



Advances in biology through agronomy, aquaculture, coastal and environmental sciences

— Volume II —

Leandri Argentel-Martínez
Ofelda Peñuelas-Rubio
Joe Luis Arias-Moscoso
Editors

Leandris Argentel-Martínez
Ofelda Peñuelas-Rubio
Joe Luis Arias-Moscoso
Editors

**Advances in biology through
agronomy, aquaculture, coastal and
environmental sciences**
Volume II



Pantanal Editora

2026

Copyright © Pantanal Editora

Editor-in-Chief: Dr. Alan Mario Zuffo

Executive Editors: Dr. Jorge González Aguilera and Dr. Bruno Rodrigues de Oliveira

Design: The editor. **Design and art:** The editor. **Cover and back cover images:** Editor(s). **Review:** Author(s), organizer(s), and editor(s).

Editorial Board

Academic degree and name

Prof. Dr. Adaylson Wagner Sousa de Vasconcelos
Profa. MSc. Adriana Flávia Neu
Profa. Dra. Albys Ferrer Dubois
Prof. Dr. Antonio Gasparetto Júnior
Profa. MSc. Aris Verdecia Peña
Profa. Arisleidis Chapman Verdecia
Prof. Dr. Arinaldo Pereira da Silva
Prof. Dr. Bruno Gomes de Araújo
Prof. Dr. Caio Cesar Enside de Abreu
Prof. Dr. Carlos Nick
Prof. Dr. Claudio Silveira Maia
Prof. Dr. Cleberton Correia Santos
Prof. Dr. Cristiano Pereira da Silva
Profa. Ma. Dayse Rodrigues dos Santos
Prof. MSc. David Chacon Alvarez
Prof. Dr. Denis Silva Nogueira
Profa. Dra. Denise Silva Nogueira
Profa. Dra. Dennyura Oliveira Galvão
Prof. Dr. Elias Rocha Gonçalves
Prof. Me. Ernane Rosa Martins
Prof. Dr. Fábio Steiner
Prof. Dr. Fabiano dos Santos Souza
Prof. Dr. Gabriel Andres Tafur Gomez
Prof. Dr. Hebert Hernán Soto Gonzáles
Prof. Dr. Hudson do Vale de Oliveira
Prof. MSc. Javier Revilla Armesto
Prof. MSc. João Camilo Sevilla
Prof. Dr. José Luis Soto Gonzales
Prof. Dr. Julio Cezar Uzinski
Prof. MSc. Lucas R. Oliveira
Prof. Dr. Luciano Façanha Marques
Profa. Dra. Keyla Christina Almeida Portela
Prof. Dr. Leandris Argentele-Martínez
Profa. MSc. Lidiene Jaqueline de Souza Costa Marchesan
Prof. Dr. Marco Aurélio Kistemann
Prof. MSc. Marcos Pisarski Júnior
Prof. Dr. Marcos Pereira dos Santos
Prof. Dr. Mario Rodrigo Esparza Mantilla
Profa. MSc. Mary Jose Almeida Pereira
Profa. MSc. Núbia Flávia Oliveira Mendes
Profa. MSc. Nila Luciana Vilhena Madureira
Profa. Dra. Patrícia Maurer
Profa. Dra. Queila Pahim da Silva
Prof. Dr. Rafael Chapman Auty
Prof. Dr. Rafael Felipe Ratke
Prof. Dr. Raphael Reis da Silva
Prof. Dr. Renato Jaqueto Goes
Prof. Dr. Ricardo Alves de Araújo (*In Memoriam*)
Profa. Dra. Sylvana Karla da Silva de Lemos Santos
Prof. Dr. Tayronne de Almeida Rodrigues
Prof. Dr. Ugur Azizoglu
Prof. Dr. Wéverson Lima Fonseca
Prof. MSc. Wesclen Vilar Nogueira
Profa. Dra. Yilan Fung Boix
Prof. Dr. Willian Douglas Guilherme

Institution

OAB/PB
Mun. Faxinal Soturno e Tupanciretã
UO (Cuba)
IF SUDESTE MG
Facultad de Medicina (Cuba)
ISCM (Cuba)
UFESSPA
UEA
UNEMAT
UFV
AJES
UFGD
UEMS
IFPA
UNICENTRO
IFMT
UFMG
URCA
ISEPAM-FAETEC
IFG
UEMS
UFF
(Colômbia)
UNAM (Peru)
IFRR
UCG (México)
Rede Municipal de Niterói (RJ)
UNMSM (Peru)
UFMT
SED Mato Grosso do Sul
UEMA
IFPR
Tec-NM (México)
Consultório em Santa Maria
UFJF
UEG
FAQ
UNAM (Peru)
SEDUC/PA
IFB
IFPA
UNIPAMPA
IFB
UO (Cuba)
UFMS
UFPI
UFG
UEMA
IFB
Sec. Mun. de Educação, Cultura e Tecnologia de Araripe
Universidade Kayseri, Türkiye
UFPI
FURG
UO (Cuba)
UFT

Scientific and Technical Council
- Esp. Joacir Mário Zuffo Júnior
- Esp. Maurício Amormino Júnior
- Lda. Rosalina Eufrausino Lustosa Zuffo

Catalog sheet

Cataloging in publication
Prepared by a Librarian Janaina Ramos – CRB-8/9166

A244

Advances in biology through agronomy, aquaculture, coastal and environmental sciences - Volume II /
Editors Leandris Argente-Martínez, Ofelda Peñuelas-Rubio, Joe Luis Arias-Moscoso. – Nova
Xavantina-MT: Pantanal, 2026.
362p. ; il.

Book in PDF format

ISBN 978-65-85756-79-2

DOI <https://doi.org/10.46420/9786585756792>

1. Biology. 2. Agronomy. 3. Aquaculture. 4. Environmental sciences. I. Argente-Martínez, Leandris
(Editor). II. Peñuelas-Rubio, Ofelda (Editor). III. Arias-Moscoso, Joe Luis (Editor). IV. Title.

CDD 570

Index to systematic catalog

I. Biology



Our ebooks are free and publicly accessible, downloadable, and shareable, but we ask that proper credit be given to Pantanal Editora, as well as to the organizers and authors. However, the use of ebooks for commercial purposes is not permitted without the express authorization of the authors and the agreement of Pantanal Editora.

Pantanal Editora

Rua Abaete, 83, Sala B, Centro. CEP: 78690-000.
Nova Xavantina – Mato Grosso – Brasil.
Telefone (66) 99682-4165 (Whatsapp).
<https://www.editorapantanal.com.br>
contato@editorapantanal.com.br

Advances in Biology through Agronomy, Aquaculture, Coastal and Environmental Sciences, Volume II, is an e-book that continues the work of the first version (<https://editorapantanal.com.br/ebooks/2023/advances-in-biology-through-agronomy-aquaculture-coastal-and-environmental-sciences/ebook.pdf>), published in 2023 by Leandris Argente!-Martínez and Ofelda Peñuelas-Rubio.

Our e-book compiles 25 manuscripts that present scientific results and reviews based on biological aspects. All of them contribute to explaining the responses of living organisms to agricultural, aquaculture, and coastal ecosystems, as well as those facing fragility or threat of climate change. This e-book was edited by Leandris Argente!-Martínez, Ofelda Peñuelas-Rubio, and Joe Luis Arias-Mosc!so, members of the Consolidated Academic Group ITVAYA-CA-3.

We appreciate the contribution of all authors for their careful attention to the editorial committee's recommendations. The review process was double-blind and conducted by internationally renowned researchers.

Special thanks to the members of the BioSecuraNet International Network for Biotechnology and Innovative Strategies for Global Food Security at the National Technological Institute of Mexico.

The Editors

Prologue	4
Agronomy	
Chapter 1	9
The reduction in chemical fertilization combined with PGPM under a controlled deficit irrigation system for maize	
Chapter 2	22
Effects of sowing date and size on the physical and physiological quality of bread wheat seeds in southern Sonora, Mexico	
Chapter 3	35
Morphophysiological response and yield of tomato (<i>Solanum lycopersicum</i> L.) to growth regulators and glutamic acid	
Chapter 4	49
Influence of benzoxazinoid metabolites in maize roots interacting with diverse microbes	
Chapter 5	64
Comparison of RGB spectrum vegetation indices to estimate agronomic variables in wheat and oats	
Chapter 6	74
Alleviation of saline stress in maize and peanut plants induced by <i>Bacillus aryabhattai</i> strain CMAA 1363	
Chapter 7	92
Bacterial consortia as a sustainable strategy for disease management and productivity improvement in maize	
Chapter 8	109
Agronomic management for oat seed production in the Bajío region, Mexico	
Chapter 9	125
Risk factors in loading and unloading operations of agricultural products in land transport units at a company in Veracruz, Mexico	
Chapter 10	145
Physicochemical characterization of four varieties of durum wheat (<i>Triticum durum</i> Desf.) under full irrigation and reduced irrigation conditions	
Chapter 11	161
Antifungal activity of edible chitosan coatings and <i>Coriandrum sativum</i> L. essential oil against <i>Colletotrichum gloeosporioides</i> and their application on mango fruits	
Chapter 12	175
Agricultural gypsum with micronutrients in citrus cultivation	
Chapter 13	186

Initial Agronomic Adaptation of *Stevia rebaudiana* Bertoni in the High Mountain Region of Veracruz and Sustainable Management of *Planococcus citri* Using a Neem-Based Bioinsecticide

Chapter 14 197

Evaluation of yield components of two F1 maize hybrids under controlled deficit irrigation in a moderately saline vertisol soil in Yaqui Valley, Sonora, Mexico

Aquaculture

Chapter 15 207

Effects of partially replacing fish meal with mesquite pod meal (*Prosopis juliflora*) on the growth of Nile tilapia (*Oreochromis niloticus*)

Chapter 16 220

Consumer preferences and value-added opportunities in the commercialization of *Oreochromis niloticus* in Tenosique, Tabasco, México

Chapter 17 228

Partial substitution of pechita (*Prosopis glandulosa*) and alfalfa (*Medicago sativa*) flour with commercial flour in diets for tilapia (*Oreochromis niloticus*) farming

Chapter 18 239

Hydrolysate of the alga *Spirulina* influences the proliferation, growth, and development of *Spathiphyllum uxpanapense* *in vitro*

Chapter 19 251

Growth of the wild juvenile common snook *Centropomus undecimalis* in captivity

Coastal Sciences

Chapter 20 260

Notes on the recreational fishing of snook (*Centropomus* spp.) in the coastal zone of Centla, Tabasco, Mexico

Chapter 21 268

Linkage among climatic variation and artisanal fisheries behavior of common snook (*Centropomus undecimalis*) in tropical Atlantic coast

Environmental Sciences

Chapter 22 277

Fungal-based arsenic bioremediation: linking enzymatic detoxification mechanisms with bioreactor engineering

Chapter 23 292

Simplified dynamic modeling for scenario analysis of the anaerobic digestion of fruit and vegetable waste

Chapter 24 303

Impact of biofertilizers on wheat (*Triticum aestivum* L.) yield in different environments of the Bajío region of Guanajuato

Chapter 25 326

Genomic Reprogramming and Epigenetic Memory: Transforming Somaclonal Variation into a Tool for Climate Resilience

Chapter 26	351
Research on the use of rhizobacteria for the biodegradation of herbicides and insecticides in agriculture and their effects on environmental protection	
Index	360
About the editors	362

Physicochemical characterization of four varieties of durum wheat (*Triticum durum* Desf.) under full irrigation and reduced irrigation conditions

Received em: 11/04/2026

Accepted em: 29/04/2026

doi 10.46420/9786585756792cap10

Joe Luis Arias-Moscoso¹ Francisco Cadena-Cadena^{1*} Leandris Argente-Martinez¹ Ofelda Peñuelas-Rubio¹ Alba Rocio Ochoa-Meza¹ Isabel Francisca Osua-Acosta¹ Odilia Azucena Higuera-Barraza¹ Nydia Estrellita Buitimea-Cantua² Gabriela Chavez-Villalva³ Elisa Magaña-Barajas⁴ 

ABSTRACT

In this study, the effect of reduced irrigation (RI) on durum wheat quality under semiarid conditions was assessed, considering genotype–water availability interactions. Four varieties (Isabel Oro, Don Lupe, Norocoro C2021, and Bayoyeca) were evaluated under full irrigation (FI) and RI using an integrated physicochemical, rheological, and color analysis. Moderate water deficit significantly altered grain composition: protein content increased across all varieties (e.g., Isabel Oro: 11.36→14.33%; Don Lupe: 11.24→14.33%), as did ash and lipid contents. Conversely, the hectoliter weight decreased in all the varieties (e.g., Bayoyeca: 82.96→77.83 kg hL⁻¹), whereas the thousand-kernel weight slightly increased. Rheologically, the RI increased wet and dry gluten (Isabel Oro: 28.50→32.97% and 9.63→11.27%, respectively) and dough stability (Don Lupe: 10.9→12.4 min), although the gluten index exhibited genotype-dependent responses (decreasing in Bayoyeca; stable in Isabel Oro). The color parameters showed minor changes in lightness (L*) and yellowness (b*). Multivariate analysis confirmed clear treatment–genotype differentiation. Overall, the RI improved the technological quality attributes (protein, gluten, and stability) at the expense of physical grain traits. Don Lupe and Isabel Oro demonstrated superior stability under water-limited conditions, highlighting their agronomic potential in semiarid environments.

Keywords: Reduced irrigation, water stress; wheat quality; gluten; rheological properties

¹ Tecnológico Nacional de México / Instituto Tecnológico del Valle del Yaqui, Bácum, Sonora, México.

² Departamento de Investigación y posgrado en alimentos, Universidad de Sonora

³ Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), Campo Experimental Norman E. Borlaug

⁴ Universidad Estatal de Sonora, Av. Ley Federal del Trabajo y Perimetral S/N, 83100. Hermosillo Sonora México.

*Corresponding author: fcadena.cadena@itvy.edu.mx

INTRODUCTION

Wheat production in arid and semiarid regions faces increasing pressure because of limited water availability, highlighting the need to optimize irrigation management without compromising yield or grain quality. In these systems, water stress not only affects productivity but also significantly alters the physicochemical composition and technological properties of wheat, which are critical for its industrial use (Buenrostro-Rodríguez et al., 2024; Yudewitz-Pohl, 2025). In particular, variables such as protein content, gluten quality, and sedimentation parameters are closely related to flour functionality, whereas characteristics such as hectoliter weight and ash content provide information on grain health, grain filling, and commercial value (Schuster et al., 2023; Yousuf et al., 2025).

Several studies have shown that the response of wheat to water stress depends largely on its genotype, highlighting the importance of evaluating specific varieties under controlled irrigation conditions. In this context, identifying materials with stable technological quality under stress conditions is a key strategy for sustaining production in scenarios of climate variability. Furthermore, the joint analysis of multiple variables allows for a better understanding of adaptation mechanisms and environment-induced changes in grain quality (Cadena-Cadena et al., 2025; Zhang et al., 2026).

In Mexico, wheat occupies a strategic position in both the food and economic spheres, as it constitutes one of the main sources of nutrients in the population's diet, second only to crops such as corn and beans (Palacios-Rojas et al., 2020). Its production is concentrated mainly in the North–Northwest and Bajío regions, where agroclimatic conditions favor its growth (Sharma et al., 2025). The state of Sonora stands out as the leading producer nationwide, accounting for more than half of the total production in recent years (SIAP, 2024). This leadership is attributed to the availability of fertile soils, suitable climatic conditions, the intensive use of agricultural technology, and the support of public policies geared toward the sector. Within this region, areas such as the Yaqui Valley represent highly significant production hubs because of their particularly favorable cultivation characteristics (Valenzuela-Antelo et al., 2018). However, despite these advantages, wheat faces significant challenges associated with increasing water scarcity, which increases its vulnerability to water stress conditions (Buenrostro-Rodríguez et al., 2022).

Wheat yield performance is typically analyzed on the basis of variables such as spike density, the number of grains per spike, and grain size. However, the evaluation of its physicochemical properties is often overlooked (Vincke et al., 2022). Wheat quality is determined by its nutritional composition and functional characteristics, including sensory attributes such as color, flavor, and aroma. Similarly, variations in protein, fiber, and mineral contents under different cropping systems are of great interest to the food industry and nutrition programs. Factors such as nutrient deficiency, soil acidity, and drought negatively affect both productivity and grain quality (Zeibig et al., 2022). Therefore, it is essential to characterize components such as proteins, carbohydrates, and minerals in grains produced under

different environmental conditions to optimize their nutritional value and health impact (Poole et al., 2021). This study posits that withholding irrigation during the final grain-filling stage causes changes in chemical composition, which could result in decreases in both yield and grain quality. Given the variability among genotypes in terms of their response to water deficit, restricted irrigation management is a useful strategy for evaluating stress tolerance and optimizing water use without compromising crop protein quality.

MATERIALS AND METHODS

Experimental site and conditions

In this study, four wheat varieties were evaluated, namely, Isabel Oro, Don Lupe, Norocoro C2021, and Bayoyeca, which were subjected to two contrasting water availability conditions: full irrigation and reduced irrigation. On the basis of this experimental design, eight treatments (M1–M8) were established, allowing for the analysis of both the individual effect of the genotype and the interaction between variety and the irrigation regime. This experimental approach facilitates the identification of distinct response patterns, as well as the detection of potential comparative advantages among varieties under stress conditions.

Proximate Chemical Analysis

Quantitative analyses were performed using standardized procedures of the Association of Official Analytical Chemists AOAC (2000).

Moisture Content

The moisture content of the food sample was determined following the protocol established in the AOAC method 950.46. Briefly, the sample was placed in a forced-air oven set at 105 °C and dried for 4–5 hours until water removal was achieved. After drying, the moisture percentage was calculated from the difference in sample weight before and after the process, and the appropriate equation was applied.

$$\text{Moisture Content (\%)} = \frac{\text{Weight loss}}{\text{Starting weight}} \times 100$$

Total ash

Approximately 3 g of the powdered sample was weighed into individual crucibles and incinerated at 550 °C for 6 hours. Following combustion, the crucibles were placed in a desiccator to cool and avoid moisture uptake and then weighed to determine the ash content.

$$\text{Total ashes (\%)} = \frac{W - Z}{N} \times 100$$

where **W** represents the combined weight of the crucible and ash residue, **Z** corresponds to the weight of the empty crucible, and **N** indicates the initial weight of the sample.

Determination of Lipids

The crude fat content of the powdered sample was determined using the Soxhlet extraction method in accordance with AOAC Method 920.39 (2000), employing petroleum ether as the solvent. Approximately 3.0 g of sample was placed in prelabeled extraction thimbles and subjected to continuous extraction in a Soxhlet system for 24 hours. Upon completion, the solvent was evaporated, and the extraction flask was cooled prior to weighing to quantify the recovered lipid fraction.

$$\text{Lipids (\%)} = \frac{\text{Weight of lipids}}{\text{Sample weight}} \times 100$$

Crude protein analysis

The crude protein content was determined by the micro-Kjeldahl method following AOAC 1990.04. A 0.15 g flour sample was digested with concentrated sulfuric acid and a catalyst until a clear solution was obtained. After dilution, the digest was distilled with 30% NaOH to release ammonia, which was collected in 2% boric acid with a methyl red indicator. The trapped ammonia was titrated with 0.1 N HCl to the endpoint. A blank was included, and the nitrogen content was calculated using the corresponding equation.

$$\text{Protein (\%)} = \frac{(\text{N of HCl})(\text{Volume of HCl used})(1.4 \text{ g/mol})(6.5)}{\text{Sample grams}}$$

Analysis of Crude Fiber

The crude fiber content was determined according to the standard procedures described by AOAC (2000). A known quantity of the sample was subjected to sequential acid and alkaline digestion to remove soluble materials. The remaining residue was filtered, thoroughly washed, dried, and weighed. The dried residue was subsequently incinerated at high temperature, and the weight loss after ashing was used to estimate the crude fiber content.

SDS-Sedimentation (mL)

Sodium dodecyl sulfate (SDS) sedimentation tests were conducted to evaluate the sedimentation capacity of flour proteins as an indicator of gluten quality. For this analysis, 1.0 g of flour sample, adjusted to a 14% moisture basis, was accurately weighed and transferred into a graduated sedimentation tube. Afterward, 10 mL of distilled water was added, and the tube was shaken vigorously to obtain a uniform suspension.

SDS Index (SDS/PROT)

After the sample was completely dispersed, 10 mL of SDS–lactic acid solution was added to the mixture. The tube was shaken for a standardized period to ensure proper interaction between the proteins and the reagent. The suspension was then allowed to stand undisturbed at room temperature for 20 minutes to allow sedimentation. At the end of the resting period, the sedimentation volume was recorded directly from the graduated scale of the tube and expressed in milliliters (mL).

The SDS sedimentation index (SDS/PROT) was calculated to standardize the sedimentation values according to the protein content of the flour samples. This index was obtained by dividing the SDS sedimentation volume (mL) by the crude protein content (%) previously determined using the micro-Kjeldahl method. The SDS index was calculated using the following equation:

$$SDS/PROT = \text{SDS sedimentation value (mL)} / \text{Protein content (\%)}$$

The resulting value was expressed as millilitres per percentage of protein (mL/% protein), providing a normalized indicator of protein quality and gluten strength.

Wet gluten (%)

The wet gluten content was determined to evaluate the quantity of gluten-forming proteins present in the flour samples. For this analysis, 10 g of flour sample was accurately weighed and placed into a gluten-washing apparatus. Distilled water was added to form a dough, which was subsequently allowed to rest for a short period to ensure complete hydration of the proteins.

After the resting stage, the dough was washed under a continuous flow of water to remove starch and soluble components, leaving only the gluten network. The washing process continued until the wash water became clear, indicating the complete removal of nongluten materials. The remaining gluten mass was collected and weighed immediately. The wet gluten content was expressed as a percentage of the original sample weight using the corresponding equation (AACC, 2025; Coca Cadena, 1998).

$$\text{Wet Gluten (\%)} = \frac{\text{Weight of flour sample (g)}}{\text{Weight of wet gluten (g)}} \times 100$$

where Weight of wet gluten = weight of the wet gluten obtained (g) and Weight of flour sample = initial weight of the sample (g).

Dry gluten (%)

Metodología para Dry Gluten (%)

The dry gluten content was determined by drying the previously obtained wet gluten residue. The wet gluten sample was placed in a drying oven maintained at 105 °C and heated until a constant weight was achieved.

After drying, the sample was allowed to cool in a desiccator to prevent moisture absorption from the environment. The dried gluten residue was then weighed, and the dry gluten percentage was calculated on the basis of the initial sample weight using the appropriate equation (AACC, 2025).

$$\text{Dry Gluten (\%)} = \frac{\text{Weight of flour sample (g)}}{\text{Weight of dry gluten (g)}} \times 100$$

where Weight of dry gluten = weight of dry gluten after drying (g) and Weight of flour sample = initial weight of the sample (g).

Gluten Index (%)

The gluten index was determined to assess the strength and quality of the gluten network. The wet gluten obtained from the washing process was placed into a standardized centrifuge chamber equipped with a sieve. The sample was centrifuged under controlled conditions for a specified period.

Following centrifugation, the portion of gluten retained on the sieve was weighed, along with the total wet gluten weight. The gluten index was calculated as the percentage of gluten remaining on the sieve relative to the total wet gluten mass using the equation provided below. The results are expressed as a percentage (%), which represents the resistance of gluten to mechanical stress (AACC, 2025).

$$\text{Gluten Index (\%)} = \frac{\text{Total wet gluten weight (g)}}{\text{Weight of gluten retained on sieve (g)}} \times 100$$

where Weight of gluten retained on the sieve = gluten remaining on the sieve after centrifugation (g) and Total wet gluten weight = total weight of wet gluten before centrifugation (g).

Statistical Analysis

Data were expressed as mean $\pm$ standard deviation. Statistical analyses were performed using a completely randomized factorial design (4×2), including four wheat varieties and two irrigation regimes. A two-way analysis of variance (ANOVA) was conducted to determine the effects of variety, irrigation regime, and their interaction. When significant differences were observed, means were compared using Tukey's test at $p \leq 0.05$. Multivariate analyses, including principal component analysis (PCA) and hierarchical clustering, were performed to explore the relationships among variables. All analyses were performed using IBM SPSS Statistics (version 22).

RESULTS AND DISCUSSION

A complete analysis of the wheat varieties evaluated under full-irrigation (RC) and reduced-irrigation (RR) conditions revealed different effects of genotype and water regime on the physical, chemical, rheological, and color properties of the grain. A consistent trend associated with moderate water stress (RR) was observed, particularly for variables related to component concentration and gluten quality.

Physicochemical properties of the grain

Thousand-kernel weight (TKW) showed moderate variation among the varieties, with values ranging from 77.8 to 80.2 g. Under RR conditions, a trend toward increased TKW was observed in all the varieties studied (Isabel Oro, 80.2 g; Don Lupe, 79.8 g) (Table 1). This behavior could be explained by reduced intraspike competition under water stress, which favors grain filling in a relatively small number of reproductive structures. However, this increase is not always consistent in the literature, where water stress frequently reduces grain size depending on its severity and timing. Pradeep et al. (2024) reported high genotypic variability in wheat varieties in terms of the contribution of spikes and awns to yield under stress.

Hectoliter weight (HW) showed the opposite trend, decreasing significantly under water stress in all the varieties. For example, Isabel Oro decreased from 81.56 to 78.53 kg hL⁻¹, whereas Bayoveca decreased from 82.96 to 77.83 kg hL⁻¹. This decrease suggests lower grain density, possibly associated with an alteration in endosperm compaction, a common phenomenon under water stress conditions. Water stress affects growth and photosynthesis through oxidative stress and physiological alterations. Morphological, osmotic, and molecular mechanisms, along with nutrients and hormonal regulators, contribute to drought tolerance. pH is a key indicator of commercial quality; therefore, this reduction may have negative implications for the industrial grading of the grain (Jain et al., 2019).

Proximate composition

The moisture content did not significantly differ among the treatments and remained within a narrow range (≈ 9 – 10%). This finding indicates that postharvest conditions or the hygroscopic equilibrium of the grain were homogeneous, allowing for reliable comparisons on a dry basis; similar results were obtained for other wheat varieties planted under similar conditions (Cadena-Cadena et al., 2025).

The ash content increased under RR in all the varieties. For example, Don Lupe increased from 1.34% to 1.64%, and Norocoro C2021 increased from 1.34% to 1.62%. This pattern suggests a higher concentration of minerals, possibly due to a reduced dilution effect under conditions of lower starch accumulation (Moreira et al., 2025).

Table 1. Grain quality parameters of durum wheat under different irrigation conditions.

Sample	Irrigation Type	Weight of 1000 grains (g)	Test WT (kg/hl)	Moisture	Ash	Fat (%)	Fiber	Protein
Isabel oro	RC	78.5 $\pm$ 0.67	81.56 $\pm$ 0.26 ^b	9.37 $\pm$ 0.61 ^a	1.34 $\pm$ 0.11 ^a	1.78 $\pm$ 0.22 ^a	2.66 $\pm$ 0.19 ^a	11.36 $\pm$ 1.09 ^a
	RR	80.2 $\pm$ 0.58	78.53 $\pm$ 0.51 ^a	10.32 $\pm$ 0.60 ^a	1.63 $\pm$ 0.08 ^a	2.19 $\pm$ 0.21 ^{bc}	2.9 $\pm$ 0.65 ^a	14.33 $\pm$ 0.54 ^b
Don lupe	RC	77.8 $\pm$ 0.72	81.26 $\pm$ 0.68 ^b	9.3 $\pm$ 0.48 ^a	1.34 $\pm$ 0.11 ^a	1.75 $\pm$ 0.31 ^a	3.22 $\pm$ 0.65 ^a	11.24 $\pm$ 1.02 ^a
	RR	79.8 $\pm$ 0.61	78.36 $\pm$ 0.76 ^a	9.66 $\pm$ 0.66 ^a	1.64 $\pm$ 0.07 ^a	2.15 $\pm$ 0.69 ^c	3.01 $\pm$ 0.37 ^a	14.33 $\pm$ 0.55 ^b
Bayoyeca	RC	79.2 $\pm$ 0.85	82.96 $\pm$ 0.54 ^b	9.03 $\pm$ 1.50 ^a	1.55 $\pm$ 0.16 ^a	1.85 $\pm$ 0.28 ^{ab}	2.63 $\pm$ 0.27 ^a	13.34 $\pm$ 0.57 ^a
	RR	80 $\pm$ 0.77	77.83 $\pm$ 0.17 ^a	8.8 $\pm$ 0.87 ^a	1.45 $\pm$ 0.08 ^a	1.8 $\pm$ 0.33 ^a	2.76 $\pm$ 0.36 ^a	14.56 $\pm$ 1.47 ^b
Norocoro	RC	81.54 $\pm$ 0.59	81.86 $\pm$ 0.69 ^b	9.41 $\pm$ 1.82 ^a	1.34 $\pm$ 0.03 ^a	1.75 $\pm$ 0.66 ^a	2.48 $\pm$ 0.31 ^a	13.02 $\pm$ 0.59 ^a
C2021	RR	78.5 $\pm$ 0.67	77.13 $\pm$ 0.58 ^a	10.14 $\pm$ 0.46 ^a	1.62 $\pm$ 0.09 ^a	2.19 $\pm$ 0.78 ^{bc}	3.56 $\pm$ 0.75 ^a	14.34 $\pm$ 1.32 ^b

* Different lowercase letters within the same column indicate significant differences according to Tukey's test ($p \leq 0.05$).

Crude fat also increased under RR conditions, with values increasing from approximately 1.75–1.85% under RC to 2.15–2.19% under RR. This increase could be related to metabolic adaptations of the grain in response to stress, where lipids play a role in the stability of cell membranes (Moreira et al., 2025). The fiber content did not clearly vary, although in some cases, such as Norocoro C2021, an increase was observed (from 2.48% to 3.56%). This could be associated with structural modifications in the cell wall under water stress. Moreover, the protein content consistently increased under RR in all the varieties. Isabel Oro increased from 11.36% to 14.33%, and Bayoveca increased from 13.34% to 14.56%. This phenomenon is attributed to lower carbohydrate accumulation, which increases the relative proportion of nitrogen in the grain. From a technological standpoint, this increase is favorable, as protein is directly related to baking quality. In the drought-tolerant and drought-susceptible wheat varieties C-306, PBW-175, NI-5439, HD-2329, and PBW-343, which were grown under controlled conditions, water stress reduced the yield and total protein content but increased the protein concentration. Factors such as precipitation, type of drought, and nitrogen management can influence yield response (Singh et al., 2008; Wan et al., 2022).

Rheological properties of gluten

The wet gluten (WG) and dry gluten (DG) contents increased under RR, particularly in Isabel Oro and Don Lupe (Table 2). For example, Isabel Oro increased from 28.50% to 32.97% for the GH and from 9.63% to 11.27% for the GS. These results are consistent with the increase in total protein, since gluten represents the functional protein fraction of wheat. However, the protein composition of wheat depends on genetic and environmental factors such as soil, temperature, drought, CO₂, and fertilization, which significantly influence gluten quality and crop yield (Wieser et al., 2023)

Table 2. Parámetros de calidad del grano en trigo duro bajo diferentes condiciones de riego.

Sample	Irrigation Type	SDS (%)	Index (mL/% protein)	Wet Gluten (%)	Dry Gluten (%)	Gluten Index (%)
Isabel oro	RC	12.04±1.2 ^a	0.72±0.025 ^a	28.50±1.25 ^b	9.63±1.25 ^a	78.00±2.87 ^a
	RR	9.92±0.70 ^b	0.90±0.037 ^a	32.97±2.42 ^{ab}	11.27±1.32 ^{ab}	78.40±3.94 ^a
Don lupe	RC	9.33±0.25 ^b	0.78±0.038 ^a	27.07±1.78 ^a	9.20±0.57 ^a	81.57±3.88 ^{ab}
	RR	11.00±0.98 ^a	0.80±0.098 ^a	31.67±1.71 ^{ab}	11.00±1.98 ^{ab}	80.23±2.14 ^{ab}
Bayoyeca	RC	10.30±0.25 ^b	0.88±0.12 ^a	30.83±1.32 ^{ab}	10.43±1.23 ^{ab}	84.17±3.87 ^{ab}
	RR	11.23±0.86 ^a	0.87±0.078 ^a	29.01±1.12 ^a	9.87±0.95 ^a	75.50±2.57 ^{ab}
Norocoro C2021	RC	9.37±0.77 ^b	0.93±0.018 ^a	30.57±1.39 ^{ab}	10.30±0.87 ^{ab}	86.23±1.31 ^{ab}
	RR	11.20±0.81 ^a	0.77±0.054 ^a	30.98±1.27 ^{ab}	10.40±0.84 ^{ab}	72.67±1.87 ^c

*Different lowercase letters within the same column indicate significant differences according to Tukey's test ($p \leq 0.05$).

The gluten index (GI) (Table 2), an indicator of gluten quality, showed variable responses depending on the genotype. While it remained relatively stable (~78%) in Isabel Oro, it decreased notably in Bayoveca under RR (from 84.17% to 75.50%), suggesting a possible impact on gluten strength. In contrast, Don Lupe maintained relatively high values (>80%), indicating greater stability under water stress. The gluten quality varies by wheat variety when water is scarce: some varieties maintain strong and stable gluten, whereas others weaken it under water stress (Han et al., 2025).

The results of the SDS sedimentation test shown in Table 2, associated with baking quality, revealed increases in some varieties under RR (Don Lupe, Bayoveca) but decreases in others (Isabel Oro). These findings demonstrate that the response to water stress is highly genotype dependent, particularly regarding the composition of glutenins and gliadins. However, the sedimentation index (Index) did not significantly differ between treatments and remained in the range of 0.72 to 0.93, suggesting that the overall functionality of the gluten was not drastically altered in terms of its hydration capacity (Shewry et al., 2024).

Color Properties

Color parameters (L^* , a^* , b^*) showed subtle but consistent changes under RR. The L^* value (luminance) increased slightly in all the varieties, indicating lighter grains. For example, Bayoveca increased from 79.9 to 81.2 (Table 3). This change could be associated with a lower concentration of pigments or modifications in the endosperm structure. However, flour color does not depend solely on the presence of pigment particles but also on the reflectance of the endosperm, which is influenced by factors such as protein content and variety-specific characteristics. This interaction of factors limits its usefulness as a precise indicator of quality, as it can generate variations in color without necessarily reflecting actual changes in the composition or technological properties of the flour (Barnes, 1986; Wang et al., 2025).

The b^* parameter (yellowness) slightly decreased under RR, which is relevant in durum wheat, where yellow color is a quality attribute for the pasta industry. This decrease could indicate a reduction in carotenoids. However, reduced irrigation stresses wheat, activating antioxidants such as carotenoids and anthocyanins to protect the cells. Wheat color is influenced primarily by genotype, environment, and processing. The yellowness index is a key predictor of pasta color. These compounds concentrate pigments in relatively small grains, increasing their color and nutritional value (Ficco et al., 2014; Troccoli et al., 2025).

Chroma and color difference (ΔE) increased under RR, suggesting perceptible changes in grain coloration. However, the hue remained virtually constant (~ 1.41 – 1.49), indicating that the overall color tone did not change substantially. The increase in chroma under reduced irrigation (RR) reflects greater color saturation or intensity, likely because of the concentration of carotenoids (Hidalgo et al., 2014). The fact that the hue angle remains constant indicates that, although the grain is more vibrant, it still belongs to the same color family (yellow–orange) without shifting toward other shades. The ΔE confirms that these variations are visually detectable (Nkhata, 2020).

Dough stability

Dough stability (Estab) (Table 2), measured in minutes, increased under RR in all the varieties. For example, Don Lupe increased from 10.9 to 12.4 min, whereas Norocoro C2021 increased from 8.2 to 9.8 min. An increase in kneading resistance could be attributed to a higher concentration and better quality of gluten proteins (Cappelli et al., 2020; da Silva Ramos et al., 2023). This behavior is consistent with the previously reported increase in protein and gluten content (Table 1). A dough with greater strength and rheological stability improves its performance during processing and contributes to the production of higher-quality final products (Cappelli et al., 2020).

In particular, Isabel Oro and Don Lupe were similar in both regimes, suggesting similar physiological responses. In contrast, Bayoveca and Norocoro C2021 exhibited greater variability, indicating a more complex interaction with water stress.

The observed separation between clusters indicates that the water regime significantly affects the overall quality of wheat, with a magnitude comparable to that of the genotype. Under reduced-irrigation conditions, this behavior is consistent with what has been reported in the literature, where water deficit significantly affects agronomic, physiological, and productive traits, indicating a strong genotype $\times$ environment interaction. In particular, water stress can induce changes in water use efficiency, stomatal conductance, and biomass allocation, which directly impact crop quality and yield. Therefore, the results highlight the need to simultaneously consider the effects of reduced irrigation and genetic variability in breeding programs and in the agronomic management of the crop (Li et al., 2024).

Reduced irrigation, far from being solely a limiting factor, can induce improvements in certain quality attributes, particularly protein content and rheological properties. However, these benefits are accompanied by reductions in physical parameters such as hectoliter weight, which can affect marketability.

From a genetic breeding perspective, varieties such as Don Lupe and Isabel Oro show greater quality stability under stress conditions, positioning them as promising candidates for production systems with limited water availability.

In contrast, varieties such as Bayoveca exhibit greater sensitivity to key parameters such as the gluten index, which could limit their use under water stress conditions if specific industrial standards are to be maintained.

The distribution of genotypes under reduced irrigation based on the evaluated quality variables is shown in Figure 2, revealing a clear differentiation in their performance. The observed dispersion indicates that water stress generates variability in technological attributes, allowing for the identification of groups with similar characteristics. Genotypes located in the same direction as the vectors show a positive association with those variables, suggesting a greater value or influence of these attributes on their performance.

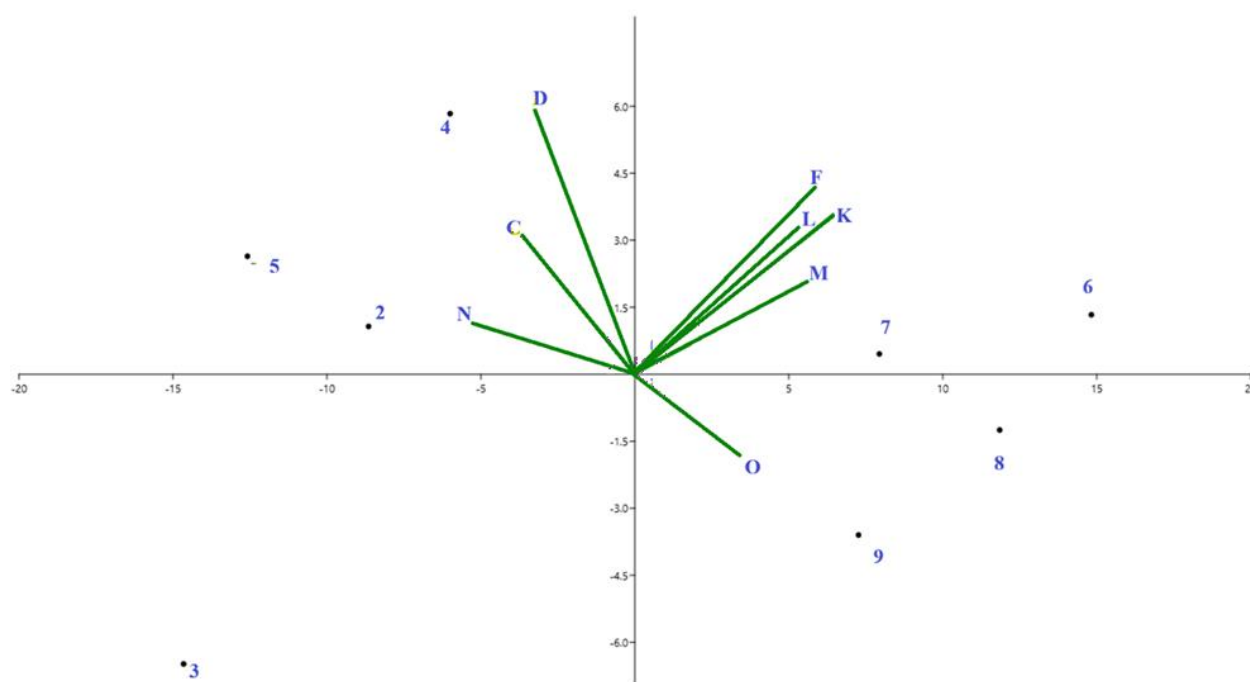


Figure 2. Biplot of the principal component analysis (PCA) of wheat genotypes under reduced-irrigation conditions, based on quality variables. The points represent the genotypes, while the arrows indicate the evaluated variables and their contribution to total variability. The direction and length of the vectors reflect the relationship and magnitude of each variable, respectively. Proximity between genotypes indicates similarity in their behavior, whereas their dispersion highlights differences in quality response under water stress. The numbers correspond to the evaluated varieties. The numbers correspond to the varieties evaluated under full irrigation (2,3,5,8) and reduced irrigation (3,5,7,9). The letters represent the vectors corresponding to the physicochemical and rheological variables analyzed: C: pH, D: Grain weight (g), F: Protein (%), K: Moisture (%), L: SDS, M: SDS Index, N: GH (%), O: GS (%)

On the other hand, genotypes situated in positions opposite the vectors show a negative relationship, indicating a weaker contribution from those variables. The length of the vectors suggests that some variables have greater weight in explaining total variability and are decisive in differentiating genotypes under reduced-irrigation conditions. Similarly, the proximity between certain vectors indicates correlations among variables, suggesting that some quality attributes are closely related to one another.

Reduced irrigation does not affect all genotypes uniformly but induces differentiated responses depending on their intrinsic characteristics. This allows for the identification of materials with greater stability or better-quality performance under water stress, which is relevant for breeding programs and for the selection of varieties under conditions of limited water availability.

CONCLUSIONS

Overall, the results show that moderate water stress (RR) induces significant changes in wheat quality, with positive effects on protein concentration and rheological properties but negative effects on the physical characteristics of the grain. The magnitude and direction of these changes depend largely on

the genotype, underscoring the importance of variety selection in scenarios of climate change and water availability. This study provides relevant evidence for optimizing management strategies and variety selection in semiarid agricultural systems, where balancing yield and quality is a constant challenge.

ACKNOWLEDGEMENTS

I would like to thank the ITVAYA CA3 academic staff for their valuable support, collaboration, and contributions to the development of this work. I would also like to express my gratitude to the BIOSECURA NET International Network for fostering scientific cooperation and the exchange of knowledge, which significantly strengthened this research.

REFERENCES

- AACC. (2025). American Association of Cereal Chemists, Method 55-10.01: Test Weight per Bushel.
- AOAC. (2000). Official methods of analysis. Vol. I. 15th ed. AOAC, Arlington, VA, 489.
- Barnes, P. J. (1986). The influence of wheat endosperm on flour color grade. *Journal of Cereal Science*, 4(2), 143-155. doi:[https://doi.org/10.1016/S0733-5210\(86\)80017-0](https://doi.org/10.1016/S0733-5210(86)80017-0)
- Buenrostro-Rodríguez, J. F., Covarrubias-Prieto, J., Solís-Moya, E., Ledesma-Ramírez, L., Cervantes-Ortiz, F., Mandujano-Bueno, A., Raya-Pérez, J. C. and Gámez-Vázquez, A. J. (2022). Impactos del ambiente y riego restringido en el rendimiento de grano de trigo en Guanajuato, México. *Revista fitotecnica mexicana*, 45(1), 65-73.
- Buenrostro-Rodríguez, J. F., Gámez-Vázquez, A. J., Solís Moya, E., Covarrubias-Prieto, J., Ledesma-Ramírez, L., Mandujano Bueno, A., González-Figueroa, S. S. and Cisneros-López, H. C. (2024). Efecto del nitrógeno sobre rendimiento y calidad de semilla de trigo en el Bajío, México. *Revista fitotecnica mexicana*, 47(2), 109-114.
- Cadena-Cadena, F., Ochoa-Meza, A. R., Argentel-Martínez, L., Peñuelas-Rubio, O., Ochoa-Meza, A. and Arias-MoscOSO, J. L. (2025). Physicochemical characterization of durum wheat (*Triticum durum* Desf.) under full irrigation conditions and water stress due to reduced irrigation. *Chilean journal of agricultural research*, 85(3), 308-317.
- Cappelli, A., Oliva, N. and Cini, E. (2020). A systematic review of gluten-free dough and bread: Dough rheology, bread characteristics, and improvement strategies. *Applied Sciences*, 10(18), 6559.
- Coca Cadena, A. (1998, 1988). Curso métodos analíticos de tecnología en cereales menores.
- da Silva Ramos, N. J., Rocha, E. B. M., Gusmão, T. A. S., Nascimento, A., Lisboa, H. M. and de Gusmão, R. P. (2023). Optimizing gluten-free pasta quality: The impacts of transglutaminase concentration and kneading time on cooking properties, nutritional value, and rheological characteristics. *Lwt*, 189, 115485.

- Ficco, D. B. M., Mastrangelo, A. M., Trono, D., Borrelli, G. M., De Vita, P., Fares, C., Beleggia, R., Platani, C. and Papa, R. (2014). The colors of durum wheat: a review. *Crop & Pasture Science*, 65(1), 1-15.
- Han, P., Wang, Y. and Sun, H. (2025). Impact of temperature stresses on wheat quality: A focus on starch and protein composition. *Foods*, 14(13), 2178.
- Hidalgo, A., Fongaro, L. and Brandolini, A. (2014). Wheat flour granulometry determines color perception. *Food Research International*, 64, 363-370.
- Jain, M., Kataria, S., Hirve, M. and Prajapati, R. (2019). Water deficit stress effects and responses in maize. In *Plant abiotic stress tolerance: Agronomic, molecular and biotechnological approaches* (pp. 129-151): Springer.
- Li, L., Li, H., Liu, N., Lu, Y., Shao, L., Chen, S. and Zhang, X. (2024). Water use characteristics and drought tolerant ability of different winter wheat cultivars assessed under whole growth circle and at seedling stage. *Agricultural Water Management*, 300, 108921. doi:<https://doi.org/10.1016/j.agwat.2024.108921>
- Moreira, J., Rodrigo, S., Pinheiro, N., Costa, R., Costa, A., Dôres, J., Patanita, M., Maças, B., Leitão, R. and Guerra, M. (2025). Durum Wheat Kernel: Influence of the Genotype and Environment on the Mineral Profile of Grains and Ashes. *Plants*, 14(22), 3414.
- Nkhata, S. G. (2020). Total color change (ΔE^*) is a poor estimator of total carotenoids lost during postharvest storage of biofortified maize grains. *Heliyon*, 6(10).
- Palacios-Rojas, N., McCulley, L., Kaeppler, M., Titcomb, T. J., Gunaratna, N. S., Lopez-Ridaura, S. and Tanumihardjo, S. A. (2020). Mining maize diversity and improving its nutritional aspects within agro-food systems. *Comprehensive Reviews in Food Science and Food Safety*, 19(4), 1809-1834.
- Poole, N., Donovan, J. and Erenstein, O. (2021). Agri-nutrition research: revisiting the contribution of maize and wheat to human nutrition and health. *Food Policy*, 100, 101976.
- Pradeep, S. D., Paul, V., Pandey, R., Harikrishna, Jain, N., Kumar, P., Singh, P. K., Meena, R. C., Aishwarya, K. R. and Dineshkumar, G. (2024). Contribution of ear and awns to the yield in wheat under terminal heat stress condition. *Plant Physiology Reports*, 29(3), 582-597.
- Schuster, C., Huen, J. and Scherf, K. A. (2023). Comprehensive study on gluten composition and baking quality of winter wheat. *Cereal Chemistry*, 100(1), 142-155.
- Sharma, K. and Sharma, P. (2025). Wheat as a nutritional powerhouse: Shaping global food security.
- Shewry, P. R. and Belton, P. S. (2024). What do we truly understand about wheat gluten structure and functionality? *Journal of Cereal Science*, 117, 103895.
- SIAP. (2024). Anuario estadístico de la producción agrícola. Ciudad de Mexico

- Singh, S., Singh, G., Singh, P. and Singh, N. (2008). Effect of water stress at different stages of grain development on the characteristics of starch and protein of different wheat varieties. *Food Chemistry*, 108(1), 130-139. doi:<https://doi.org/10.1016/j.foodchem.2007.10.054>
- Troccoli, A., Ficco, D. B. M., Platani, C., D'Egidio, M. G. and Borrelli, G. M. (2025). Prediction of pasta color considering traits involved in color expression of durum wheat semolina. *Foods*, 14(3), 392.
- Valenzuela-Antelo, J. L., B nitez-Riquelme, I., Villase nor-Mir, H. E., Huerta-Espino, J., Lobato-Ortiz, R., Bueno-Aguilar, G. and Vargas-Hern ndez, M. (2018). Comparaci n del rendimiento de trigos harineros y cristalinos a trav s de diferentes ambientes de riego. *Revista fitotecnia mexicana*, 41(2), 159-166.
- Vincke, D., Mercatoris, B., Eylenbosch, D., Baeten, V. and Vermeulen, P. (2022). Assessment of kernel presence in winter wheat ears at spikelet scale using near-infrared hyperspectral imaging. *Journal of Cereal Science*, 106, 103497.
- Wan, C., Dang, P., Gao, L., Wang, J., Tao, J., Qin, X., Feng, B. and Gao, J. (2022). How does the environment affect wheat yield and protein content response to drought? A meta-analysis. *Frontiers in plant science*, 13, 896985.
- Wang, B., Kang, J., Wang, S., Haider, F. U., Zhong, Y. and Zhang, P. (2025). Variations in the End-Use Quality of Whole Grain Flour Are Closely Related to the Metabolites in the Grains of Pigmented Wheat (*Triticum aestivum* L.). *Plants*, 14(2), 171.
- Wieser, H., Koehler, P. and Scherf, K. A. (2023). Chemistry of wheat gluten proteins: Qualitative composition. *Cereal Chemistry*, 100(1), 23-35.
- Yousuf, H. M. B., Yasin, M., Rebouh, N. Y., Aldawood, A. S., Ali, U. and Rosentrater, K. A. (2025). Comparative assessment of conventional and hermetic storage facilities on wheat grain quality, pest infestation, and bread development. *Scientific Reports*, 15(1), 34725.
- Yudewitz-Pohl, G. (2025). Fenotipado en ambientes h dricos contrastantes de la poblaci n WAMI de *Triticum aestivum* con  nfasis en el rendimiento y sus componentes.
- Zeibig, F., Kilian, B. and Frei, M. (2022). The grain quality of wheat wild relatives in the evolutionary context. *Theoretical and Applied Genetics*, 135(11), 4029-4048.
- Zhang, M., Zhao, W., Li, X. and Li, J. (2026). Effects of variable rate irrigation and fertilization under center pivot system on water conservation, fertilizer efficiency, and yield in winter wheat. *Precision Agriculture*, 27(1), 18.

A

Alfalfa, 256, 258, 261
 anaerobic digestion, 324, 325, 326, 330, 331
 Anthracnose, 184, 189
 Aquaculture, 280, 281
Arachis hypogea, 76
 Arsenic, 307, 309, 311, 316

B

Benzoxazinoids, 58
 Biomass yield, 9, 16, 17
 Bioreactor, 310, 316
 bioremediation., 394
 Borlaug, 25, 27, 28, 29, 30

C

calcium prohexadione, 36, 38, 41, 42, 43, 44
 Centla, 289, 290, 291, 292, 293, 294
Centropomus undecimalis, 297, 298, 299, 303, 304

Ch

Chitosan, 184, 185, 191
 Chlorophyll content, 15, 16

C

consortia, 94, 95, 97, 99, 100, 101, 103, 104
Coriandrum sativum L., 184, 185, 186, 190, 191, 194
 CPUE, 289, 291, 292, 294
 cytokinins, 36, 38, 40, 41, 42, 43, 44, 46

D

Dates, 116, 122, 133, 139, 146
 Degradation, 392
 Detoxification, 310, 311

E

ENSO, 297, 298, 300

F

Fertilization, 339
 fish, 232, 233, 234, 237, 239, 240, 242
 fruit and vegetable waste, 324, 325, 331

G

Gluten, 172, 175
 Grain quality, 174
 Growth, 260

H

hybrids, 222, 223, 224, 225, 226, 227, 228
 Hydrolyzed extract, 273
 Hypopótamo, 13, 18

I

In vitro culture, 269
 irrigation, 222, 223, 225, 226, 227, 228

L

Locations, 344

M

maize, 50, 51, 53, 54, 55, 56, 57, 222, 223, 225, 227, 228
 Maize, 94, 95, 97, 98, 99
 Mango, 188
 mesquite, 232, 233, 234, 238, 240, 241, 242
 Mesquite, 256, 258, 261, 262
 Microbial, 99, 101, 104
 Morphometric analysis, 289, 293
 morphophysiological, 36, 37, 38, 45, 46

N

NDVI, 9, 10, 12, 14, 15, 18
 nile tilapia, 232
 NOM-017-PESC-1994, 289, 290, 291, 293, 294

O

Oat, 67

Oreochromis niloticus, 232, 233, 234, 241, 242, 246, 247

P

paclobutrazol, 36, 38, 40, 41, 42, 43, 44, 45, 46, 47

Pantanos de Centla, 290

Particle size, 324

physiological quality, 22, 23, 24, 29, 31

Planting, 115, 116, 119, 122, 123, 131, 133, 135, 139, 140

Prosopis juliflora, 232, 233, 234, 238, 240

Protein content, 171

R

Recreational fishing, 289

Reduced irrigation, 167, 178, 179

RGB, 65, 66, 68, 69, 70

Rheological properties, 175

S

S/I ratios, 324, 328, 329, 330, 331

saline, 222, 223

SDS sedimentation, 171, 176

size, 22, 23, 24, 25, 26, 27, 28, 29, 31

Spirulina sp, 267, 269, 270, 276

substrate-to-inoculum, 324, 325, 329, 331

T

Tabasco, 289, 290, 291, 292, 294, 297, 298, 299, 300, 301, 302, 303, 304

Tilapia, 260

tomato, 36, 37, 38, 40, 42, 43, 44, 45

Treatments, 339, 341, 343, 344, 349, 351, 352

V

Varieties, 119, 122, 123, 136, 139, 141

Vegetation indices, 65, 69

VFAs, 325, 326, 328, 331

volatile fatty acids, 325, 326

W

Water stress, 173

Weight, 116, 118, 119, 122, 123, 133, 135, 136, 139, 140, 141

wheat, 22, 23, 24, 25, 26, 27, 28, 29, 31

Wheat, 67

Wild juveniles, 283

Y

yield, 22, 24, 25, 27, 28, 29, 31

Yield, 116, 118, 119, 120, 122, 123, 125, 133, 135, 136, 137, 139, 140, 141, 143, 343, 345, 351, 352

Z

Zea mays, 75, 76, 77, 85, 222

About the editors



 **Dr. Leandris Argente-Martínez**

Professor and Senior Researcher "C" at the National Technological Institute of Mexico, Valle del Yaqui Campus (ITVY). Member of the National System of Researchers, Level 1. Professor with a Desirable Profile (PRODEP) from the Mexican Ministry of Public Education. Leader of the ITVAYA-CA-3 Academic Group. Leader of the BioSecuraNet International Network. PhD in Biotechnology Sciences. Research focuses on physiological mechanisms, anaplerotic pathways, and molecular mechanisms activated by organisms during their adaptation to abiotic stresses. Use of molecular markers of organismal tolerance to abiotic stress (salinity, drought, and heat). Application of stable isotope techniques to monitor biochemical reactions in cells and tissues. Application of univariate and multivariate experimental techniques for data processing. Contact email: oleinismora@gmail.com



 **Dra. Ofelda Peñuelas-Rubio**

Professor and Senior Researcher "C" at the National Technological Institute of Mexico, Valle del Yaqui Campus (ITVY). Member of the National System of Researchers, Level 1. Professor with Desirable Profile (PRODEP) from the Mexican Ministry of Public Education, member of the ITVAYA-CA-3 Academic Group. Mexico. She completed two postdoctoral fellowships (January 2016 - December 2017) within the CONACYT National Fellowship Program at the Interdisciplinary Research Center for Regional Integral Development, Sinaloa Unit, of the National Polytechnic Institute, in the area of Rhizosphere Molecular Ecology. She holds a PhD in Sciences specializing in Biotechnology. Contact email: ofeperub@gmail.com



 **Dr. Joe Luis Arias-Moscoso**

Professor and Senior Researcher "C" at the National Technological Institute of Mexico, Valle del Yaqui Campus (ITVY). Member of the National System of Researchers, Level 1. Professor with Desirable Profile (PRODEP) from the Mexican Ministry of Public Education, member of the ITVAYA-CA-3 Academic Group. Mexico. She completed two postdoctoral fellowships (January 2016 - December 2017) within the CONACYT National Fellowship Program at the Interdisciplinary Research Center for Regional Integral Development, Sinaloa Unit, of the National Polytechnic Institute, in the area of Rhizosphere Molecular Ecology. She holds a PhD in Sciences specializing in Biotechnology. Contact email: jarias.moscoso@itvy.edu.mx



9786585756792



BioSecuraNet

**Red Internacional de Biotecnología y
Estrategias Innovadoras
para la Seguridad Alimentaria Global**

Pantanal Editora

Rua Abaete, 83, Sala B, Centro. CEP: 78690-000

Nova Xavantina – Mato Grosso – Brasil

Telefone (66) 99682-4165 (Whatsapp)

<https://www.editorapantanal.com.br>

contato@editorapantanal.com.br