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Final Report

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Title: Evaluation of CIMMYT elite nurseries for physiological traits associated with yield and abiotic stress adaptation

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Introduction

Wheat (*Triticum aestivum L.*) is one of the most affordable staple crops and a cornerstone of global food security, which supplies more than half of the caloric and protein intake for over one-third of the world's population (Marček et al., 2019). My motive in working on staple crops, particularly wheat, for increasing productivity and combating hunger stems from my deep concern for the global food supply and my commitment to climate-resilient crop development practices. The International Maize and Wheat Improvement Center (CIMMYT), being the pioneer in global wheat improvement through its intensive multi-location research trials and due to its significant contribution at the time of Green Revolution in developing high-yielding, and disease-resistant wheat varieties, has always been a dream place to work with. The decisive support from Prof. Dr. Folkard Asch, Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), and Dr. Matthew Reynolds, Distinguished Scientist, Global Wheat Program CIMMYT, Mexico, was instrumental in making it possible, through the ATSAF-Junior Scientists Tandem (JST) initiative, to conduct my research under the Heat and Drought Wheat Improvement Consortium (HeDWIC) project at CIMMYT, Mexico.

Research Background

As the global population projected to reach 9 billion by 2050, the demand for wheat is expected to rise by 60%, making the maintenance of yield stability under increasingly variable climatic conditions a scientific priority. However, wheat yields are highly sensitive to abiotic stresses, such as heat and drought, both of which are intensifying under climate change. At the time of green revolution, the physiological approaches for wheat improvement initially targeted plant height, where dwarfing genes were introduced to enhance the harvest index and yield; however, as gains from these traits have plateaued, current efforts focus on biomass production through radiation use efficiency (RUE) (Brancourt-Hulmel et al., 2003; Álvaro et al., 2008). RUE, defined as the slope of the regression between crop biomass accumulation and the cumulative amount of photosynthetically active radiation intercepted, is a key trait for improving grain yield. However, direct measurement of RUE is challenging because it relies on destructive biomass sampling at multiple phenological stages. Therefore, this project aims to employ high-throughput remote sensing technologies to estimate RUE efficiently. High-throughput phenotyping is an optical remote sensing technique that uses reflected wavelengths from 350 to 2500nm across the visible, near-infrared (NIR), red edge, and short-wave infrared (SWIR) spectra (Gamon et al., 2019). It is used to predict physiological traits using vegetative indices derived through relationships between specific wavelengths and physiological traits or through full-spectrum approaches.

Key Objectives of the project include:

1. Modeling for Radiation Use Efficiency (RUE) using Spectral Reflectance Indices (SRIs) under contrasting environments of CIMMYT‘s latest wheat international nursery trails.
2. Characterization of genetic variation in key physiological traits associated with wheat yield and stress tolerance to identify potential targets for breeding.
3. Defining physiological trait combinations indirectly selected by breeders through their association with yield, to facilitate routine integration of physiological breeding strategies into the CIMMYT Bread Wheat (BW) Program.

Research Location:

The research experiment was conducted at CIMMYT's Campo Experimental Norman E. Borlaug (CENEB) in Ciudad Obregón, Sonora, Mexico. It is located in the northwest of Mexico, characterized by an arid climate and minimal precipitation. The experiment was carried out in the latest international nurseries of CIMMYT specific to targeted environments: 45 ESWYT targeting higher yield potential and well-water conditions; 32 SAWYT targeting drought-prone environments, and 23 HTWYT targeting high-temperature stress conditions. The experiment consisted of 50 genotypes with 2 replicates in each environment and arranged in an alpha lattice design.

Fig.1 Experimental site at Campo Experimental Norman E. Borlaug (CENEB) in Ciudad Obregón, Mexico.

Fig.2 Well watered trial: 45ESWYT (left), Drought trial: 32 SAWYT (middle) and Heat trial: 23 HTWYT (right)

Data collection:

Data collection involved the use of various high-throughput phenotyping devices:

- The canopy reflectance measurements were taken from each plot using a potable spectroradiometer (ASD Field Spec® 3) at booting, heading, and grain-filling phenological stages.
- The fluorescence imaging was performed at booting and heading +10 days with a FluorCam system to evaluate photosystem II performance and plant stress responses.
- The stomatal conductance and photosynthetic parameters were measured using an LI-COR 600 porometer/fluorometer system at weekly intervals.
- The Normalized Difference Vegetation Index (NDVI) measurements were obtained using a GreenSeeker handheld sensor, which estimates crop vigor and biomass by measuring canopy reflectance in the red and near-infrared regions of the spectrum.
- The light interception was measured using a Ceptometer (AccuPAR LP-80), a device that quantifies photosynthetically active radiation (PAR) above and below the canopy to assess the proportion of light intercepted by the crop.
- The chlorophyll content was measured using an SPAD meter, a portable device that estimates leaf chlorophyll concentration non-destructively by assessing leaf light absorbance.
- The canopy temperatures were measured using infrared thermometers, which non-destructively assess leaf or canopy surface temperature to evaluate plant water status and stress responses.

Fig.3 Canopy reflectance measured with ASD Field Spec® 3 (left), photosynthetic traits assessed using LICOR-6800 and Porometer/Fluorometer (middle) and light interception measured with AccuPAR LP-80 (right).

Fig.4 Wheat field day celebrations at CENEB-CIMMYT Ciudad Obregón, Sonora

Research experience and Personal Reflections:

- Working on my research at CIMMYT's experimental station in Ciudad Obregón was one of the most formative experiences of my academic journey. Initially I was surprised to see such a huge research division of wheat, which included durum wheat breeding, bread wheat breeding, gentics and molecular breeding, wheat physiology, wheat quality and pathology teams all together working for global wheat improvement and food security. My research was focused on CIMMYT international nurseries, a component

of the bread wheat breeding pipeline that distributes elite germplasm targeted to specific environments worldwide. Working independently on such trials was a highly responsible task due to the precision of data collection and handling of large datasets, methodological consistency, timely measurements, and judgemental decisions regarding the plant phenology in real field complexities. Although managing large-scale plots was challenging initially, the experience gained during the process enhanced my efficiency and speed.
Among other trials, working in the heat trail was very challenging due to the extreme heat environments of the Obregon desert climate. It was always challenging to measure traits in this trial due to rapid phenological advancement of plants under heat stress.

- However, experience at the CIMMYT head quarters located in Texcoco, Mexico, was completely different, as it welcomed me with cool and seasonal showers. I was involved in descriptive analysis of my data with Dr. Carolina Rivera, the associate scientist of wheat physiology and expert in data management at CIMMYT, along with Dr. Alejandro Pieters from the University of Hohenheim. I could gain deeper insights into data analysis and scientific publications. Staying at CIMMYT HQ was one of the most enriching experiences of my time in Mexico, owing to its scenic environment, excellent amenities, vibrant research atmosphere, and opportunities for international collaboration and learning.

Fig.5 Farewell day celebrations at CIMMYT HQ, with acknowledgements from Dr. Matthew Reynolds and Dr. Carolina.

Fig.6 At CIMMYT Global headquarters, El Batán, Texcoco Mexico.

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