Research and Innovation Fellowship for Agriculture

# The International Maize and Wheat Improvement Center (CIMMYT)
# RIFA Project Opportunities 2018

**1. Project:** Analysis of genetic variability for wheat grain fructans and/or arabinoxylans.

**Project Description:**
Fructans and arabinoxylans are functional food ingredients that deserve attention for their potential health benefits. They selectively promote the growth of beneficial bifidobacteria in the human gut, making the digestive system work more effectively, thereby increasing the absorption of more beneficial nutrients, particularly calcium and iron. Iron availability and absorption are particularly important, given that billions of people are iron deficient. Significant genotypic variation has been described for these bioactive components, with grain fructans content ranging from 0.7 to 2.9% of grain dry weight. There is no evidence of strong genotype-by-environment interaction, and therefore breeding approaches could be carried out to increase fructans content. For this purpose, the first step is to analyze the genetic variability in current CIMMYT lines to have an idea about the available genetic variability. This step also involves developing/validating a high-throughput methodology to quickly quantify grain fructans and arabinoxylans at a low cost, which is necessary when analyzing large numbers of lines developed by the breeding program.

The fellow will be in charge of developing, testing and validating different high-throughput protocols to analyze wheat grain fructans and arabinoxylans and to screen for their concentration in different sets of wheat samples, in order to have an idea of the genetic variability for this trait in CIMMYT germplasm. Those sets will include different wheat lines grown in different environments to analyze environmental and GxE effects on fructans and arabinoxylans concentration. The student will be responsible for analyzing the results and publishing them in an SCI journal.

**Work Environment:**
The student will work at CIMMYT's Headquarters in Texcoco, which is located 40 km outside Mexico City. The workplace is in the CIMMYT Bioscience lab.

**Desired Skills of Fellow(s):**
Ability to work with chemical/biochemical methodologies in the laboratory.

**Funding Notes:** Office costs & Internet access, lab costs and airport transfer is provided by CIMMYT.

**Language**: English

**Desired Duration In-Country**: 6 months

**Number of Fellows**: 1

**Main Point of Contact**: Carlos Guzman; C.Guzman@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: Carlos Guzman

**University of California Faculty/Staff Counterpart (Mentor):** Student must find.

**2. Project:** Stochastic simulation for support decision in plant breeding research.

**Project Description:**
Plant breeding has been fundamental for improving and adapting crops to human needs and benefits. Those achievements were obtained through selection that increases the net genetic merit of target traits, which are typically quantitative traits. However, while crop yields have increased over the past decades, current estimates show that the pace of progress is not going to be enough to satisfy the projected population demand or to overcome additional challenges, such as global climate change. When addressing these complex questions, breeders face a set of intricate subjects. These issues may be analyzed under quantitative genetic assumptions; some are easily evaluated but others are not. In this sense, stochastic simulation can play an important role by delivering a cheap and quick answer when evaluation is not feasible due to the time and/or resources it requires. Stochastic simulation has already been successfully applied here at CIMMYT. Although several options for quantitative genetic simulation are currently available, one that merges features such as high performance, cross platform, flexibility, friendly interface and free/open source is still being developed by the BSU/GRP team.

Parallel to the ongoing work on this theme here at CIMMYT, the fellow is expected to join the development efforts of that project, i.e, assist in its implementation, testing, debugging, documentation and maintenance with the aim of improving and extending the current version of the software. Specifically, the fellow will work on classic and well-founded genetic designs (e.g., Mathers, diallel and North Carolina types I and II) that involve using whole-genome data. He/she will also be trained to use the upcoming achievements in his/her own simulation project under the guidance of his/her supervisor and in agreement with his/her thesis advisor. The project will also support the thesis activities; plan and script the simulation trials using our high performance computing facilities; summarize the outcomes and communicate the results.

**Work Environment:**
The fellow will work at CIMMYT's Headquarters in Texcoco, which is located 40 km outside Mexico City. The workplace is in the office area of the BSU (Biometrics and Statistics Unit.

**Desired Skills of Fellow(s):**
Ability in programming languages R and C++ desirable.

**Funding Notes:** Office costs & Internet access, lab costs and airport transfer is provided by CIMMYT.

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**Language**: English fine

**Desired Duration In-Country**: 6 months

**Number of Fellows**: 1

**Main Point of Contact**: Fernando Toledo; F.TOLEDO@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: Fernando Toledo

**University of California Faculty/Staff Counterpart (Mentor):** Student must find.

**3. Project:** Heat Shock Tolerance Mechanisms in Wheat

**Project Description:**
The negative effects of heat shocks (short periods of 1–4 consecutive days during which maximum temperature increases 2-4°C) on wheat yields during the grain-filling period are expected to become more common as a consequence of climate change. Heat shock can reduce grain weight and, sometimes, grain number, if it occurs before or soon after flowering, causing serious damage to wheat quality. Modeling studies by Asseng et al. (2011) suggested a yield reduction of ~0.2 t/ha for each such day, because of an assumed dramatic acceleration of leaf senescence in proportion to the number of such shocks. These effects should be influenced by the level of soil water and the previous acclimation of the wheat plants. The present study aims to identify physiological mechanisms associated with heat shock tolerance in a range of environments (drought, irrigation and heat) and the ability of different wheat genotypes to recover from brief 'heat shock' events.

The fellow will conduct research at CIMMYT's experiment station in the Yaqui Valley (Northwest Mexico, Ciudad Obregon) during a period of 5 months (from February to June). The fellow will spend an additional month (July) at CIMMYT headquarters (in Texcoco) working with the data and statistical analysis for the publication.

During the period in Cd. Obregon, the fellow will work with the same genotypes under drought, irrigated and heat (late sowing) conditions. Two different heat shocks will be induced at heading stage and ten days after anthesis using specially designed tents in all three environments. Physiological characterization before, during and after heat shock will be conducted in the control and treated plots.

**Work Environment:**
The fellow will conduct research at CIMMYT's experiment station in the Yaqui Valley (Northwest Mexico, Ciudad Obregon) during a period of 5 months (from February to June). After that he/she will spend an

additional month (July) at CIMMYT's headquarters (in Texcoco) working with the data and statistical analysis for the publication.

**Desired Skills of Fellow(s):**
The fellow should be able to work in the field under high temperature conditions (up to 40°C) and have basic knowledge of statistical analysis.

**Funding Notes:** Office costs & Internet access, field costs, local air travel to Ciudad Obregon and back and airport transfer is provided by CIMMYT.

**Language**: Spanish, basic knowledge.

**Desired Duration In-Country**: 6 months, desired. The fellow should be available for field work during a period of 5 months (from February to June). The fellow will spend an additional month (July) at CIMMYT's headquarters (in Texcoco) working with the data and statistical analysis for the publication.

**Number of Fellows**: 1

**Main Point of Contact**: Gemma Molero; g.molero@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: Gemma Molero

**University of California Faculty/Staff Counterpart (Mentor):** Student must find.

**4. Project:** The role of stomatal conductance and leaf porosity for maximizing radiation use efficiency of wheat in irrigated and heat environments.

**Project Description:**
It is predicted that future increases in yield potential will rely largely on improved biomass production boosted by higher radiation use efficiency (RUE). Major improvement in photosynthetic capacity and/or efficiency will be required to maximize RUE. One strategy for increasing photosynthetic capacity is to increase canopy photosynthesis, including photosynthesis in leaves situated at different strata of the canopy. However, relatively little is known about genetic diversity for the photosynthetic rate of leaves below the flag leaf and their contribution to final biomass, probably due to the amount of time needed to make these measurements.

A useful proxy for measuring photosynthesis is to measure stomatal conductance using a porometer. In previous studies, a positive correlation between yield and stomatal conductance in the flag leaf was observed. To date, information regarding stomatal conductance and stomatal density at the different canopy strata and their

regulation in response to environment in wheat is scarce. Given their importance, a clear opportunity exists to genetically improve crops for stomatal behavior through increased understanding of their distribution along the canopy, their response to environment, and through exploitation of genetic diversity.

Stomatal conductance and leaf porosity will be studied along the canopy strata with the goal of identifying genetic variation associated with radiation use efficiency in different environments (irrigated and heat) where increasing RUE is a target for increasing yield in wheat.

The fellow will conduct research at CIMMYT's experiment station in the Yaqui Valley (Northwest Mexico, Ciudad Obregon) during a period of 5 months (from February to June). The fellow will spend an additional month (July) at CIMMYT headquarters (in Texcoco) working with the data and performing statistical analysis for publication.

During the period in Cd. Obregon, the fellow will work with genotypes that have contrasting canopy architecture under irrigated and heat (late sowing) conditions. Stomatal conductance and leaf porosity will be measured at booting initiation and during grain-filling at different canopy strata (flag leaf, leaf 2, leaf 3 and leaf 4). These measurements will be included in growth and RUE analysis.

**Work Environment:**
The fellow will conduct research at CIMMYT's experiment station in the Yaqui Valley (Northwest Mexico, Ciudad Obregon) during a period of 5 months (from February to June). After that he/she will spend an additional month (July) at CIMMYT headquarters (in Texcoco) working with the data and statistical analysis for the publication.

**Desired Skills of Fellow(s):**
The fellow should be able to work in the field under high temperature conditions (up to 40°C) and have basic knowledge of statistical analysis.

**Funding Notes:** Office costs & Internet access, field costs, local air travel to Ciudad Obregon and back and airport transfer is provided by CIMMYT.

**Language**: Spanish, basic knowledge

**Desired Duration In-Country**: 6 months desired. The fellow should be available for field work during a period of 5 months (from February to June). He/she will spend an additional month (July) at CIMMYT's headquarters (in Texcoco) working with the data and statistical analysis for the publication.

**Number of Fellows**: 1

**Main Point of Contact**: Gemma Molero; g.molero@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: Gemma Molero

**University of California Faculty/Staff Counterpart (Mentor):** Student must find.

**5. Project:** Developing an R-library for spatial analysis of experiments.

**Project Description:**
Incomplete block designs and alpha-lattice field designs have helped increase the precision of estimating genetic values of breeding individuals. However, blocks or incomplete blocks do not capture all the plot-to-plot variability in a field experiment; therefore, appropriate modeling of the error term in field trials is indeed necessary. Analytical models that model the spatial variability considering the grid location of plots in the field have improved the precision of estimating the treatment mean, which produces greater genetic gains in plant breeding than when this spatial adjustment is not performed. A limited number of expensive commercial software (SAS, ASReml, Genstat) and specifically one of the most used spatial models, the separable autoregressive in the direction of the rows and the columns, can model this spatial variability. However, no free software is available for this analysis. Some efforts have been made in R but the results are not reliable. Free software for spatial analysis of experiments will provide breeders with more precise genetic values at minimum cost.

The main objective of this proposal is to develop a free R-library for the spatial analysis of experiments. A review of existing R libraries for the analysis of experiments should be performed to identify the most suitable library, which will then be modified to include the modeling of the error by a spatial model. If no suitable library is found, a new R package including spatial analysis of field trials must be developed. Other activities included in the project are to produce technical documents for scientists and plan training activities to disseminate the new library.

**Work Environment:**
The fellow will work at CIMMYT's Headquarters in Texcoco, which is located 40 km outside Mexico City. The workplace is in the office area of the BSU (Biometrics and Statistics Unit).

**Desired Skills of Fellow(s):** Linear mixed models and computing programming in R.

**Funding Notes:** Office costs & Internet access and airport transfer is provided by CIMMYT.

**Language**: English

**Desired Duration In-Country**: 6 months
**Number of Fellows**: 1

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**Main Point of Contact**: Gregorio Alvarado; G.Alvarado@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: Gregorio Alvarado

**University of California Faculty/Staff Counterpart (Mentor):** Student must find.

**6. Project:** Optimization of experimental design strategies in multi-phase studies.

**Project Description:**
Traits that are measured in the laboratory are expensive and it is not possible to have data for all the experimental units that are in the field. Schemes for sampling the experiments have been proposed to obtain data from all the treatments together with an approximate estimation of the experimental error. Although this type of sampling reduces the overall cost of the experiment, it also reduces the precision of the estimation of some effects. The main objective of this research is to design and compare different sampling strategies based on the cost and precision of the produced data. Specific objectives are to: (1) determine the advantages and disadvantages of this type of sampling; (2) identify factors that affect the optimality of the sampling and measure their effect; (3) suggest randomization strategies for the lab phase and evaluate alternative design options for optimizing efficiency; and (4) write a scientific article and a technical document useful for scientists.

The fellow is expected to complete the work and, at the end of the visit, to have an article for publication and also a technical document for scientists. The student will perform a literature review and the analyses needed to complete the research. He/she will also be responsible for writing the first drafts of the documents to be published. In addition to activities directly related to the proposed research, the student would participate in other CIMMYT activities such as meetings, discussions with other scientists, and visits to research stations..

**Work Environment:**
The student will work at CIMMYT's Headquarters in Texcoco, which is located 40 km outside Mexico City. The workplace is in the office area of the BSU (Biometrics and Statistics Unit).

**Desired Skills of Fellow(s):** An understanding of experimental design concepts, use of analytical software (R, SAS, Genstat). M.Sc. or Ph.D. preferred.

**Funding Notes:** Office costs & Internet access and airport transfer is provided by CIMMYT. All other costs including health insurance should be absorbed by the student through his scholarship.

**Language**: English fine

**Desired Duration In-Country**: 6 Months, desired.

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**Number of Fellows**: 1

**Main Point of Contact**: Juan Burgueño; J.Burgueno@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: Juan Burgueño

**University of California Faculty/Staff Counterpart (Mentor):** Student must find.

**7. Project:** Spatial variability of high-throughput phenotypic data in field experiments.

**Project Description:**
High-throughput precision phenotyping (HPP) is rapidly becoming popular in plant breeding for its ability to facilitate measurement of data points from a broad spectrum of light reflectance wavelengths. When the obtained data points correlate well with a phenotypic trait of interest (e.g., grain yield), this allows using this technology to evaluate several plant phenotypes of agronomical importance. For example, HPP can predict grain yield weeks before harvesting date, thus reducing harvesting costs and making it possible to make decisions for the next sowing season. However, it is not clear how spatial variability affects the relationship between HPP data and the traits of interest. It is known that soil characteristics can create a spurious relationship between different variables including HPP data. Spatial or soil variability can be handled by the experimental design and by the statistical model used to analyze the data, thereby improving the use of high-throughput phenotypic data.

The overall aim of this project is to understand and develop statistical models to analyze spatial variability of HPP data and their relationship with traits of interest, i.e., grain yield, flowering date. Specific objectives: (1) to test different spatial models and their ability to model HPP data; (2) to analyze the relationship between the HPP data, the spatial model and the experimental design; and (3) to publish scientific papers and technical documents to disseminate research results. The student will be responsible for collecting and curating the data, analyzing them and writing the documents. The student will work closely with BSU colleagues and give lectures to CIMMYT staff and partners.

**Work Environment:**
The student will work at CIMMYT's Headquarters in Texcoco, which is located 40 km outside Mexico City. The workplace is in the office area of the BSU (Biometrics and Statistics Unit).

**Desired Skills of Fellow(s):** Experimental design, linear mixed models.

**Funding Notes:** Office costs & Internet access and airport transfer is provided by CIMMYT. All other costs including health insurance should be absorbed by the student through his scholarship.

**Language**: English fine

**Desired Duration In-Country**: 6 months, desired

**Number of Fellows**: 1

**Main Point of Contact**: Juan Burgueño; J.Burgueno@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: Juan Burgueño

**University of California Faculty/Staff Counterpart (Mentor):** Student must find

**8. Project:** A Bayesian genomic prediction model combining pedigree and incomplete genotyped individuals.

**Project Description:**
Quantitative trait variation may display a complex genetic architecture, which is the underlying basis of a phenotype, with few genes with large effects and several genes with small effects. The genes can show additive, dominance or/and epistatic effects and different types of interaction with the environment. Advances in plant genomics –and, more recently, in DNA sequencing of many species– coupled with the availability of statistical and biometric methods for analyzing genetic and phenotypic data with friendly software, have made it feasible to map and dissect complex quantitative trait variation. Genomic selection (GS) and prediction based on genome-wide single nucleotide polymorphism genotyping, pedigree and phenotypic data are very powerful tools for capturing small genetic effects dispersed over the genome; this allows predicting an individual's phenotype. New methods and tools are continuously being developed to integrate GS into genetics research.

One of the key issues with GS is the fact that there are usually many more individuals that have been phenotyped and have pedigree data than individuals with marker data. When attempting to make predictions, only lines with marker, pedigree and phenotypic data can be used, thus leaving out lines with pedigree and phenotypic data that have missing marker data. This project aims to develop a novel approach that uses Bayesian statistics to combine genotypic data with pedigree and phenotypic data and therefore use all available data. This project will lead to developing new algorithms and software for GS based on advanced statistical methods that will cause a paradigm shift in this field.

The phenotypic variation of a plant population measured across locations, seasons or years can be attributed to its genetics, the environment where it grows, and genotype × environment interaction. Biometric models are

used to explain traits with continuous variation because algebraic equations facilitate the understanding of quantitative genetics, which is the study of complex traits affected by the action of multi-genes. Quantitative genetic models include genes having major or small effects and the non-genetic factors affecting a complex trait. Genomic prediction (GS) uses genome-wide single nucleotide polymorphisms, pedigree and phenotypic data, and is a very powerful tool to capture small genetic effects dispersed over the genome, which allows predicting an individual's phenotype. New methods and tools are continuously being developed to integrate GS into genetics research. One of the key issues with GS is the missing values in the genotyped data, which makes it difficult to develop GS models with different numbers of lines with pedigree, marker, and phenotypic data.

The overall aim of this project is to develop a theoretical model that includes pedigree and missing genotyping data in a unified approach, and test it with real data available from international multi-environment wheat breeding nursery trials. The specific objectives are: (1) to mix the A matrix obtained from the pedigree with the G matrix obtained from the markers into one unified H matrix. The Bayesian approach used to compute matrix H will be compared with other models used as references in GP; and (2) the prediction accuracy of our H matrix will be compared with the prediction accuracy of other methods used to compute matrix H.

**Work Environment:**
The fellow will conduct research at CIMMYT's experiment station in the Yaqui Valley (Northwest Mexico, Ciudad Obregon) during a period of 5 months (from February to June). After that he/she will spend an additional month (July) at CIMMYT headquarters (in Texcoco) working with the data and statistical analysis for the publication.

**Desired Skills of Fellow(s):** Bayesian analysis and computer programming in R.

**Funding Notes:** Office costs & Internet access, field costs, local air travel to Ciudad Obregon and back and airport transfer is provided by CIMMYT. All other costs including health insurance should be absorbed by the student through his scholarship.

**Language**: Spanish, basic

**Desired Duration In-Country**: 6 months, desired. The fellow should be available for field work during a period of 5 months (from February to June). He/she will spend an additional month (July) at CIMMYT's headquarters (in Texcoco) working with the data and statistical analysis for the publication.

**Number of Fellows**: 1

**Main Point of Contact**: José Crossa; j.crossa@cgiar.org, Tel. +52 55 5804 2004

**Principal Field Based Collaborator**: José Crossa

**University of California Faculty/Staff Counterpart (Mentor):** Student must find.