 85 to 98 cm (Figure 5). The average number of days for physiological maturity of the group of advanced lines and cultivars CIANO M2018 and Borlaug 100 with two complementary irrigations was 120.8 with a range of 117 to 124, and 123.4 with a range of 120 to 126 for the group with four complementary irrigations (Figure 6). Genotypes with the highest grain yield under two complementary irrigations were CIANO M2018 with 7,361 kg ha^{-1} (Figure 3, No. 1), BORL14*2//KACHU/ KIRITATI with 7,112 (No. 4), SWSR22T.B.//TACUPETOF2001*2/BRAMBLING/3/2*TACUPETOF2001*2/ BRAMBLING/4/BORL14 with 6,983 (No. 8), WBLL1*2/BRAMBLING//TAM200/ TUI/3/VILLAJUAREZ F2009/4/2*BORL14 with 6,978 (No. 2), and Borlaug 100 with 6,825 (No. 12).

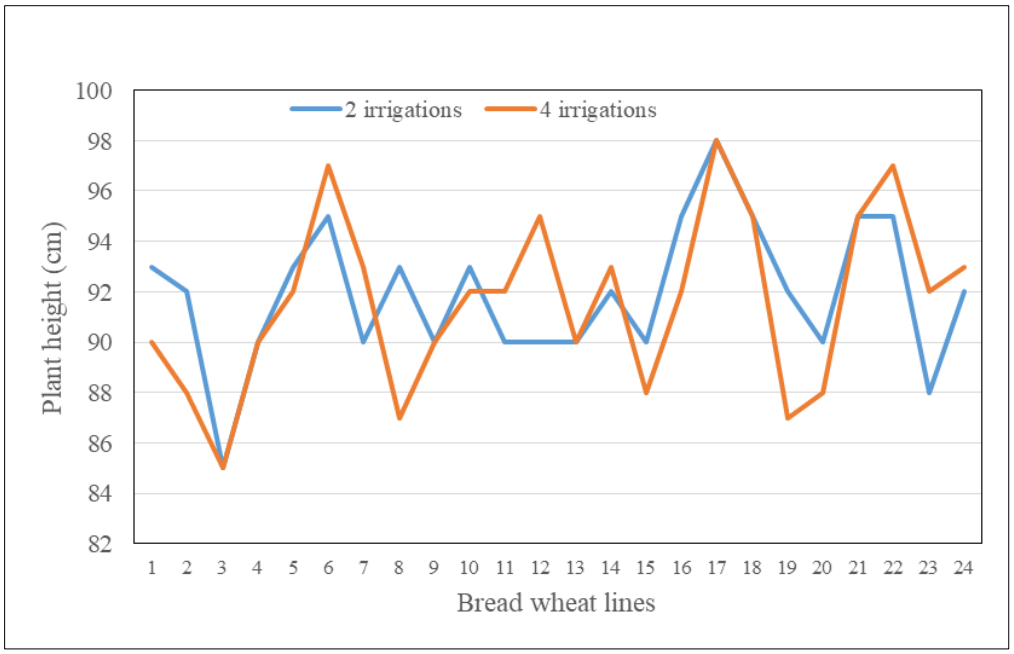

Figure 5 Plant height of bread wheat cultivars CIANO M2018 (No. 1) and Borlaug 100 (No. 12), and 22 advanced bread wheat lines at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

Figure 6 Days to physiological maturity of bread wheat cultivars CIANO M2018 (No. 1) and Borlaug 100 (No. 12), and 22 advanced bread wheat lines, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico'

Genotypes with the highest grain yield under four complementary irrigations were CIANO M2018 with 7,928 kg ha^{-1}, sister line BECARD/FRNCLN//2*BORL14 (CMSS14B01371T-099TOPY-099M-0SY-46M-0WGY, No. 3) with 7,911, BAJ#1/KISKADEE#1/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/KURUKU with 7,825 (No. 23), WBLL1*2/ BRAMBLING//TAM200/TUI/3/VILLAJUAREZF2009/4/2*BORL14 with 7,781 (No. 2), and KINDE*2/4/T.DICOCCON PI94625/AE.SQUARROSA(372)//TUI/CLMS/3/2*PASTOR/5/PFAU/MILAN//TROST/3/PBW65/2*SERI.1B*2/4/ MUNAL#1 with 7,717 (No. 7). The average grain yield difference between four and two complementary irrigations was 761 kg, with a range of 441 (SWSR22T.B.//TACUPETOF2001*2/BRAMBLING/3/2*TACUPETOF2001*2/BRAMBLING

/4/BORL14, No. 8) to 1,536 (BAJ#1/KISKADEE#1/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/KURUKU, No. 23). Other lines that had a difference greater than 1,000 kg were KINDE*2/4/T.DICOCCONPI94625/AE.SQUARROSA (372)//TUI/CLMS/3/2*PASTOR/5/PFAU/ MILAN//TROST/3/PBW65/2*SERI.1B*2/4/MUNAL#1 with 1,284 kg (No. 7), sister line BECARD/FRNCLN//2*BORL14 (CMSS14B01371T-099TOPY-099M-0SY-46M-0WGY, No. 3) with 1,091, and BORL14*2/7/SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/KRONSTADF2004/5/MUNAL/6/MUNAL#1 (No. 14) with 1,068. Commercial cultivars CIANO M2018 and Borlaug 100 had a grain yield difference below the group average. The highest average grain yield of both complementary irrigations was shown by CIANO M2018 with 7,519 kg ha^{-1}, followed by lines WBLL1*2/BRAMBLING//TAM200/TUI/3/VILLAJUAREZF2009/4/2*BORL14 (No. 2) with 7,435, BECARD /FRNCLN//2*BORL14 (CMSS14B01371T-099TOPY-099M-0SY-46M-0WGY, No. 3) with 7,413, BORL14*2//KACHU/ KIRITATI (No. 4) with 7,382, and BECARD/FRNCLN//2*BORL14 (CMSS14B01371T-099TOPY-099M-0SY-21M-0WGY, No. 5) with 7,276. However, there were no statistical differences among cultivars and lines. The coefficient of variation was 4.2 %. Although cultivar Borlaug 100 ranked No. 12 in average grain yield in this evaluation, it is the bread wheat most used by farmers in southern Sonora; in the 2019-2020 wheat season, 94,865.61 ha of bread wheat were established, of which 88.9 % of the area was sown with this cultivar [8]; in 2020-2021, 42,694.86 ha of bread wheat were established, of which 86.38 % of the area was covered by Borlaug 100 [23]; and in 2021-2022, of 40,376.46 ha established with bread wheat, 91.7 % of the area was covered by this same cultivar [11]. All the genotypes evaluated in this study showed good grain yield potential under both two and four complementary irrigations, probably due to the favorable conditions that prevailed for growth and crop development, with a temperature range of 10.3 to 27 °C, the accumulation of 350 CU, and the occurrence of temperatures above 30 °C were more consistent from April 20 onwards, when the plant is already in the phenological stages from hard dough to grain hard (Zadoks stages 87 to 91, Zadoks [24]). Félix-Valencia *et al*. [18] 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*. [25] reported that approximately 300 CU are needed to ensure good tillering which is directly correlated with grain yield. Martínez Cruz *et al*. [26] reported that a reduction in the amount of water applied from 1 to 0.8, 0.6, and 0.4 m caused a grain yield reduction of 14.4, 37.6, and 76.8 %, respectively, and that under limiting humidity conditions, cultivars Temporalera M87 and Náhuatl F2000 combined higher grain yield with high variables of biological yield, number of grains and spikes. These cultivars could be used as parents in breeding programs to generate progenies that combine these characteristics (Temporalera M87 could be used as parent to generate progenies with greater grain weight, and in the case of Náhuatl F2000, to increase the number of grains). According to Ledesma-Ramírez *et al*. [27] the grain yield under five irrigations was superior by 34.3 and 71.6 % compared to the three and two irrigations, respectively. In our study, yield grain reduction from four to two complementary irrigations ranged from 5.9 % in line SWSR22T.B.//TACUPETOF2001*2/BRAMBLING/3/ 2*TACUPETO F2001*2/BRAMBLING/4/BORL14 to 19.6 % in line BAJ#1/KISKADEE#1/3/SWSR22T.B./2*BLOUK#1// WBLL1*2/KURUKU, while cultivars CIANO M2018 and Borlaug 100 showed a reduction of 7.1 and 8.5 %, respectively. Despite the lower grain yield obtained with two complementary irrigations, the average yield of the group of experimental lines, that is, without taking into consideration the two cultivars, was 650 kg higher than the national average obtained in the wheat fall-winter season 2019-2020 [5]. This reflects the report by Ledesma-Ramírez *et al*. [27] who indicate that under reduced irrigation (2 and 3 irrigations), bread wheats were superior to durum wheats regardless of the class; they also observed that in general, the tested wheats showed higher water efficiency (considered as water productivity) under reduced irrigation than under normal irrigation. They also reported that the reduction from five to three and two irrigations only reduced the cycle to heading in one to two days, but days to maturity were reduced in five and eleven days, respectively (Tukey ≤ 0.05). In our study, the maximum difference in days to flowering between two and four irrigations was two days (line No. 3), while for physiological maturity it was four days (lines No. 2 and 3). Unlike the report by Ledesma-Ramírez *et al*. [27], where the genotypes evaluated under the two-irrigation treatment registered plants significantly shorter (Tukey ≤ 0.05) than the plants under three and five irrigations, in our study, cultivar CIANO M2018 and eight lines were taller with two complementary irrigations than with four, with a range of 1 to 6 cm. There was no presence of leaf rust in any of the cultivars and lines evaluated. In Sonora, a large percentage of the wheat crop is managed under irrigation by gravity, with three or four irrigations per hectare, and most of the water comes from runoff generated by rainfall and is stored in a system of dams [28]. In recent years, national wheat production has been threatened by low rainfall in the region, therefore, the selection of candidate lines for subsequent field evaluations must be based on the efficient use of water, due to the production conditions in southern Sonora.

4. Conclusion

The highest average grain yield with two and four complementary irrigations was shown by cultivar CIANO M2018 with 7,519 kg ha^{-1}, and 10 lines overcame the grain yield of cultivar Borlaug 100.

In addition to cultivar CIANO M2028, four lines were identified with a grain yield greater than 7,700 kg ha^{-1} with four complementary irrigations, and three as well as CIANO M2018 with a grain yield greater than 6,900 kg ha^{-1} with two complementary irrigation.

Yield grain reduction from four to two complementary irrigations ranged from 5.9 in line SWSR22T.B.//TACUPETOF2001*2/BRAMBLING/3/2*TACUPETOF2001*2/BRAMBLING/4/BORL14 to 19.6 % in line BAJ#1/KISKADEE#1/3/SWSR22T.B./2*BLOUK#1//WBLL1*2/KURUKU, while cultivars CIANO M2018 and Borlaug 100 showed a reduction of 7.1 and 8.5 %, respectively.

The average temperature during the crop season 2019-2020 was 19.0 °C with a maximum of 36.3 °C and a minimum of 1.0 °C; the average relative humidity was 69.0 %; there were 17.0 mm of precipitation, and the number of heat and cold units was 229 and 350, respectively.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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