



ATSAF - CGIAR++ Junior Scientists Program Final Report

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Title: Estimation of genetic gain for yield and disease resistance to late blight in a CIP potato breeding population

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Background

In the period between January 2023 and July 2023, I participated at the CGIAR++ Junior Scientists Program of ATSAF e.V. to write my master thesis on “Estimation of genetic gain for yield and disease resistance to late blight in cip potato breeding population.” This took place with the kind support of my professor Prof. Dr. Hans-Peter Piepho at Institute for Crop Science, Biostatistics Unit, University of Hohenheim, Stuttgart, Germany and with Dr. Moctar Kante and the International Potato Center, Lima, Peru.

The project was based to evaluate the efficiency of potato breeding program run over years. Potatoes hold immense importance in Peru, not just as a staple food but also as a cultural and nutritional cornerstone. Peru is home to a staggering variety of potatoes, with over 4,000 native types, each offering unique Flavors and textures. This biodiversity plays a crucial role in the nation's food security, offering resilience against crop failures. Beyond sustenance, potatoes are rich in essential nutrients like vitamin C, potassium, and dietary fibre. They combat malnutrition and promote overall health, particularly in rural areas. In essence, the potato's nutritional significance in Peru goes hand in hand with its deep-rooted cultural and agricultural heritage. Late blight is the major disease contributing to crop loss and yield reduction over the years. Breeding for disease resistance in potatoes is difficult because of its complex genetics and environmental interaction. Unfortunately, most of the resistance is overcome by the rapid evolution of pathogens.

The International Potato Center (CIP) is a research facility based in Lima, Peru, was established in 1971 that aims to reduce poverty and achieve food security in developing countries through scientific research and related activities on potato, sweet potato, other root, and tuber crops, and on the improved management of natural resources in the Andes and other mountain areas. CIP has a research presence in more than 20 countries in Africa, Asia, and Latin America, and it works with partners to achieve food security, well-being, and gender equity for poor people in root and tuber farming and food systems in the developing world. The center's research has increased yields and incomes, improved vitamin A deficiency, and preserved almost 5,000 varieties of potato. Participatory research at CIP with potato farming systems in the Andes has evolved and has prospects for future development.



Fig.1: International potato centre(CIP), Lima, Peru

Project Details

The objectives of this research encompass a comprehensive exploration of key aspects in the realm of crop improvement. Firstly, it seeks to quantify both genetic and non-genetic advancements in disease resistance, a crucial element in securing robust and resilient crops. Secondly, it aims to evaluate genetic and non-genetic enhancements in yield characteristics, essential for optimizing agricultural productivity. Moreover, this study endeavours to understand the intricate interplay between breeding for disease resistance and its potential impact on overall yield, shedding light on the delicate balance between these attributes. Additionally, it seeks to identify the most suitable data analysis approach, ensuring the precision and reliability of findings. Furthermore, this research strives to determine the repeatability of trials, ensuring the consistency and reproducibility of results. Lastly, it aims to estimate variance components, contributing valuable insights into the genetic and environmental factors influencing crop performance. These objectives collectively pave the way for informed and effective strategies in crop improvement and agricultural sustainability.

CIP's late blight breeding program created Population B to improve resistance to *Phytophthora infestans*. It consists of three subpopulations: B1 from native cultivars, B2 for agronomic traits, and B3 with enhanced late blight resistance through recurrent selection. The study utilized advanced trials from the B3 population over three cycles, conducted at two locations in Peru, Oxapampa and Comas, known for high rainfall and disease pressure. Randomized Complete Block Design (RCBD) with 2-4 replications was employed. The dataset included controls: Yungay (susceptible), Amarilis (moderately resistant), and Kory (resistant) across all trials. Fungicide application followed CIP standard procedures to assess late blight resistance. The area under the disease progress curve (AUDPC) was calculated, with relative AUDPC (rAUDPC) for comparative analysis. Tuber yield (TTYNA) was measured in tonnes per hectare after harvest. This comprehensive approach allowed for robust evaluation of late blight resistance and yield traits.



Fig.2: Diversity of potato collection in CIP,Lima

In this study, genetic gain from historical data of advanced trials from three cycles of the B3 population was estimated, by regressing the adjusted genotype means against the year in which genotypes were first present. To have an overview of the impact of resistance breeding on yield, genetic gain for yield was estimated. Different statistical models were included in the study to evaluate the robustness of the findings. The main findings of the thesis are as follows. The genetic gain estimates for disease susceptibility varied from - 0.002 to 0.009. All except the least value were

significant. In contradiction, genetic gain estimates for yield varied from -0.54 to 0.03 t/ha with the least value being significant. The significant values of the genetic gain show an increase in disease susceptibility and a decrease in yield. The genetic gain per cycle also reported similar results. The estimation of variance components showed high genetic variance. The non-genetic trend showed varying results due to the short time span. The breeding program showed no increase in disease resistance and yield over three selection cycles while maintaining high genetic variance.

During my work at CIP, Peru, I actively participated in various breeding meetings and conferences, which provided me with valuable insights into the organization's research activities. I also had the opportunity to accompany the team on field visits aimed at data collection for our research trials. CIP's main station in Lima boasts an impressive array of facilities, including a processing unit, genebank unit, molecular laboratory, and a dedicated breeding team, all focused on advancing potato and sweet potato research. The genebank, a critical component of their research efforts, conserves germplasm through various methods, including seeds, tubers, shoot tips, and seedlings at various developmental stages.

During my time at CIP, I gained hands-on experience in shoot tip preservation and cryopreservation using liquid nitrogen at a chilling temperature of -196°C . Additionally, I conducted extensive nutrient analysis of potatoes, exploring correlations among the various nutrients present in this essential crop. CIP's well-maintained herbarium houses a diverse collection of specimens dating back many years, serving as a valuable resource for researchers. During my field visits, I diligently gathered data on trial growth stages, tuber development, and pest and disease attacks in Huanuco. Furthermore, I actively participated in the harvesting of advanced trials within the third cycle population in Huancayo. This involved sorting harvested trials based on size and recording crucial data such as tuber count, weight, quality, color, and shape. The collected tuber samples were carefully packaged and sent to the main station for subsequent processing and chemical analysis of the different varieties.



Fig.3: shoot tip preservation in liquid nitrogen



Fig.4: Harvesting of tubers.

Additionally, I had the opportunity to visit the Huancayo substation and genebank, where I received a comprehensive overview of their operations. Notably, I witnessed the potato crossing process in the CIP-Huancayo greenhouses, where meticulous maintenance of potato lines and expert crossing techniques were evident. My role extended to plant selection, crossbreeding, harvesting of seedpods, seed extraction, drying, and seed counting—an invaluable hands-on learning experience. CIP also maintains a nursery for cultivating seedlings, where I gained insights into the intricacies of potato seed production, understanding both its advantages and limitations. Overall, my field visits proved to be exceptionally educational, offering valuable exposure to the entire research

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and production process. Upon returning to the main station, the harvested samples underwent rigorous analysis to assess their post-harvest processing qualities. These included evaluations of dry matter content, sugar levels, and frying quality, particularly relevant for products like chips and French fries, which constitute a significant market segment for potatoes.

Apart from the Potatoes I also got to learn about other crops like Sweet Potato, Andean root and tuber crops. These included Oca (*Oxalis tuberosa*) that is the second most widely cultivated tuber after potato which is high in protein, with a good balance of amino acids, it is also a good source of fibre, and high in antioxidants. Ulluco (*Ullucus tuberosus*) is the most widely recognized and popular for its taste. It is easy to grow and resistant to stress. Mashua (*Tropaeolum tuberosum*) is one of the highest yielding Andean tubers and one of the easiest to grow. Maca (*Lepidium meyenii*) which nowadays is becoming superfood is grown only in Peru at altitudes of 4000m where no other crop can thrive. Other crops include Ahipa, Arracacha, Yacon, Achira and Mauka Ahipa Project is a CIP initiative focused on identifying high yielding varieties, improving the availability of ahipa collections and breeding lines, and capturing the full food potential of this highly nutritious crop. The CIP has got vast diversity of Potato collection and their wild relatives.

Interactions at the CGIAR center and local staff

My experience with CG-Center CIP on various occasions of participation was very rewarding. I was given many resources to gain a broader understanding of the goals, functions, and processes of the comprehensive project. I had the privilege of participating in online workshops and was granted access to a One drive folder containing all pertinent documents, enabling me to closely monitor the project's progress. My supervisor, Dr. Moctar Kante, was extremely helpful, patient, and kind. He assisted me in developing a topic for my thesis that could serve as a helpful tool for the intervention. Throughout the entirety of my thesis work, we maintained open and effective communication, and he provided invaluable support in various tasks, including the formulation of a suitable research question and theory. The CIP organization was also supportive of my thesis. Even with the start of the project, my supervisor supported me in every step. His interest and guidance helped me to successfully complete this internship and thesis.

I must confess that I had some concerns before traveling to CGIAR station CIP in Peru, as it was not considered one of the safest destinations at that time. The country was grappling with political unrest, and widespread protests and chaos had engulfed the city I was to visit. However, with the reassurances provided by my supervisor and the human resources department, I decided to proceed with my travel plans. The staff demonstrated exceptional kindness in assisting me in securing accommodation and conducting safety assessments for my stay. They also facilitated seamless travel arrangements, even as some staff members were working remotely. I was provided with bus services for commuting to the office. The team members exhibited warmth and generosity by extending invitations to join them for lunches, dinners, and social gatherings. The atmosphere within the CGIAR center was exceptionally positive and welcoming. I found that I could visit any colleague's office at any time, and my concerns were always addressed with the utmost priority. I was encouraged to visit all the department and learn from the experts. I had the privilege to visit other breeding stations in the Peru like Huancayo and Huanuco trials. They took care of my safety and security during my field trips. Since there was lot of altitude differences as the trials were at higher

altitudes, everyone made sure that I had no sickness during travels. Even during a hospital visit, they provided unwavering companionship and support throughout the entire process. My experience with the CGIAR center was truly heartwarming and one that I will cherish.

Conclusion

My time at International Potato Centre was a transformative experience. It gave me a unique opportunity to immerse myself in a different culture and civilization. Despite facing formidable language barriers, I seamlessly integrated into both the team and the country, thanks to my adaptability and determination. The only notable challenge I encountered during my stay was related to my dietary preferences as a vegan. Finding nutritious and healthy vegan food in Peru proved to be a bit of a challenge. Additionally, acclimating to the local climate and altitude in our trial location required some time. However, the warmth and friendliness of the people I encountered made every moment worthwhile. From a professional standpoint, my experience at CIP Peru was profoundly enriching. Prior to this venture, I possessed minimal experience in research, let alone conducting field trials and data analysis. I had the privilege of confronting and conquering the various challenges and complexities inherent in these processes. The journey of planning, preparation, and ultimate data analysis was both stimulating and insightful. This experience allowed me to not only explore a new country and culture but also to acquire proficiency in the Spanish language and enhance my transcultural skills. I extend my heartfelt gratitude to ATSAF e.V. for affording me the opportunity to participate in the CGIAR++ Junior Scientists Program. This experience has been instrumental in shaping my future research career. It equipped me with invaluable insights into field research projects, provided me with the chance to expand my professional network, and solidified my commitment to the field of plant breeding and sustainable crop improvement.

In summary, my time at CIP Peru was a transformative experience that fostered personal and professional growth. I not only gained a deeper understanding of plant breeding techniques and methodologies but also developed a profound appreciation for the dedication and passion of the scientists and researchers in the field. It broadened my horizons, strengthened my skills, and reinforced my dedication to the field of plant breeding and sustainable crop improvement. I am grateful for the mentorship, knowledge, and friendships I gained during my internship at CIP. I thank everyone for this opportunity.



Fig.5: Breeding team at CIP,Lima