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Investigation note

Grain yield assessment of 55 triticale lines in the Mexicali Valley

José Luis Velasco-López[1,§]
Norma Angélica Ruiz-Torres[1]
Mayra Alejandra Sosa-Flores[1]
Carlos Enrique Aíl-Catzim[2]
Francisco Javier Sánchez-Ramírez[1]

1 Departamento de Fitomejoramiento-Universidad Autónoma Agraria Antonio Narro. Calzada Antonio Narro 1923, Buenavista, Saltillo, Coahuila, México. CP. 25315. Tel. 844 4110220. (n-nruiz@hotmail.com; mayras446@gmail.com; frajavsanram@gmail.com).

2 Instituto de Ciencias Agrícolas-Universidad Autónoma de Baja California. Carretera Delta s/n, Ejido Nuevo León, Mexicali, Baja California, México. CP. 21705. (carlos.ail@uabc.edu.mx).

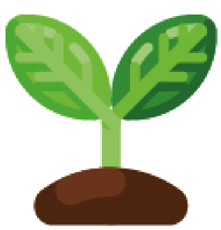
Autor para correspondencia: ljose1924@gmail.com.

Abstract

Triticale in the arid and semiarid regions of Mexico is postulated as an alternative crop to corn and wheat because it produces forage and grain of ideal quality for livestock feed, and the new varieties show grain yield potential similar to wheat. Therefore, this study aimed to evaluate the grain yield and its components in 55 advanced triticale lines in the Mexicali Valley during the autumn-winter 2015-2016 cycle under a randomized complete block design. The results showed 11 triticale lines with yields between 6.5 and 8.3 t ha^{-1}, which were higher than the control, which obtained 3.8 t ha^{-1}. Under the agroecological conditions of this study, it was determined that of the 55 triticale lines evaluated, 11 of them are considered to have grain yield potential since they outperformed the control.

Keywords:

forage, grain, indirect selection, yield components.



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In the arid zones of Mexico, low soil fertility and water availability are some of the limiting factors in the production of forage and grain for livestock feed (Ballesteros *et al*., 2015). In these regions, triticale is postulated as an alternative crop to corn and wheat because it produces forage and grain of ideal quality for feeding dairy and fattening cattle (Ballesteros *et al*., 2015).

Recent studies mention that triticale is used for feeding farm animals because it has between 10 and 20% higher protein content compared to wheat and has 0.13% and 0.04% more lysine and phosphorus compared to corn (García-Ramírez *et al*., 2023). Triticale represents an option for the preparation of products for human consumption, such as breads, cookies, tortillas, liquor, and beer, as an alternative to wheat, barley, and corn grains due to its high protein content and essential amino acids (Zhu, 2017).

From the agronomic point of view, the triticale crop presents adaptability to adverse drought conditions, low soil fertility, and resistance to diseases; in addition, the new varieties show grain yield potential similar to wheat, between 8 and 12.72 t ha^{-1} (Mellado *et al*., 2005). Nevertheless, the grain yield of triticale varieties is mainly defined by their genetics and the environmental conditions of the crop, so these factors affect the profitability and efficiency of triticale production (Lalević and Biberdžić, 2015).

Under the above context, field evaluation of triticale lines with diverse genetic bases is necessary to determine their productive potential; therefore, this study aimed to evaluate the grain yield and its components in 55 advanced triticale lines in the Mexicali Valley because this area is outstanding in the production of milk and beef cattle, where the outstanding lines would be used for the production of feed.

The study was carried out during the cycle of the fall-winter (A-W) 2015-2016 in the experimental field of the Institute of Agricultural Sciences of the Autonomous University of Baja California, in the ejido Nuevo León, Mexicali, Baja California, Mexico. Fifty-five triticale lines of spring growth habit were evaluated and a variety of triticale (Bicentennial TCL 2010) was used as a control; they were established in a randomized complete block design with two replications. Triticale materials were provided by the International Maize and Wheat Improvement Center (CIMMYT, for its acronym in Spanish) and the experimental plot consisted of four rows/plot, with row spacing of 0.3 m by 2 m long (2.4 m^2).

Sowing was carried out manually in dry and flat soil (December 19, 2015) with a density of 120 kg ha^{-1}, the fertilization was with the formula 120N-80P-00K, and four supplemental irrigations were applied during the phenological stages of tillering, stem elongation, flowering, and grain filling. The grain yield and its components were estimated for the evaluated lines; for this purpose, 2 m linear of plants were cut with a sickle in two central rows of each plot.

The yield components were estimated by randomly collecting 10 spikes from each plot, which had the following variables measured: spike length in cm (SL) and number of spikelets/spike (SS). Subsequently, the spikes were threshed individually and the remaining variables were measured: grains/spike (GS) and weight of grains/spike in g (WGS). The number of spikes m^{-2} (SM2) at the time of the harvest stage was also estimated, where the spikes were counted with two representative replications in a linear meter of two central rows of each of plot (Bendada, 2022).

Analyses of variance, comparison of means with Tukey's test (#= 0.05), and correlation analyses were performed for each of the variables recorded using the SAS 9.0 statistical package (SAS, 2002). The results of the analyses of variance showed significant differences (*p*# 0.01) between the triticale lines evaluated for grain yield and its components (spike m^2, spike length, spikelets/spike, grains/spike, and weight of grains/spike).

The average grain yield of the total triticale lines evaluated was 5 t ha^{-1} (Table 1). For the yield components, the average values in this study were 362 spikes m^{-2}, 28 spikelets $spike^{-1}$, 75 grains $spike^{-1}$, 10.9 cm in spike length and 3.3 g grains $spike^{-1}$ (Table 1).

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Table 1. Mean comparison tests of grain yield and its components in 55 triticale lines evaluated in the A-W 2015-2016 cycle in the Mexicali Valley, Baja California.

Line	GY	SM2	SS	GPS	SL	WGS
MX-13	8.3^{a}	575^{a}	28^{a-j}	91^{a-c}	10.4^{h-t}	3.3^{a-f}
MX-23	8^{a}	388^{a-g}	28^{a-j}	81^{a-i}	10.1^{j-t}	3.4^{a-f}
MX-53	7.5^{a-d}	550^{ab}	29^{a-h}	76^{a-k}	10.3^{i-t}	3^{a-f}
MX-12	7.5^{a-d}	515^{a-c}	27^{a-j}	74^{c-l}	9.9^{l-t}	2.9^{b-f}
MX-11	7.4^{a-d}	423^{a-g}	29^{a-i}	72^{d-l}	10.6^{f-s}	3.7^{a-f}
MX-24	7.2^{a-d}	438^{a-g}	28^{a-j}	80^{a-i}	10.6^{f-o}	3.3^{a-f}
MX-43	7.1^{a-d}	390^{a-g}	28^{a-j}	73^{c-l}	12^{a-i}	4.1^{a}
MX-49	6.8^{a-d}	358^{a-g}	27^{a-j}	83^{a-h}	10.5^{g-t}	3.6^{a-f}
MX-45	6.6^{a-d}	295^{c-g}	29^{a-i}	70^{e-l}	11.8^{a-k}	3.8^{a-d}
MX-52	6.6^{a-d}	370^{a-g}	27^{a-g}	77^{a-k}	12.1^{a-g}	3.5^{a-f}
MX-08	6.5^{a-d}	340^{c-g}	21^{k}	47^{m}	7.9^{u}	2.6^{f}
MX-21	6.4^{a-d}	430^{a-g}	27^{a-j}	75^{c-l}	11.4^{b-m}	3.2^{a-f}
MX-38	6.2^{a-d}	313^{c-g}	29^{a-i}	78^{a-k}	12.6^{a-c}	3.9^{a-c}
MX-17	6.1^{a-d}	383^{a-g}	27^{b-j}	75^{b-l}	10.4^{h-t}	3.5^{a-f}
MX-14	6^{a-d}	483^{a-e}	25^{f-k}	74^{c-l}	9.7^{m-t}	4^{ab}
MX-53	6^{a-d}	400^{a-g}	32^{a-c}	71^{e-l}	12^{a-i}	2.9^{b-f}
MX-18	5.9^{a-d}	473^{a-f}	27^{a-j}	95^{a}	11.4^{b-m}	3.8^{a-d}
MX-20	5.9^{a-d}	353^{a-g}	28^{a-j}	72^{d-l}	11^{c-p}	3.3^{a-f}
MX-25	5.9^{a-d}	480^{a-f}	32^{ab}	70^{e-l}	13.2^{a}	3.1^{a-f}
MX-39	5.9^{a-d}	378^{a-g}	28^{a-j}	78^{a-k}	12.2^{a-f}	2.9^{b-f}
MX-42	5.8^{a-d}	333^{c-g}	31^{a-e}	79^{a-j}	12.5^{a-d}	3.2^{a-f}
MX-06	5.6^{a-d}	500^{a-d}	28^{a-j}	63^{i-m}	10.8^{d-r}	3^{a-f}
MX-41	5.2^{a-d}	390^{a-g}	32^{ab}	90^{a-d}	13^{ab}	3.3^{a-f}
MX-34	5.2^{a-d}	270^{d-g}	25^{g-k}	77^{a-k}	9.5^{o-u}	3^{a-f}
MX-22	5.1^{a-d}	330^{b-g}	31^{a-e}	78^{a-k}	12.2^{a-f}	3.4^{a-f}
MX-36	5.1^{a-d}	358^{a-g}	27^{b-j}	66^{g-l}	9.3^{q-u}	2.8^{c-f}
MX-09	5^{a-d}	358^{a-g}	32^{a-d}	86^{a-f}	12^{a-i}	3.3^{a-f}
MX-40	5^{a-d}	290^{c-g}	27^{a-j}	78^{a-k}	10.3^{j-t}	3.1^{a-f}
GM	5	362	28	75	10.9	3.3
SD	1.5	78	2.3	9.2	1.2	0.4
Min	2.5	238	21	47	7.9	2.6
Max	8.3	575	32	95	13.2	4.1

Within each column, means with equal letters are not statistically different (Tukey, α= 0.05); GY= grain yield; SM2= spikes m^{-2}; SS= spikelets/spike; GPS= grains/spike; SL= spike length; WGS= weight of grains/spike; control= Bicentenario TCL 2010; GM= general mean; SD= standard deviation; Min= minimum value; Max= maximum value.

In the Tukey mean comparison tests, for the grain yield variable, 11 triticale lines were observed with yields ranging from 6.5 to 8.3 t ha^{-1}, which were higher than the control variety (Bicentenario TCL 2010), with a yield of 3.8 t ha^{-1} (Table 2). These results are within the range of what was reported by Güngör *et al*. (2022), who evaluated eight triticale genotypes and obtained yields of 4.1 to 9.1 t ha^{-1} in arid and semiarid regions of Turkey.

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Table 2. Mean comparison tests of grain yield and its components in 55 triticale lines evaluated in the A-W 2015-2016 cycle in the Mexicali Valley, Baja California.

Line	GY	SM2	SS	GPS	SL	WGS
MX-35	4.9^{a-d}	365^{a-g}	27^{a-j}	80^{a-i}	10.8^{d-r}	3.6^{a-f}
MX-07	4.9^{a-d}	368^{c-g}	27^{a-j}	61^{j-m}	9.6^{o-u}	3^{a-f}
MX-51	4.8^{a-d}	430^{a-g}	31^{a-e}	84^{a-g}	10.8^{d-r}	3.3^{a-f}
MX-02	4.7^{a-d}	465^{a-g}	25^{g-k}	73^{c-l}	9.2^{r-u}	3.2^{a-f}
MX-44	4.6^{a-d}	248^{fg}	28^{a-j}	75^{b-l}	11.4^{b-m}	3.4^{a-f}
MX-50	4.6^{a-d}	370^{a-g}	27^{c-j}	60^{k-m}	8.8^{tu}	3^{a-f}
MX-10	4.5^{a-d}	370^{a-g}	28^{a-j}	81^{a-i}	9.7^{n-t}	3^{a-f}
MX-15	4.3^{b-d}	298^{c-g}	29^{a-j}	72^{d-l}	11.7^{a-k}	3.3^{a-f}
MX-33	4.2^{b-d}	325^{c-g}	30^{a-f}	85^{a-g}	10.5^{g-t}	3.8^{a-e}
MX-37	4.2^{b-d}	325^{b-g}	26^{e-j}	70^{e-l}	10.3^{j-t}	3.5^{a-f}
MX-32	4.2^{b-d}	315^{c-g}	29^{a-i}	86^{a-e}	9.4^{p-u}	3.3^{a-f}
Testigo	3.8^{b-d}	290^{c-g}	26^{d-j}	85^{a-f}	12.1^{a-h}	3.3^{a-f}
MX-31	3.7^{b-d}	288^{c-g}	30^{a-g}	87^{a-e}	11^{c-q}	3.2^{a-f}
MX-19	3.7^{b-d}	363^{a-g}	28^{a-j}	73^{d-l}	11.8^{a-k}	2.7^{d-f}
MX-28	3.6^{b-d}	298^{c-g}	28^{a-j}	74^{c-l}	10.6^{f-s}	3.4^{a-f}
MX-48	3.6^{b-d}	365^{a-g}	30^{a-g}	75^{b-l}	12.2^{a-f}	3.1^{a-f}
MX-01	3.6^{b-d}	310^{c-g}	27^{a-j}	65^{h-m}	9.6^{o-u}	2.7^{d-f}
MX-46	3.5^{b-d}	283^{c-g}	29^{a-i}	87^{a-e}	12.2^{a-g}	4^{ab}
MX-29	3.4^{bcd}	310^{c-g}	24^{h-k}	70^{e-l}	11.4^{b-n}	3.1^{a-f}
MX-04	3.4^{b-d}	258^{e-g}	25^{g-k}	57^{lm}	12.4^{a-e}	2.9^{a-f}
MX-05	3.4^{b-d}	323^{b-g}	24^{i-k}	67^{f-l}	10.7^{e-s}	2.6^{ef}
MX-27	3.3^{cd}	345^{a-g}	28^{a-j}	66^{g-l}	9.1^{s-u}	2.7^{c-f}
MX-03	3.1^{d}	323^{b-g}	24^{jk}	79^{a-k}	10.3^{h-t}	3.3^{a-f}
MX-55	3.1^{d}	423^{a-g}	31^{a-e}	71^{d-l}	11.2^{c-o}	3.3^{a-f}
MX-26	3^{d}	248^{fg}	28^{a-j}	69^{e-l}	11.6^{b-l}	3^{a-f}
MX-30	2.9^{d}	253^{g}	32^{a}	94^{ab}	12.4^{a-e}	3.8^{a-d}
MX-16	2.9^{d}	238^{g}	27^{c-j}	64^{i-m}	10.4^{h-t}	3^{a-f}
MX-47	2.5^{d}	293^{c-g}	31^{a-f}	77^{a-k}	11.9^{a-j}	3.8^{a-d}

Within each column, means with equal letters are not statistically different (Tukey α= 0.05); GY= grain yield; SM2= spikes m2; SS= spikelets/spike; GPS= grains/spike; SL= spike length; WGS= weight of grains/spike.

In addition, the MX-13, MX-23, MX-53, and MX-12 lines, which have the highest yields with 8.3, 8, 7.5, and 7.5 t ha^{-1} (Table 1), respectively, have a similar genetic base, they share parents, such as Pollmer, which is a variety with yield potential of 10 t ha^{-1} under optimal irrigation and fertilization conditions (Hede, 2001).

The results of this study showed that the 11 triticale lines with grain yields greater than 6.5 t ha^{-1} can compete with the durum wheat yields produced in the Mexicali Valley, where Borbón *et al*. (2022) reported average yields of 6.3, 6.6, 6.6, and 6.9 t ha^{-1} of the main cultivated varieties, CIRNO C2008, CENEB Oro C2017, Quetchehueca Oro C2013 and Don Lupe Oro C2020, respectively. This place triticale as a cost-effective alternative to replace wheat grain or to be a complement in cattle feed without consequences for their growth and development (Gheorghe *et al*., 2022).

For the yields components, 40 triticale lines were found with values of 27 and 32 spikelets spike^{-1}; likewise, 31 lines were observed with values of 345 and 575 spikes m^{-2}, higher than the control

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with 26 spikelets spike^{-1} and 290 spikes m^{-2} (Table 1 y 2). The values observed are similar to those found in a study evaluating triticale genotypes conducted by Ramírez-Calderón *et al*. (2003), where 27.7 to 30.8 spikelets spike^{-1} were counted.

For the number of spikes m^{-2}, the results of this study are superior to those observed by Miranda-Domínguez *et al*. (2016), who reported 266 spikes m^{-2}. For the rest of the components, 23 superior lines were observed with values of 11.3 and 13.8 cm in spike length, 26 superior lines with values between 76 and 95 of grains spike^{-1}, 47 superior lines with values between 2.9 and 4 g of grains spike^{-1} (Table 1 y 2).

These lines were statistically equal to the control variety, which produced 12 cm spikes, with 85 grains spike^{-1} and 3.3 g of grains spike^{-1}. These values are similar to those recorded in studies evaluating triticale yield components conducted by Miranda-Domínguez *et al*. (2016); Güngör *et al*. (2022), where they found that the spike length ranged from 15 to 16.3 cm, number of grains spike^{-1} from 79.9 to 95.7 and weight of grains spike^{-1} from 2.6 to 3.8 g.

The correlation analyses showed that the spikes m^{-2} component has a significant and positive correlation with grain yield (r= 0.65**) unlike the rest of the components that did not show a significant correlation for this study. These results coincide with what was reported by Ramírez-Calderón *et al*. (2003), who observed a significant high correlation between the number of spikes m^{-2} and grain yield (r= 0.7**).

The correlation results showed that the spike m^{-2} component can be considered as an indirect selection criterion of triticale lines for grain yield, without leaving aside the environmental and interaction conditions since the yield components are mainly influenced by changes in the genetic composition of triticale materials in response to environmental and genetic-environmental interaction conditions (Lalević and Biberdžić, 2015; Oral, 2018; Güngör et al., 2022; Lalević et al., 2022)..

Conclusions

Under the agroecological conditions of this study, it was determined that of the 55 triticale lines evaluated, 11 have grain yield potential since they surpassed the control TCL 2010 Bicentennial and were also higher than the average durum wheat yield in the Mexicali Valley. It was observed that the yield component of spikes m^{-2} is the one that can contribute to indirect selection and increase the yield in triticale materials. The 11 selected triticale lines are potential candidates for grain production and are a viable alternative for feeding beef or dairy cattle in the Mexicali Valley.

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