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Yield components and protein content in two durum wheat (*Triticum durum*) varieties under an organic production system

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Abstract

This study evaluated the yield components and protein content of two durum wheat (Triticum durum) varieties, CIRNO C2008 and CENEB ORO C2017, cultivated under an organic production system. The results showed that CENEB ORO C2017 outperformed CIRNO C2008 in grain yield per hectare (7.117 t ha^{-1} vs. 6.075 t ha^{-1}), which was mainly attributed to its higher number of spikes per square meter (271 vs. 253) and greater number of grains per spike. Although CIRNO C2008 produced heavier grains (5.664 g) compared to CENEB ORO C2017 (4.829 g), the higher spike density in CENEB ORO C2017 compensated for this difference, resulting in a higher total yield. Regarding protein content, no significant differences were observed between the varieties (CIRNO C2008: 10.51% vs. CENEB ORO C2017: 10.01%). This suggests that, under an organic system, environmental and nutritional factors may play a key role in determining protein content. It was concluded that both varieties are suitable for cultivation under organic management; however, CIRNO C2008 is susceptible to leaf rust. A cost-benefit analysis is recommended to evaluate the feasibility of its use.

Keywords: Wheat; Organic agriculture; Yield components; Protein

1 Introduction

Wheat (Triticum aestivum L.) is one of the most important crops worldwide due to its contribution to food security and the supply of essential nutrients, representing one of the main grains cultivated globally and covering a substantial portion of human caloric and protein needs. Studies have shown that wheat is a key food in human diets and that both yield and grain quality are crucial for the sustainability of food chains in diverse agricultural contexts, including both organic and conventional production systems [1]. Recent reports indicate that Mexico produces millions of tons of wheat annually, with the main production regions being Sonora, Baja California, and Guanajuato, which concentrate most of the national output under irrigated conditions [2]. Wheat production in Mexico not only meets part of domestic consumption but also integrates into industrial value chains that generate added value in flour and derivative products, reflecting the strategic importance of this crop for the Mexican food economy [3].

Organic wheat production aims to implement cultivation methods that avoid synthetic inputs and promote soil health and biodiversity, which can significantly influence yield components and grain composition, including protein content. Research comparing wheat grown under organic management versus more intensive systems has reported notable differences: while cereal yields in organic systems are generally lower than in conventional systems, organic crops may exhibit differences in protein quality and other nutritional traits, depending on the variety and cultivation practices [4]. Several studies have reported lower yields under organic production compared to conventional [5, 6, 7 and 8], largely attributing the reduced output to the use of organic fertilizers with limited nitrogen availability or slow nitrogen release. However, comparative studies in maize have reported yields of 6.6 and 11.3 t ha^{-1} for organic and conventional management, respectively, with organic systems achieving 3.5% lower production costs and gross revenues exceeding conventional management by 71% [9]. Long-term organic maize studies have shown that, although initial yields were

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lower than conventional, over time yields equalized, and under extreme drought conditions, organic production surpassed conventional by more than 30% [10].

Yield components play a central role in determining final grain yield. In organic crops, these components can be affected by nutrient availability and crop management. For instance, studies on organically grown wheat have shown reduced yields compared to conventional systems, mainly due to lower mineral nitrogen availability, but also indicate that specific organic practices and appropriate fertility management can reduce this gap and improve overall grain yield and protein content [4].

Grain protein is a critical attribute for both nutritional quality and technological functionality. The protein composition of wheat grain, comprising different protein groups (gliadins, glutenins, albumins, and globulins), directly affects the rheological properties of flour and its suitability for baking and industrial processing [11]. Variations in protein content among varieties and production systems are common, with soil fertility, nitrogen availability, and climatic factors (such as temperature and water stress) significantly influencing both protein levels and yield components [12]. In organic systems, the interaction between nitrogen availability, crop management, and genetic characteristics of wheat varieties largely determines productive and grain quality outcomes. Experiments on wheat under organic management have shown that certain combinations of practices and varietal selection can improve protein content even when total yields do not increase, reflecting a complex balance between physiological and environmental factors that requires careful evaluation when comparing two durum wheat varieties under organic conditions [13].

In any agricultural region, the most important criteria for selecting a crop are yield and profitability. In the Yaqui Valley, Sonora, several studies on certified organic production have reported results comparable to conventional systems [14]. However, yield components and protein content in wheat under organic management have been less studied. Understanding how yield components and grain protein respond in two durum wheat varieties under an organic production system is essential for informed agronomic decision-making. This knowledge can aid in selecting suitable genetic materials, optimizing ecological management practices, and contributing to the sustainable production of high-quality wheat for regional and national markets, particularly in environmentally challenging areas such as southern Sonora, where agriculture faces water and resource limitations. The objective of this study was to evaluate the relationship between yield components and protein content in the production of two durum wheat varieties on a certified organic farm.

2 Material and methods

The present evaluation was conducted during the 2018–2019 fall-winter growing season at the Norman E. Borlaug Experimental Field of INIFAP, located in Block 910 of the Yaqui Valley, Sonora, at 27.36805° N and -109.92771° W, on a clay-textured soil. The site has a hot arid climate [BW(h)] with episodes of extreme heat, according to the Köppen classification modified by García [15]. The wheat varieties CENEB ORO C2017 [16, 17] and CIRNO C2008 [18] were established in a certified organic field [19, 20 and 21]. The field was prepared with three passes of a harrow to incorporate residues from the previous crop, followed by a leveling pass and furrowing at 0.80 m spacing. Fertilization was performed using 7.5 t ha^{-1} of chicken manure-based compost (BIDA) from novedades agricola's DASA [22], whose composition is described in Table 1. Sowing was carried out on December 14, 2018, in a double-row system with a 0.30 m row spacing. The experimental unit consisted of 12 rows, each 110 m long and spaced 0.80 m apart. In terms of pest management, two applications targeting aphids were performed using products based on garlic, cinnamon, and chili extracts [23]. Weed control consisted of one mechanical cultivation and two manual weedings. Irrigation included one pre-sowing application and three supplementary irrigations during the growing cycle. The harvest was conducted manually using a sickle. Samples from the useful plot were weighed and recorded as bundle weight (BW), spikes were counted (S), and the spikes were threshed using a stationary Pullman-type thresher. The obtained grain was manually cleaned to remove straw and glume residues, and the resulting wheat was recorded as grain weight (GW). One hundred grains from each cleaned sample were extracted and weighed.

Yield components were calculated using the following formulas: grains per square meter: grain/m^2= [(PG*100)/(weight 100 grain)]/0.8 m. The number of grains per spike was calculated using the following formula: grain/spike= (PG/PM)/(E). The following formula was used to calculate the number of spikes per square meter: spike/m^2=(E)/(0.8 m). Finally, to estimate yield per hectare, grain weight per square meter was used as the primary variable, applying the following formula: yield/ha=[(PG)/(0.8 m)]*10,000. To obtain yield in tons per hectare, the result was divided by 1,000. The relationships between yield components were analyzed using Microsoft Excel. The experimental design was a randomized complete block design with six replications.

Table 1 Guaranteed minimum composition of major and minor elements contained in the organic product Bida.

Guaranteed composition	**Content**
Nitrogen %	2-3
Phosphorus %	2-3
Potassium %	2-3
Sulfur %	0.5 - 1.5
Calcium %	6-8
Magnesium %	1 - 106
Iron %	0.4 - 1
Zinc ppm	400 - 700
Copper ppm	60 - 90
Manganese ppm	450 - 800
Boron ppm	40 - 100

3 Results and discussion

Statistical analysis revealed significant differences (P ≤ 0.05) for all variables evaluated, except for protein content. The highest yield was recorded for CENEB ORO 2017, which outperformed CIRNO C2008 by 17%. The yields of both varieties under certified organic farming were similar to those reported for conventional wheat at the regional and national levels at the time of this evaluation, 6.41 and 6.08 t ha^{-1}, respectively (SIAP, 2025). Regarding protein content, CIRNO C2008 exhibited 4.99% higher protein than CENEB ORO 2017.

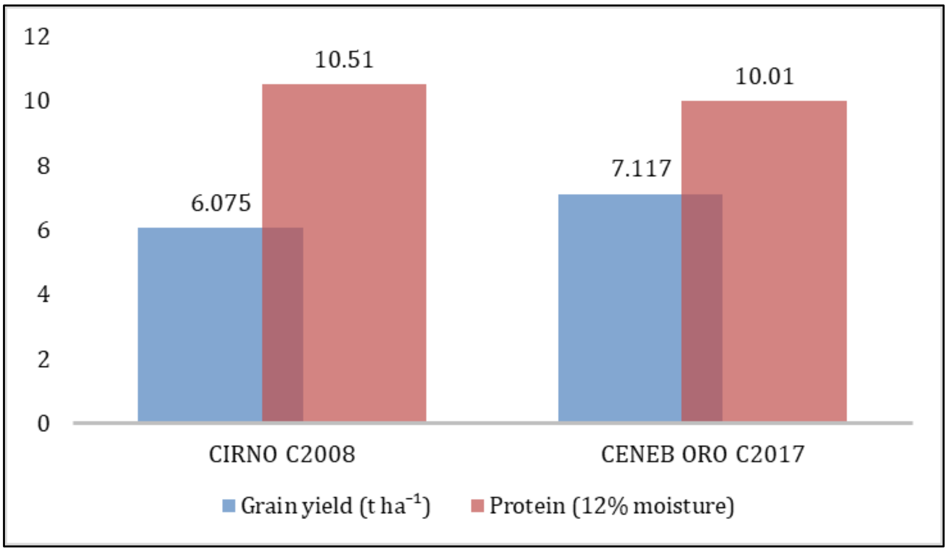

Figure 1 Wheat yield and protein content at 12% moisture in the varieties CIRNO C2008 and CENEB ORO C2017, established under certified organic production. CENEB-INIFAP, fall–winter cycle 2018–2019

The literature indicates that the relationship between yield and protein content is often negative or weak, as increases in yield per hectare tend to dilute protein content when nitrogen availability is limited, as commonly occurs in organic systems [24]. Recent studies have reported that protein content and grain yield can be genetically or physiologically uncoupled, depending on management practices and nutrient availability, particularly nitrogen, which explains why high yields do not always correspond to higher grain protein [25]. Similar results have been observed in previous years, where a negative correlation between wheat yield and protein content was reported; these studies also documented protein differences between varieties [26]. Management practices and environmental conditions tend to influence yield components more than protein content [27].

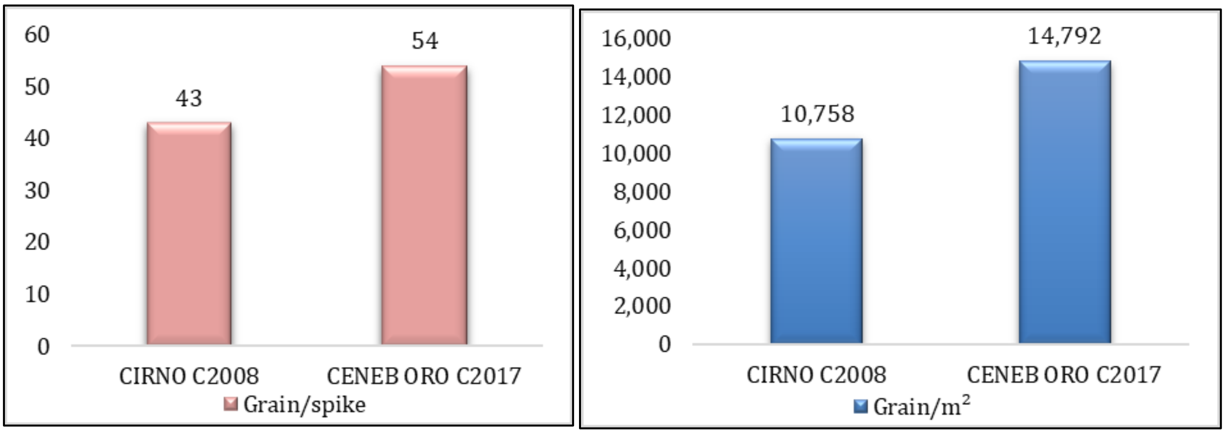

Figure 2 Left: number of grains per spike; right: grains per square meter of the varieties CIRNO C2008 and CENEB ORO 2007, evaluated under certified organic production. CENEB-INIFAP, fall–winter cycle 2018–2019

Regarding grain yield per square meter, the CENEB ORO C2017 variety exhibited a higher yield (0.455 kg/m^2) than CIRNO C2008 (0.389 kg/m^2). This result can be attributed to differences in the number of spikes and grains per spike: CENEB ORO C2017 showed more grains per spike and more spikes per square meter (Figure 2). Recent studies have found that the number of spikes and grains per unit area are critical components that explain much of the variation in wheat yield, especially under resource-limited conditions, such as in organic systems where nitrogen availability is lower and constrains individual grain filling [28]. Biomass per square meter was also higher in CENEB ORO C2017 (1.494 kg/m^2) compared to CIRNO C2008 (1.370 kg/m^2). This suggests that CENEB may allocate a greater proportion of resources to total dry matter production, which could be an advantage in organic systems where edaphoclimatic interactions and soil microbial nutrition determine resource use efficiency [27].

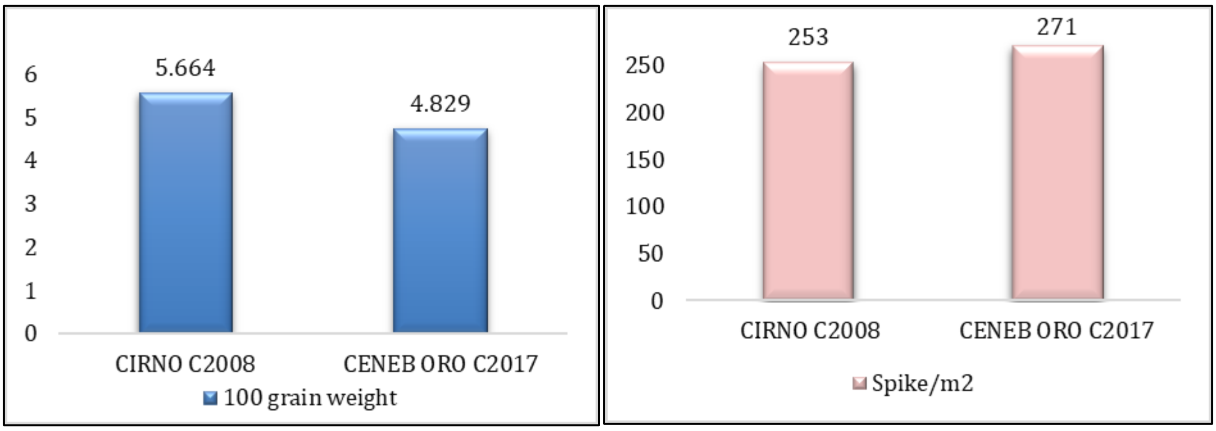

Figure 3 100-grain weight and spikes per square meter of the varieties CIRNO C2008 and CENEB ORO 2017, evaluated under certified organic production. CENEB-INIFAP, fall–winter cycle 2018–2019

The weight of 100 grains, a yield component reflecting grain size, was significantly higher in CIRNO C2008 (5.664 g) than in CENEB ORO C2017 (4.829 g). Results like these are consistent with studies showing physiological trade-offs between grain number and grain size in wheat, where an increase in one can lead to a reduction in the other when resources, particularly nitrogen and water, are limited [29].

Spike density per square meter is a key wheat yield component, as it determines the crop's capacity to produce grains per unit area. In this study, CENEB ORO C2017 presented 271 spikes m^{-2}, slightly higher than CIRNO C2008with 253 spikes m^{-2}. Although moderate, this difference contributes to CENEB ORO C2017 higher grain yield per hectare by increasing the number of reproductive units available for grain formation [1]. The literature indicates that even relatively small differences in spike number can translate into significant improvements in total yield, provided that grains can fill adequately [30]. In this case, although CIRNO C2008 produced heavier grains (5.664 g compared to 4.829 g in CENEB ORO 2017), the higher number of spikes in CENEB ORO C2017 partially compensated for the lower individual grain weight, resulting in a higher absolute yield. This illustrates the compensatory nature of yield components: an increase in spikes per area versus a reduction in grain weight [31].

Regarding the relationship between yield components and wheat grain yield, Table 2 shows that the component most strongly associated with yield is biomass per square meter. These results are consistent with several reports in the literature, which indicate that increases in wheat grain yield are often associated with increases in total biomass production [32, 33].

Table 2 Linear regression between yield components determined in two durum wheat varieties under organic management and grain yield. 2018–2019 season.

Component	**Regression equation**	**R^2**	**r**
CIRNO C2008			
Biomass/m^2	y= 4.5448x – 0.1495	0.9851	0.9925
Spikes/m^2	y= 0.0488x – 6.2620	0.7962	0.8923
Grains/spike	y= 0.2012x – 2.4329	0.9573	0.9784
Grains/m^2	y= 0.0005x + 0.7182	0.9615	0.9805
CENEB ORO C2017			
Biomass/m^2	y= 5.9499x – 1.7682	0.9867	0.9933
Spikes/m^2	y= 0.0763x – 13.577	0.8650	0.930
Grains/spike	y= 0.0450x + 4.3212	0.8288	0.9104
Grains/m^2	y= 0.0004x + 0.8824	0.9418	0.9705

The results observed in this study emphasize that yield components are not independent, but rather interrelated and often compensatory, as has been reported in other contexts of organic and multivarietal wheat [34]. Likewise, the stability of protein content between varieties under organic management suggests that grain nutritional quality may be more uniform than yield, which has important implications for the sustainable production of durum wheat in markets that value consistent grain quality [35]. Overall, these results indicate that varietal selection for organic production should consider both the yield component profile and the nutritional limitations of the system, aiming for a balance between yield and grain quality that optimizes productive efficiency without compromising essential nutritional quality. For the purposes of this evaluation, both varieties are suitable for organic farming; however, CIRNO C2008 has lost its resistance to leaf rust, making it advisable to perform a cost-benefit analysis to determine whether its cultivation is economically viable. To date, CIRNO C2008 remains the variety with the largest planted area in southern Sonora, as farmers prefer it despite its susceptibility to the aforementioned disease."

4 Conclusión

- CENEB ORO C2017 exhibited higher grain yield due to its greater spike density and number of grains per spike, confirming the importance of these components in wheat productivity.
- CIRNO C2008 showed higher 100-grain weight and higher grain protein content.
- Biomass per square meter was the component most strongly associated with grain yield.
- Both varieties are suitable for cultivation under organic management; however, CIRNO C2008 is susceptible to leaf rust. A cost-benefit analysis is recommended to evaluate the feasibility of its use.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that No conflict of interest.

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