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CEVY Oro C2008, a new durum wheat cultivar for southern Sonora, Mexico.

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Introduction. Wheat production in Mexico is estimated at 3.4 x 10^6 tons, which do not satisfy the consumer needs of 6.3 10^6. The Mexican milling industry produces approximately 3.5 x 10^6 tons of flour, which includes semolina; 43% of the wheat is produced in Mexico and 57% is imported. Of the total amount of wheat that the industry processes, 65.3% corresponds to bread wheat, 26.3% corresponds to wheat used for cookies, and only 8.4% is used for pasta. In northwest Mexico (Sonora, North Baja California, Sinaloa, and South Baja California), 63.18% of all wheat in the country was grown on 457,419 ha during the agricultural season autumn–winter 2008–09. The production value was about $350 x 10^6 USD in 2007. Wheat in this region is spring type and is cultivated under irrigation.

Before the 1990s, bread wheat was the dominant class in northwest Mexico. In the state of Sonora, bread wheat occupied more than 50% of the area dedicated to wheat from the agricultural season 1983–84 to 1993–94. However, many wheat producers decided to start growing durum wheat, because the mexican government implemented the domestic quarantine No. 16, which limited the cultivation of bread wheat in fields where Karnal bunt had been detected at levels greater than 2% infected grains. Other important factors were that durum wheat showed a greater grain yield than that of bread wheat, and during that period of time, did not have problems with leaf rust. In addition, there were opportunities for export of durum wheat.

Despite the economic and operational problems caused by Karnal bunt at the beginning of the 1980s, during 1990–91 bread wheat was still grown on 220,409 ha, which represented 89% of the total area dedicated to wheat in the state. However, durum wheat was consolidated as the dominat class grown in Sonora from the agricultural season 1994–95. Altar C84 was the dominant cultivar up to 2002–03, despite the fact that its resistance to leaf rust had already been overcome by a wheat race, which caused production losses during 2000–01 and 2001–02. Seed production of the cultivar Júpare C2001 (resistant to leaf rust) through a collaborative project between the Mexican National Institute for Forestry, Agriculture, and Livestock Research (INIFAP) and the International Maize and Wheat Improvement Center (CIMMYT) with support by the farmer´s union (PIEAES) of the Yaqui Valley, made it the most grown cultivar in southern Sonora from 2003-04 to 2008-09 (Table 1).

Table 1. Percent of the wheat-growing area (ha) in southern Sonora, Mexico during the agricultural season 2008–09.

Cultivar	Area (ha)	Percentage
Durum wheat		
Júpare C2001	119,327.38	42.34
Átil C2001	53,106.07	18.84
Samayoa C2004	29,062.75	10.31
Banámichi C2004	13,652.76	4.84
Platinum	7,741.92	2.75
Aconchi C89	1,067.14	0.38
Altar C84	491.66	0.17
Rafi C97	478.20	0.17
Nácori C97	10.00	0.004
TOTAL	224,937.90	
Bread wheat		
Kronstad F2004	29,818.81	10.58
Tacupeto F2001	23,733.23	8.42
Tarachi F2000	1,615.60	0.57
Rayón F89	1,045.33	0.37
Abelino F2004	638.18	0.23
Navojoa M2007	9.60	0.003
Roelfs F2007	9.60	0.003
TOTAL	56,870.34	

However, most of the durum wheat production for human consumption is for export, and the cultivar Júpare C2001 does not comply with the expected protein content in the grain and color, which are very important parameters of quality. In addition, new races of leaf rust present during 2008–09 overcame the resistance of Júpare C2001; therefore, cultivar options for this region must be increased, so that they contribute to help the long-lasting use of cultivars by wheat producers in Sonora and in northwest Mexico, and at the same meet current minimum quality requirements for export.

After evaluating grain yield since the agricultural season of 2001–02 at the Yaqui Valley Experimental Station (CEVY), we proposed to release the experimental durum wheat line 'SCRIP_1//DIPPER_2/BUSHEN_3/4/ARMENT//SRN_3/NIGRIS_4/3/ CANELO_9.1' as the cultivar CEVY Oro C2008. Yield and quality comparisons are given with respect to cultivar check Júpare C2001, which was the most cultivated durum wheat cultivar in southern Sonora up to 2008–09. Information also is provided about the main phenotypic and agronomic characteristics as well as the reaction to diseases of this new cultivar.

CEVY Oro C2008 is a spring-type, durum cultivar that originated from hybridizations made in the Durum Wheat Breeding Program of CIMMYT. The cross number and history selection is CDSS02Y00381S-0Y-0M-19Y-0M (Table 2). Shuttle breeding was carried out between the experimental stations of El Batán, state of Mexico (B) (19°30'N and 2,249 msnm), San Antonio Atizapán, state of Mexico (M) (19°17'N and 2,640 msnm), and the Yaqui Valley (Y) (27°20'N and 40 msnm), in Sonora.

Table 2. Selection history and localities where cultivar CEVY Oro C2008 was evaluated (seasons are F–W = Fall–Winter and S–S = Spring–Summer; Irrigation was RR = regular rainfed and N = normal). Planting dates for the INIFAP yield trials were 15 and 30 November, 15 December, and 1 January.

Activity	Locality	Season	Irrigation
Simple genetic cross	Cd. Obregon, Sonora	F–W/2001–02	N
F_1 Generation	El Batan, Mexico	S–S/2002	RR
F_2 Generation	Cd. Obregon, Sonora	F–W/2002–03	N
F_3 Generation	Atizapan, Mexico	S–S/2003	RR
F_4 Generation	Cd. Obregon, Sonora	F–W/2003–04	N
F_5 Generation	Atizapan, Mexico	S–S/2004	RR
F_6 Generation	Cd. Obregon, Sonora	F–W/2004-05	N
Yield trials by CIMMYT			
Yield trials by INIFAP at different planting dates	Cd. Obregon, Sonora	F–W/2006–07 F–W/2007–08 F–W/2008–09	N

Description. The most important phenotypic characteristics of this cultivar, according to the International Union for the Protection of New Varieties of Plants (UPOV), are shown in Table 3 (p. 122). Cultivar CEVY Oro C2008 and check cultivar Júpare C2001 have a similar biological cycle with an average of 121 days for physiological maturity; however, the cycle is shortened due to the lack of cold hours, if planting is late and may average 108 days when sowing is done at the end of December. CEVY Oro C2008 is tall with an average height of 93 cm (Fig. 1), with a maximum of 105 and a minimum of 85. Plant growth habit is erect and shows no or low frequency of recurved flag leaves. The shap of the spike in profile view is tapering, density is medium, and the length excluding awns is short; awns are longer than spike. Spike is weakly glaucous, and the awns are distributed along the entire length and are brown. At maturity, the spikes become white. Glume shape is ovoid (spikelet in middle third of the spike) and are not hairy on the external surface. The shape of the shoulder is rounded and narrow in width; the beak is short and slightly curved. Grain shape is semi-elongated (Fig. 2, p. 122), and the length of brush hair in dorsal view is short. Grain coloration when treated with phenol is none or very light (Fig. 2, p. 122).

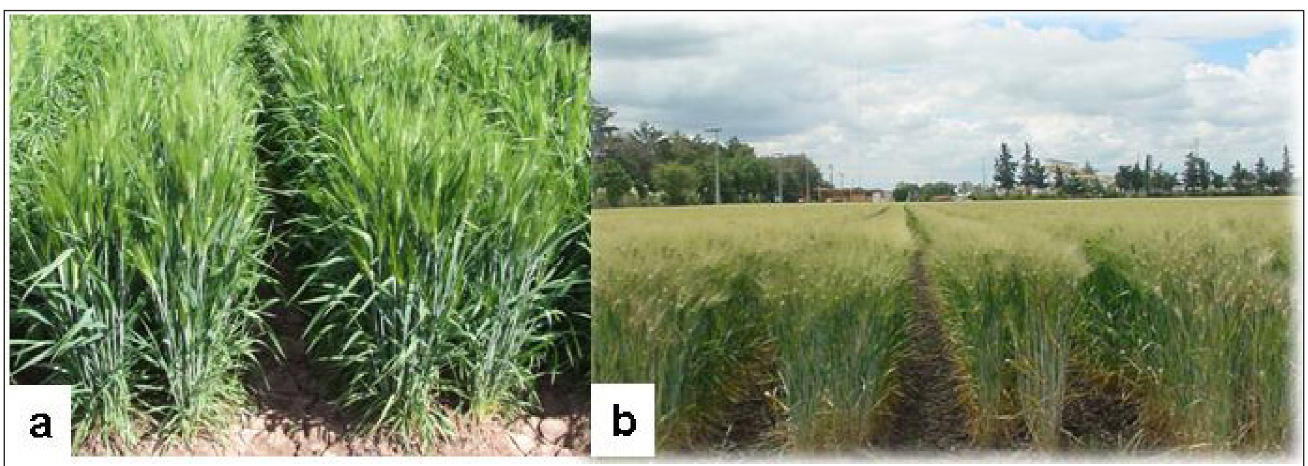

Fig. 1. The CEVY Oro C200 durum wheat cultivar is classified as tall, with an average height of 93 cm. Plants are erect and present no or a very low frequency of recurved flag leaves (a – heading; b – repening).

Table 3. Characteristics and description of phenotypic components of cultivar CEVY Oro C2008.

Structure	Characteristic	Description
Coleoptile	Anthocyanin coloration	Medium
First leaf	Anthocyanin coloration	Weak
Plant	Growth habit	Erect
	Frequency of plants with recurved flag leaves	Absent or very low
	Length (stem, spike and awns)	Long
	Seasonal type	Spring
Spike	Time of emergence	Early
	Glaucosness	Weak
	Distribution of awns	Whole length
	Length excluding awns	Short
	Hairiness of margin of first rachis segment	Wheat
	Color (at maturity)	White
	Shape in profile view	Tapering
	Density	Medium
Flag leaf	Glaucosness	Medium
	Glaucosness of blade	Weak
Awn	Anthocyanin coloration	Absent or very weak
	At tip of spike in relation to whole spike	Longer
	Color	Brown
Culm	Hairiness of uppermost node	Absent or very weak
	Glaucosness of neck	Weak
Grain	Shape	Semi-elongated
	Length of brushhair in dorsal view	Short
	Coloration with phenol	None or very light
Lower glume	Shape (spikelet in mid-third of ear)	Ovoid
	Shape of shoulder	Rounded
	Shoulder width	Narrow
	Length of beak	Short
	Shape of beak	Slightly curved
	Hairiness on external surface	Absent
Straw	Pith in cross section (half way between base of ear and stem node below)	Medium

Agronomic characteristics. CEVY Oro C2008 and the check cultivar Júpare C2001 are phenotypically very similar during early stages of development. Days-to-heading, physiological maturity, and plant height are very similar (Table 4, p. 123); however, after heading, the awns of CEVY Oro C2008 turn brown in contrast to the white awns of Júpare C2001. Because the height of CEVY Oro C2008 may reach 105 cm and the stems are thin, the lowest nitrogen rate is recommended, particularly when the third complementary irrigation (during the milky stage of the grain) is applied, in order to avoid lodging.

Fig. 2. Grain shape of the CEVY Oro C2008 durum wheat cultivar is semielongated. In the dorsal view (left), pubescence is short. Grain coloration after treatment with phenol is none or very light (right).

Reaction to disease. The evaluations carried out during the last three wheat seasons have shown that CEVY Oro C2008 and Júpare C2001 are different in resistance to leaf rust. Júpare C2001 became susceptible to this disease during the agricultural season 2007–08 when new races of the fungus were present in southern Sonora, whereas CEVY Oro C2008 showed resistance during all seasons of evaluation. The release of this new cultivar will allow wheat producers more economic benefits, because they will not have to rely on fungicides for control of leaf rust. Regarding Karnal bunt, CEVY Oro C2008 and Júpare C2001 have shown infection levels below 1% when artificially inoculated, so they are considered resistant (Table 4, p. 123).

Grain yield. Evaluation of grain yield and industrial quality of CEVY Oro C2008 started in season 2006–07 at the Yaqui Valley Experimental Station. The average yield was 5.5 t/ha, 200 kilograms lower than that of the check cultivar Júpare C2001 (Table 5). Based on statistical analysis, the best planting dates for CEVY Oro C2008 are between 15 November and 1 December. In two farmers' fields, CEVY Oro C2008 showed an average yield potential of 7.1 t/ha during the 2008–09 season (Table 6).

Table 4. Agronomic characteristics (average) and reaction to diseases of cultivar CEVY Oro C2008 and the check cultivar Júpare C2001 during the agricultural seasons 2006-07 to 2008-09, at the Yaqui Valley Experimental Station in Sonora, Mexico (R = resistant and S = susceptible).

	Cultivar	
Characteristic	CEVY Oro C2008	Júpare C2001
Heading (days)	81	80
Physiological maturity (days)	121	121
Plant height (cm)	93	92
Leaf rust	R	S
Karnal bunt	R	R

Table 5. Experimental average grain yield (t/ha) of cultivar CEVY Oro C2008 and the check cultivar Júpare C2001 during agricultural seasons 2006–07 to 2008–09 grown at the Yaqui Valley Experimental Station in Sonora, Mexico. Experimental trials were at four planting dates with a total of four irrigations.

	Cultivar	
Agricultural season	CEVY Oro C2008	Júpare C2001
2006–07	5.970	5.962
2007–08	4.749	6.185
2008–09	5.965	5.134
Average	5.561	5.760

Quality. Several physico-chemical parameters affect the industrial quality of durum wheat cultivars. However, protein content, quality, and the pigment present in the endosperm of the grain noticeably affect the evaluation parameters of semolina used for pasta making. Although protein content and quality are affected by crop management, mainly by nitrogen fertilization, cultivar and yield potential are associated with protein present in the grain. Evaluations from 2006–07 to 2008–09 have shown that CEVY Oro C2008 is consistently superior to the check cultivar Júpare C2001 in yellow pigment content (Fig. 3). CEVY Oro C2008 produces a grain with an average specific weight of 83 kg/hl, and 13.5% protein at 12% moisture content. These two parameters are similar to those of the cultivar check Júpare C2001 (Table 7). From the farmer's point of view, grain yield has been the main parameter for choosing a cultivar; however, in the case of durum wheat, pigment is a very important factor to consider for export. The intensity of yellow pigment in the endosperm of CEVY Oro C2008 grain has an average of 28.1 points on the Minolta b scale, whereas Júpare C2001 has an average of 20.7.

Table 6. Grain yield (t/ha) of cultivar CEVY Oro C2008 and the check cultivar Júpare C2001 in two farmers' fields during the agricultural season 2008–09 in the Yaqui Valley, Sonora, Mexico.

		Cultivar	
Season	Block	CEVY Oro C2008	Júpare C2001
2008–09	609	6.7	6.7
	2518	7.5	7.9
Average		7.1	7.3

Table 7. Industrial quality characteristics of cultivar CEVY Oro C2008 and the check cultivar Júpare C2001 during the agricultural seasons 2006–07 to 2008–09 at the Yaqui Valley Experimental Station, Sonora, Mexico.

	Cultivar	
Characteristic	CEVY Oro C2008	Júpare C2001
Specific weight (kg/hl)	83.0	83.6
Grain protein (%)	13.1	13.8
Color (Minolta b value)	28.1	20.7

Fig. 3. CEVY Oro C2008 (right) produces a greater concentration of pigment compared with Júpare C2001 (left).

The information for the release of durum wheat cultivar CEVY Oro C2008 was generated in southern Sonora, however, based on agroecological data, this cultivar can be grown in the irrigated areas of northwest Mexico, which includes the states of South Baja California, North Baja California, Sinaloa, and Sonora. CEVY Oro C2008 represents a new option in durum wheat with an acceptable grain yield potential and better quality for pasta making, for those farmers interested in wheat grain for export.

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Evaluation of agronomic characteristics in durum wheat cultivars and advanced lines for northwestern Mexico during 2008–09.

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Introduction. In northwestern Mexico, comprised of the states of Sonora, South Baja California, North Baja California, and Sinaloa, wheat is the crop with the greatest area planted in the country (approximately 63% of the total area). In southern Sonora, the area grown with wheat occupies about 300,000 ha. For the agricultural season 2008–09, the average grain yield was 5.9 ton/ha with a total production of 1.8 x 10^6 ton (OEIDRUS 2010). Wheat in this region is spring type, cultivated during the autumn–winter under irrigation (Huerta and González 2000). Beginning with the crop season 1994–95, durum wheat was consolidated as the wheat class more cultivated in the state of Sonora and during 2008–09 occupied about 225,000 ha in the southern part of the state. Because southern Sonora is in a coastal area, the relative humidity is high and leaf rust is a recurrent disease that develops rapidly in susceptible cultivars. New, more virulent races of the pathogen, which cause loss of resistance in the most widely grown cultivars (Herrera-Foessel et al.,2005; Singh et al. 2003), occurred in the 2000–01 and 2007–08 growing seasons with cultivars Altar C84 (Figueroa-López et al. 2002), Átil C2000, and Júpare C2001 (Figueroa-López 2009). In order to generate and release a cultivar as a new alternative for wheat producers, the germ plasm must feature resistance to diseases, acceptable grain yield, good agronomic characteristics, and industrial quality. The collaborative wheat breeding program between the Mexican National Institute for Forestry, Agriculture, and Livestock Research (INIFAP) and the International Maize and Wheat Improvement Center (CIMMYT) is generating advanced lines and cultivars of durum wheat with good yield potential and other characteristics in order to widen the options for wheat production in northwestern Mexico. Our objective was to evaluate the agronomic characteristics of a group of durum wheat cultivars and elite lines at several sowing dates under furrow irrigation.

Establishment of the trial. The study was carried out at the Yaqui Valley Experimental Station (the station was named Norman E. Borlaug Experimental Station–CENEB, in March, 2010), which belongs to the Northwest Regional Research Center (CIRNO) of INIFAP, during the wheat season of the autumn–winter 2008–09. The genetic material consisted of nine commercial cultivars of durum wheat and sixteen advanced lines from CIMMYT (Table 8, continued on p. 125). The experimental design was a split plot randomized complete block with three replications. Main plots were the sowing dates and the subplots consisted of the different cultivars and lines. Experimental plots were 4-m long on beds with two rows; space between beds was 0.8 m. Sowing dates were 15 November, 2008, 1 and 15 December, and 1 January, 2009, in dry soil using 100 kg of seed per hectare. Fertilization consisted of 300 kg/ha of urea and 130 kg/ha of monomonium phosphate before seeding. The trial was irrigated immediately after seeding and later during the season, three complementary irrigations were provided. Before the first complementary irrigation, 100 kg/ha of urea were applied. The herbicide Situi® xl at 25 g/ha of commercial product was sprayed over the trial 30 days after sowing.

Table 8. Durum wheat comercial cultivars and elite lines evaluated during the agricultural season 2008–09, at the Yaqui Valley Experimental Station, Sonora Mexico.

Entry	Cultivar/line	Selection history
1	Átil C2000	CD91B1938-6M-030Y-030M-4Y-0M
2	Júpare C2001	CD91Y636-1Y-040M-030Y-1M-0Y-0B-1Y-0B
3	Banámichi C2004	CDSS95B00803M-D-0M-1Y-0B-3Y-0B-0Y-0B-15EY-0Y
4	Samayoa	C2004CDSS95B00181S-0M-1Y-0B-1Y-0B-0Y-0B-14EY-0Y
5	CEVY ORO C2008	CDSS02Y00381S-0B-0Y-0M-19Y-0M-0Y
6	CIRNO C2008	CGSS02Y00004S-2F1-6Y-0B-1Y-0B
7	PATRONATO ORO C2008	CDSS02Y00390S-0Y-0M-8Y-0Y
8	Sáwali Oro C2008	CDSS02Y00786T-0TOPB-0Y-0M-2Y-0Y
9	Platinum	

Table 8 (continued). Durum wheat comercial cultivars and elite lines evaluated during the agricultural season 2008–09, at the Yaqui Valley Experimental Station, Sonora Mexico.		
Entry	Cultivar/line	Selection history
10	CNDO/PRIMADUR//HAI-OU_17/3/SNITAN/4/STOT//ALTAR 84/ALD/5/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN	CDSS02Y01208T-0TOPB-0Y-0M-22Y-0Y
11	GUAYACAN INIA/POMA_2//SNITAN/4/D86135/ACO89//PORRON_4/3/SNITAN	CDSS02B00562S-0Y-0M-2Y-1M-04Y-0B
12	PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/POHO_1/10/DIPPER_2/BUSHEN_3//SNITAN	CDSS02B01115T-0TOPB-0Y-0M-1Y-4M-04Y-0B
13	TGBB/CANDEF//LALA/GUIL/3/BONVAL/4/TILO_1/LOTUS_4/5/TILO_1/LOTUS_4	CDSS02B01344T-0TOPB-0Y-0M-2Y-2M-04Y-0B
14	COMARA//SOOTY_9/RASCON_37/3/2*AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9	CDSS02B00743S-0M-1Y-06Y-1M-1Y-0B
15	NUS/SULA//5*NUS/4/SULA/RBCE_2/3/HUI//CIT71/CII*2/5/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1	CDSS04Y00888T-0TOPB-26Y-0M-06Y-2M-1Y-0B
16	KOFA/10/LD357E/2*TC60//JO69/3/FGO/4/GTA/5/SRN_1/6/TOTUS/7/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69/8/SOMBRA_20/9/STOT//AL-TAR 84/ALD	CDSS04SH00003S-25Y-8M-2Y-1M-1Y-0B
17	MOHAWK/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR	DSS04SH00022S-22Y-2M-5Y-1M-1Y-0B
18	KOFA/3/SOMAT_3/PHAX_1//TILO_1/LOTUS_4	CDSS04SH00001S-27Y-10M-5Y-3M-1Y-0B
19	CMH83.2578/4/D88059//WARD/YAV79/3/ACO89/5/2*SOOTY_9/RASCON_37/6/1A.1D 5+10-6/3*MOJO/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13	CDSS02B00720S-0Y-0M-8Y-1M-04Y-0B
20	CNDO/PRIMADUR//HAI-OU_17/3/SNITAN/4/STOT//ALTAR 84/ALD	CDSS02B00250S-0M-1Y-06Y-2M-1Y-0B
21	CNDO/PRIMADUR//HAI-OU_17/3/SNITAN/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/7/CHEN_11/POC//TANTLO/5/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69/6/MINIMUS/COMB DUCK_2//CHAM_3	CDSS04Y00864T-0TOPB-17Y-0M-06Y-1M-1Y-0B
22	CHEN/ALTAR 84/3/HUI/POC//BUB/RUFO/4/FN-FOOT/5/STOT//ALTAR 84/ALD/3/PATKA_7/YAZI_1/6/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN	CDSS04Y00786T-0TOPB-18Y-0M-06Y-4M-1Y-0B
23	CNDO/PRIMADUR//HAI-OU_17/3/SNITAN/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/7/CHEN_11/POC//TANTLO/5/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69/6/MINIMUS/COMB DUCK_2//CHAM_3	CDSS04Y00864T-0TOPB-1Y-0M-06Y-2M-1Y-0B
24	SOMAT_4/INTER_8//VERDI/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/RAFI97/9/MALMUK_1/SERRA-TOR_1	CDSS04Y01242T-0TOPB-4Y-0M-06Y-3M-1Y-0B
25	KOFA/4/DUKEM_1//PATKA_7/YAZI_1/3/PATKA_7/YAZI_1	CDSS04SH00008S-16Y-6M-2Y-4M-1Y-0B

Data analysis. Grain yield, specific weight (kg/hl), days-to-heading (50% of ears completely emerged), physiological maturity (loss of rachis coloration), and plant height were recorded. An analysis of variance was performed and multiple LSD (0.05) was used to compare means. A correlation was analyzed between specific weight as the independent variable and grain yield as the response variable.

Results and Discussion. The analysis of variance showed significant differences ($p < 0.001$) in grain yield, specific weight, days to heading, and plant height, and the interactions between genotypes and sowing dates. The mean comparison between cultivars and lines for grain yield and other agronomic characteristics is shown in Table 9. Cultivar CIRNO C2008 had an average of 6,421 kg/ha compared to Átil C2000 with 4,105 kg/ha. This difference in yield is related to the incidence of leaf rust and the difference in susceptibility–resistance. CIRNO C2008 originated from the cross between Átil C2000 with the line Camayo, which is resistant to leaf rust (Foessel-Herrera et al. 2005). Other cultivars that showed lower yields than that of CIRNO C2008 were Júpare C2001 (5,134 kg/ha), Banámichi C2004 (4,767kg/ha), and Platinum (3,931 kg/ha). Of the genotypes evaluated, eight produced more than 6,000 kg/ha (compared with the average regional yield in 2007–08 of 5,900 kg/ha). Outstanding were 'CIRNO C2008', 'GUAYACAN INIA/POMA_2//SNITAN/4/D86135/ACO89//PORRON_4/3/SNITAN', and Samayoa C2004, which are characterized as possessing resistance genes from Camayo, Guayacan/INIA, and *Lr14a*, respectively (Herrera-Foessel et al. 2005, 2008). Grain yield was positively correlated with specific weight with a determination of coefficient of $r^2 = 0.78$ (Fig. 4). The general average of this last variable was reduced from 82.7 kg/hl at the first sowing date to 80.3 kg/hl at the last one, which could be attributed to the effect of different factors that affect grain filling, such as leaf rust severity. A compensating effect between grain weight and number of grains/spike was noticed, because at the later sowing dates, a difference in grain distribution in distal part is expressed as smaller in size and, therefore, cause a reduction in the average grain weight (Slafer et al. 1996). In general, the cultivar CEVY ORO C2008 was the tallest (96.2 cm), with the longest vegetative cycle (79 days to heading and 120 to physiological maturity) in contrast with the cultivar Platinum (67 days to heading and 110 to physiological maturity), which has been described as a cultivar with a vegetative short cycle. Solis et al. (2006) reported a shortening of the wheat vegetative cycle to physiological maturity as leaf rust severity increases, whereas Soto et al. (2009) pointed out the importance of the duration of the vegetative state of the foliar area measured from spike emergence to physiological maturity, which is related to grain yield. The environmental conditions that prevailed during the wheat season during this study al-

Table 9. Grain yield and agronomic characteristics of durum wheat commercial cultivars and advanced lines, evaluated during the agricultural season 2008–09 at the Yaqui Valley Experimental Station, Sonora, Mexico.

Entry No.	Yield (kg/ha)	Specific weight (kg/hl)	Days-to-flowering	Days-to-physiological maturity	Plant height (cm)
6	6,421	83.56	76.00	119.8	74.58
13	6,335	83.57	73.75	116.6	87.92
11	6,275	83.63	71.67	114.3	83.33
15	6,181	84.10	76.25	117.5	90.00
14	6,163	83.68	72.58	117.4	85.00
18	6,130	84.06	74.58	117.7	90.83
24	6,056	82.81	71.67	116.6	84.17
4	6,012	82.23	71.33	116.1	80.42
5	5,965	83.29	79.67	120.7	96.25
17	5,959	82.14	74.58	118.3	81.25
10	5,940	82.33	73.75	117.5	83.75
25	5,901	81.80	78.58	120.1	93.33
19	5,878	83.75	78.50	120.3	87.50
7	5,865	83.05	77.58	119.7	84.17
8	5,825	83.07	76.92	120.7	88.33
20	5,691	81.45	74.17	117.2	87.50
16	5,617	82.49	73.42	118.1	86.67
23	5,590	82.47	70.92	115.3	85.83
21	5,510	83.04	74.75	116.8	90.83
22	5,344	81.58	75.50	119.1	84.58
12	5,159	80.62	73.33	117.4	87.50
2	5,134	82.63	75.67	118.7	90.83
3	4,767	80.43	72.92	116.8	79.17
1	4,105	79.78	78.50	119.3	82.50
9	3,931	78.20	67.08	110.4	65.00
LSD (0.05)	390	0.50	0.63	1.2	2.79

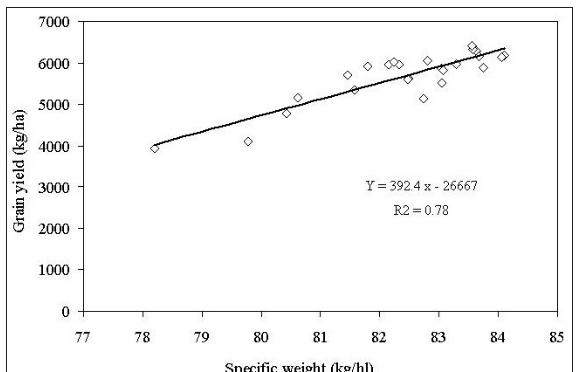

Fig. 4. The correlation between specific weight and grain yield of a group of durum wheat cultivars and advanced lines evaluated during the agricultural season 2008–09 at the Yaqui Valley Experimental Station, Sonora, Mexico.

lowed us to evaluate the effect of leaf rust, grain yield potential, and other agronomic characteristics of genotypes, some of which can be considered as the best options for durum wheat production in southern Sonora.

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Evaluating grain yield in ten genotypes of durum wheat at different sowing dates and irrigation conditions at the Yaqui Valley Experimental Station, Sonora, Mexico.

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Introduction. High produciton levels make wheat is the most important crop in northwestern Mexico. Of the wheat classes cultivated in the state of Sonora, durum wheat has occupied the greatest area for the last several years; influenced by grain yield potential. To evaluate the performance of the material generated by breeding programs, it is necessary to measure stability of genotypes in the prevailing environments (Solano et al. 1998). Selection of the most appropriate genotypes for specific environments might be relatively easy, however, as environments diversify and cover a wider area, the variability in climatic factors increases and, consequently, plants can not maintain productivity within a range of high yields. Our objective was to evaluate the grain yield potential of ten genotypes of durum wheat at different sowing dates and irrigation conditions.

Table 10. Durum wheat lines evaluated during the agricultural season 2006–07 at the Yaqui Valley Experimental Station, Sonora, Mexico.

Line	Cross and selection history
1	SOMAT_4/INTER_8 CDSS95B00181S-0M-1Y-0B-1Y-0B-0Y-0B-14EY-0Y
2	CS/TH.CU//GLEN/3/GEN/4/MYNA/VUL/5/2*DON87/6/2*BUSCA_3 CDSS95B00803M-D-0M-1Y-0B-3Y-0B-0Y-0B-15EY-0Y
3	ADAMAR_15//ALBIA_1/ALTAR84/3/SNITAN/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9 CDSS02Y00214S-0Y-0M-5Y-0Y
4	GREEN_2/HIMAN_12//SHIP_1/7/ECO/CMH76A.722//YAV/3/ALTAR84/4/AJAIA_2/5KJOVE_1/6/ MALMUK_1/SERRATOR_1 CDSS02Y00287S-0Y-0M-10Y-0Y
5	1A.1D 5+106/3*MOJO//RCOL/3/SNITAN/SOMAT_3//FULVOUS_1 /MFOWL_13 CDSS02Y00405S-0Y-0M-18Y-0Y
6	1A.1D5+10-6/3*MOJO//RCOL/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1 CDSS02Y00408S-0Y-0M-6Y-0Y
7	MUSK_1//ACO89/FNFOOT_2/4/MUSK_4/3/PLATA_3//CREX/ALLA/5/OLUS*2/ILBOR//PATKA_7/YAZI_1 CDSS02Y00786T-0TOPB-0Y-0M-2Y-0Y
8	STOT//ALTAR 84/ALD*2/3/KHAPLI CGSS01B00033T-099Y-099B-099B-147Y-0B
9	SOOTY_9/RASCON_37/3/STOT//ALTAR 84/ALD CGSS02Y00002S-2F1-48Y-0B-11Y-0B
10	SOOTY_9/RASCON_37//CAMAYO CGSS02Y00004S-2F1-6Y-0B-1Y-0B

Materials and Methods. A grain yield trial was carried out at the Yaqui Valley Experimental Station (27°22 LN, 109°55 LW, at 37 masl; the station was named Norman E. Borlaug Experimental Station – CENEB, in March, 2010), during the agricultural season 2006–07 in the southern part of Sonora. In this region, the climate is warm, extreme warm, and dry BW (h') and BS (h¨) according to Koppen's classification, modified by García (1964). The soil is heavy clay. The genetic material consisted of ten durum wheat advanced lines (Table 10, p. 127) sown on four dates (15 November, and 1, 15, and 29 December), with two and three complementary irrigations (Table 11). Experimental plots were 5-m long in two beds with two rows each with a density of 100 kg/ha under a randomized complete block design with three replications. The agronomic management followed the technical recommendations made by the National Institute for Forestry, Agriculture, and Livestock Research (INIFAP) for the region. Climatic conditions during the course of the trial were recorded from the agroclimatic network system in the Yaqui Valley, station block 910 (Table 12; AGROSON 2009).

Table 11. Sowing dates and number of irrigations for ten durum wheat lines, during the agricultural season 2006–07 at the Yaqui Valley Experimental Station, Sonora, Mexico.

Sowing date	# of irrigations	Irrigation dates
15 November	2	5 January and 14 February
15 November	3	29 December, 2 and 28 February
1 December	2	23 January and 28 February
1 December	3	12 January, 16 February, and 12 March
15 December	2	6 February and 8 March
15 December	3	29 January, 1 and 23 March
29 December	2	26 February and 27 March
29 December	3	12 February, 9 March, and 3 April

Table 12. Climatic data registered at station block 910, Yaqui Valley, during November 2006 to May 2007 in Sonora, Mexico (accumulated rain = 24.4 mm; accumulated cold hours = 512).

Month	Year	Average temperature (°C)	Maximum average temerature (°C)	Minimum average temperature (°C)	Maximum relative humidity (%)	Minimum relative humidity (%)	Maximum average solar radiation (kwatt/m²)
November	2006	20.53	30.40	12.28	87.93	25.37	0.74
December	2006	15.35	24.52	7.56	87.00	27.30	0.70
January	2007	13.59	21.72	6.22	88.00	33.54	0.72
February	2007	15.49	25.18	7.34	92.00	31.53	0.88
March	2007	17.63	28.62	8.23	91.09	26.35	0.96
April	2007	19.65	29.23	10.85	91.62	25.55	0.98
May	2007	24.21	34.15	13.56	82.64	19.06	1.05

Results and Discussion. Significant differences were found between lines sown on 15 November with two irrigations (Table 13, p. 129). Average yield for the ten lines was 5,432 kg/ha with two irrigations and 6,769 for three. Average yield of individual lines ranged from 4,285 to 5,983 kg/ha. Wheat lines (9) SOOTY_9/RASCON_37 /3/STOT//ALTAR84/ALD, (7) MUSK_1//ACO89/FNFOOT_2/4/MUSK_4/3/PLATA _3//CREX/ALLA/5/OLUS*2/ILBOR//PATKA_7/ YAZI_1, and (1) SOMAT_4/INTER _8 had the highest yield. For the 15 November sowing date with three irrigations, average yield for individual lines ranged from 5,854 kg/ha to 7,608. Lines 7 and 9 showed the highest yield with 7,608 and 7,479, respectively. Both lines showed 1,639 and 1,496 kg more than with two irrigations.

For the second sowing date with two irrigations, average yield for the ten lines was 5,159 kg/ha; for three irrigations it was 6,240. The average yield of the individual lines with two irrigations ranged from 4,517 to 5,612 kg/ha. Line 9 showed the highest yield, followed by lines 2 (CS/TH.CU//GLEN/3/GEN/4/ MYNA/VUL/5/2*DON87/6/2*BUSCA_3) and 7. For the same sowing date with three irrigations, average yield of individual lines ranged from 5,581 to 6,663 kg/ha. Lines 7, 9, and and 1 showed the highest yield with 6,663, 6,658, and 6,583 kg/ha, respectively. These lines had 1,242, 1,046, and 1,225 kg/ha more than with two irrigations.

For the third sowing date with two irrigations, the average yield for the ten lines was 4,853 kg/ha and for three irrigations it was 5,494. The average yield of individual lines with two irrigations ranged from 4,320 to 5,411

Table 13. Grain yield and physiological maturity of ten experimental durum wheat lines with two and three complementary irrigations in four sowing dates at the Yaqui Valley Experimental Station, Sonora, Mexico (means in columns with the same latter are statistically similar DMS, 0.05; PMat = days-to-physiological maturity).

	15 November				1 December				15 December				29 December			
	2 irrigations		3 irrigations		2 irrigations		3 irrigations		2 irrigations		3 irrigations		2 irrigations		3 irrigations	
Line	Yield	PMat	Yield	PMat	Yield	PMat	Yield	PMat	Yield	PMat	Yield	PMat	Yield	PMat	Yield	PMat
1	5,927 az	126 e	16,829 cd	129 d	5,358 ab	120 ef	6,583 a	122 d	4,973 a	115 cd	5,476 bcd	114 de	4,634 ab	104 d	5,324 a	110 a
2	5,591 ab	126 e	6,625 cde	129 d	5442 ab	119 f	6161 bc	121 d	5,071 a	112 e	5,683 abc	113 e	3,845 de	103 e	5,212 a	106 b
3	5,375 bc	130 bc	6,904 cd	133 bc	5,146 bc	123 bcd	6,429 ab	126 b	4,495 a	118 ab	5,462 cd	117 ab	4,290 bc	108 a	5,458 a	111 a
4	4,285 e	132 a	5,854 f	134 ab	4,517 d	124 abc	5,658 d	128 a	4,735 a	117 abc	5,912 ab	117 ab	4,251 bcd	108 ab	5,272 a	112 a
5	4,713 de	131 ab	6,454 de	135 a	4,787 cd	125 a	6,027 c	128 a	4,320 a	118 ab	5,105 d	118 a	3,648 e	109 a	5,068 a	112 a
6	5,028 cd	130 ab	6,125 ef	133 ab	4,700 d	124 ab	5,581 d	127 ab	4,780 a	119 a	5,519 abcd	117 ab	4,241 bcd	108 ab	4,941 a	111 a
7	5,969 a	128 cde	7,608 a	130 d	5,421 ab	122 cd	6,663 a	126 bc	4,406 a	116 bcd	5,173 cd	116 bc	4,057 cde	108 ab	5,149 a	111 a
8	5,686 ab	129 bcd	6,733 cd	129 d	5,350 ab	122 cd	6,070 c	123 d	5,071 a	116 bcd	5,233 cd	115 cd	3,957 cde	108 ab	5,149 a	110 a
9	5,983 a	127 de	7,479 ab	131 cd	5,612 a	121 de	6,658 a	125 c	5,411 a	114 de	5,327 cd	116 bc	4,362 bc	107 bc	5,575 a	111 a
10	5,766 ab	129 bcd	7,088 bc	131 cd	5,263 ab	122 cd	6,573 a	125 c	5,274 a	116 abc	6,050 a	116 abc	4,810 a	106 cd	5,661 a	110 a
CV (%)	4.89	0.96	4.32	0.98	4.09	0.83	2.86	0.73	10.63	1.34	5.96	0.93	6.07	0.89	7.11	1.3

kg/ha. Line 9 showed the highest yield, followed by lines 10 (SOOTY_9/RASCON_37//CAMAYO), 2, and 8 (STOT//ALTAR 84/ALD*2/3/KHAPLI). For the same sowing date with three irrigations, the average yield of individual lines ranged from 5,105 to 6,050 kg/ha. Lines 10, 4 (GREEN_2/HIMAN_12//SHIP_1/7/ECO/ CMH76A.722//YAV/3/ALTAR84/4/AJAIA_2/5KJOVE_1/6/MALMUK_1/SERRATOR_1), and 2 showed the highest yield with 6,050, 5,912, and 5,683 kg/ha, respectively; these lines had 776, 1,177, and 612 kg/ha more than with two irrigations.

For the fourth sowing date with two irrigations, the average yield for the ten lines was 4,209 kg/ha and for three irrigations it was 5,280. The average yield of individual lines with two irrigations ranged from 3,648 to 4,810 kg/ha. Line 10 showed the highest yield, followed by line 1. For the same sowing date with three irrigations, average yield of individual lines ranged from 4,941 to 5,661 kg/ha. Lines 10 and 9 showed the highest yield with 5,661 and 5,575 kg/ha, respectively; these lines had 851 and 1,213 kg/ha more than with two irrigations.

The average yield of the group of lines showed a continuous decrease with later sowing dates (Fig. 5, p. 130) in this particular agricultural season (2006–07). The maximum average yield difference at the different sowing dates with two irrigations was 1,223 kg/ha and for three it was 1,489. Six lines showed a consistent grain yield reduction from the first to the second sowing dates, then to the third and the fourth sowing dates when two complementary irrigations were applied, whereas for three irrigations, eight lines showed the same pattern. The most outstanding line for grain yield under two irrigations was SOOTY_9/RASCON_37 /3/STOT//ALTAR 84/ALD, which produced the highest yield in the first three sowing dates (5,983, 5,612, and 5,411 kg/ha, respectively) and was third (4,362 kg/ha) at the fourth date. These results clearly indicate that this line has the capacity to perform well under water stress. Other lines that showed acceptable performance under these conditions were SOOTY_9 /RASCON_37//CAMAYO, which was first in yield in the fourth sowing date (4,810 kg/ha) and second in the third date (5,274 kg/ha); SOMAT_4/INTER_8, which was second in yield in the fourth sowing date (4,634 kg/ha) and third in the first date (5,927 kg/ha); and MUSK_1//ACO89/FNFOOT_2/4/MUSK_4/3/PLATA_3//CREX/ALLA/5/OLUS*2/ ILBOR//PATKA_7/YAZI_1, which was second in yield in the first sowing date (5,969 kg/ha) and third in the second date (5,421 kg/ha). In overall average grain yield at the four sowing dates under two complementary irrigations, SOOTY_9/RASCON_37 /3/STOT//ALTAR84/ALD was first, SOOTY_9/RASCON_37//CAMAYO second, and SOMAT_4/INTER_8 third. For the overall average grain yield in the four sowing dates under three complementary irrigations, SOOTY_9/RASCON_37//CAMAYO was first, SOOTY_9/RASCON_37/3/STOT//ALTAR84/ALD second, and MUSK_1//ACO89/ FNFOOT_2/4/MUSK_4/3/PLATA_3//CREX/ALLA/5/OLUS*2/ILBOR//PATKA_7/YAZI_1 third. This last line produced the highest average yield in the whole trial with 7,608 kg/ha. There was a tendency to greater grain yield by early wheat lines at the first two sowing dates (November 15 and December 1) as compared to late sowing (December 15 to January 1) (Table 13, p. 129), where earliness was not a factor that determined yield of lines under the prevailing conditions during the study.

The maximum, minimum, and average daily temperatures from the day of wheat emergence are given in Fig. 6. The data indicate that stress conditions were present and affected the experimental genotypes during different phenological stages. During December–January, the average maximum temperature was 24 and 21°C, respectively, which was favorable for wheat growth. At this phenological stage, good soil coverage is achieved and tillers are completely developed. On the other hand, plants are exposed continuously to environmental stimuli that affect their development and productivity. For some species, small changes in the levels of stimuli might become stress factors. Environmental stress may be present in different ways but, in general, their common effect is the hydric status of the plant (Bohnert et al. 1995). The plant response to such conditions will depend on species, because the mechanisms that confer tolerance to stress, in many instances, have evolved specifically for certain groups. Similarly, response to stress is based on the stage of development in which plants have experienced unfavorable conditions (Bohnert and Jensen 1996). Fokar et al. (1998) and Savin et al. (1997) found significant variation in the reduction of number and grain weight/spike under heat; on the other hand, under cool conditions (10°C), the plant expresses the real yield potential, because there is a high correlation between yield and cold hours. Under this scheme, there was a 22% yield reduction in treatments with two and three irrigations during the fourth sowing date with respect to the first date.

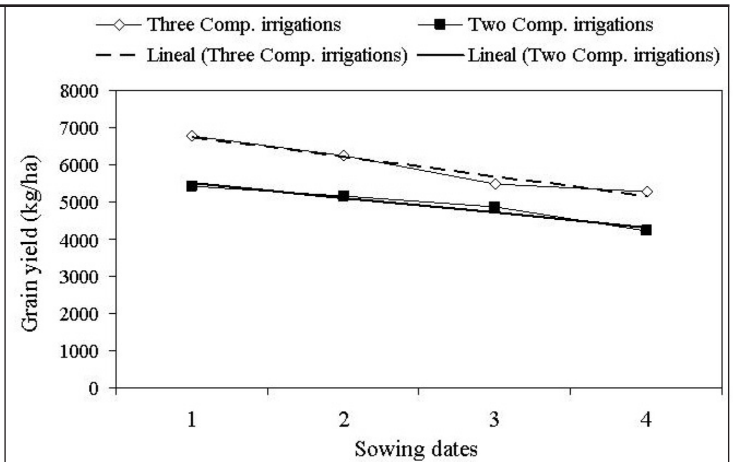

Fig. 5. Average grain yield in four sowing dates and the tendency wity two and three complementary irrigations of ten durum wheat advanced lines during the agricultural season 2006–07 at the Yaqui Valley Experimental Station, Sonora, Mexico.

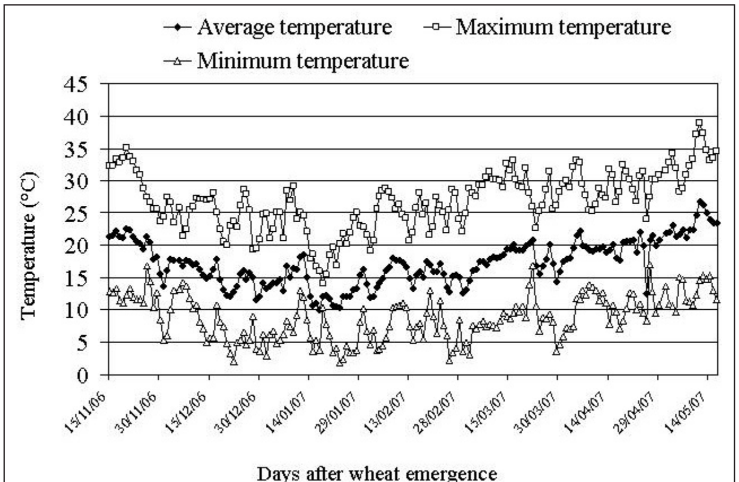

Fig. 6. Daily temperature recorded during the grain yield trial of ten durum wheat advanced lines during the agricultural season 2006–07 at the Yaqui Valley Experimental Station, Sonora, Mexico.

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