

Project Title: Hunger Solution in West Africa: Genetic Diversity and Spatial Distribution of Native Frafra Potato Plants

Background and Rationale

Food security is of global concern, as approximately 1 billion people suffer from starvation and malnourishment (Sasson, 2012). Although some improvements have been made to address these issues in the past 15 years, over 780 million people in developing countries in Southeast Asia and Sub-Saharan Africa are still malnourished (Tandon et al., 2017; Webb et al., 2018). The impact of food insecurity in Sub-Saharan Africa negatively affects the most vulnerable populations that include women, children, and female teenagers who receive less nutrition than their male counterparts (Sasson, 2012). Africa's success in achieving long term food and nutrition security is dependent on strategies in the food and agricultural sector that promote access to nutritious food for all (Ha, 2018).

Sub-Saharan Africa has numerous nutrient-rich indigenous crops that can help achieve food security on the continent and are better adapted to the rapidly changing climate. One such plant is Frafra potato (*Solenostemon rotundifolius*), which is native to Ghana and Western Africa. However, most of these crops are on the verge of extinction and are restricted to communities where older generations appreciate its nutritional and medicinal values. Despite the direct contribution of Frafra potato as an economically important, medicinal, and potential food security crop, very little is known about the genetic makeup of this crop, including its genetic diversity and post-harvest storage diseases. Thus, there is a **critical need** to evaluate the genetic diversity and spatial structure of indigenous crops such as Frafra potato, to understand the adaptive potential of his plant, and to inform breeding programs for large-scale production towards achieving food security.

Frafra potato is one of the hardiest and underutilized crops grown in nutrient poor soils in the Northern Ghana (Nkansah, 2004). The plant belongs to the mint family (Labiaceae) and has the characteristic minty smell. It has clustered tubers, with gluten free properties, and is a rich source of dietary macro and micronutrients. The calcium, beta-carotene (vitamin A precursor) and iron contents in these tubers are significantly higher than those of cassava, sweet potatoes, and yam (Nkansah, 2004). The leaves are used in the treatment of dysentery, and as carminatives and anthelmintics (Anbuselvi et al., 2013). The nutritional, medicinal, and adaptational values of Frafra potato uniquely places this plant as a potential food security crop for Western Africa. Due to the potential economic and societal values of Frafra potato, the **overall goal** of the proposed study is to evaluate the genetic diversity within and among Frafra potato populations in Ghana and Burkina Faso. Our **central hypothesis** is that cultivated populations of Frafra potato are genetically diverse and spatially clustered within Ghana and Burkina Faso. This research will build upon the work of my co-advisor, Dr. Denita Hadziabdic (University of Tennessee), and her collaborator Dr. Naalamle Amissah (University of Ghana). Together, as part of Dr. Hadziabdic's Fulbright Fellowship to Ghana, they characterized the germplasm of Frafra potato using morphological and molecular tools. Our transdisciplinary research team composed of plant scientists (Dr. Kusi [Savannah Agricultural Research Institute, Ghana], Dr. Amissah, and Michelle Odoi) and a population geneticist (Dr. Hadziabdic) is well positioned to undertake the proposed project and achieve our overall goal.

My **research interests** are centered around addressing food security using indigenous crops and developing breeding programs for these crops. The skills acquired from this study will further my own research interests and assist my advisor, Dr. Hadziabdic, to continue her research collaborations with Ghanaian scientists. Also, I will learn novel molecular laboratory skills, population genetic data analyses, and basic and molecular plant pathology approaches that I will use throughout my dissertation. Additionally, this study will enable me to promote science literacy and educate the next generation of scientists both in the U.S.A. and my home country of Ghana. I am also passionate about developing teaching and research programs in Ghana that will empower females and minorities to become scientists and science ambassadors.

Research Methods and Proposed Plan

A total of 900 leaf samples of Frafra potato have been collected from two regions in Ghana and five provinces in Burkina Faso by Drs. Amissah, Hadziabdic, and Kusi in 2019. DNA will be isolated from approximately 50 mg of leaf tissue using the Omega Bio-Tek E.Z.N.A. Plant DNA DS kit (Norcross, GA). PCR (polymerase chain reaction) will be conducted using specific microsatellite loci developed by our lab (Hua et al., 2018). Microsatellite loci are species-specific short tandem repeats widely used in population genetic studies and among the most variable types of DNA sequences in the genome of any organism (Guichoux et al., 2011; Ellegren, 2004). Amplified PCR products will be visualized using QIAxcel Capillary Electrophoresis System and cleaned using the ScreenGel software (Qiagen, Germantown, MD). Data from ScreenGel will be binned into allelic categories using the Excel macro FLEXIBIN (Amos et al., 2007). The binned data will then be analyzed in R (v.3.6.2) using the R packages poppr (Kamvar et al. 2014) and STRUCTURE (Pritchard et al. 2000) to illustrate patterns in population structure and genetic diversity.

Assessment of projected outcome

Results from this population genetic study will be used to correlate the morphological information already established in Ghana and Burkina Faso. These data will enable plant breeders in West Africa to select adaptive, potential and resilient lines to climate change for future breeding projects. Additionally, the data will provide insights into the existing germplasm and facilitate Ghanaian institutions to expand their research programs and enhance their breeding programs to use the full potential of Frafra potato as a food security crop.

Plan for disseminating the results

The findings will be published in peer-review journal articles, and presented at regional and/or national scientific conferences by student PI, Ms. Odoi. Also, information gathered from this study will inform breeding efforts for Frafra potato in Ghana and Western Africa.

Submission for external funds

These data will be used for future funding opportunities related to Frafra potato research and outreach including post-harvest diseases, whole genome sequencing, comparative genomics, and microbiome studies.

Bibliography

Amos, W., Hoffman, J., Frodsha, A., Zhang, L., Best, S. & Hill, A (2007). Automated binning of microsatellite alleles: problems and solutions. *Molecular Ecology Resources*, 7(1):10-14.

Anbuselvi, S., & Priya, M. H. (2013). Nutritional and anti-nutritional constituents of *Plectranthus rotundifolius*. *International Journal of Pharmaceutical Science Review and Research* 22(1), 213-215.

Diao, X., Hazell, P., & Thurlow, J. (2010). The role of agriculture in African development. *World Development*, 38(10), 1375-1383.

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Guichoux, E., Lagache, L., Wagner, S., Chaumeil, P., Léger, P., Lepais, O., Lepoittevin, C., Malausa, T., Revardel, E., Salin, F., & Petit, R. J. (2011). Current trends in microsatellite genotyping. *Molecular Ecology Resources*, 11(4), 591-611.

Ha, J. K. (2018). Opportunities and challenges for research on food and nutrition security and agriculture in Asia Opportunities for future research and innovation on food and nutrition security and agriculture—a global perspective. *Asian-Australasian Journal of Animal Sciences*, 31(11), 1840.

Hadziabdic, D., Fitzpatrick, B. M., Wang, X., Wadl, P. A., Rinehart, T. A., Ownley, B. H., Windham, T. M & Trigiano, R. N. (2010). Analysis of genetic diversity in flowering dogwood natural stands using microsatellites: the effects of dogwood anthracnose. *Genetica*, 138(9-10), 1047-1057.

Hadziabdic, D., Wang, X., Wadl, P. A., Rinehart, T. A., Ownley, B. H., & Trigiano, R. N. (2012). Genetic diversity of flowering dogwood in the Great Smoky Mountains National Park. *Tree Genetics & Genomes*, 8(4), 855-871.

Hua, L., Hadziabdic, D., Amisah, N., Nowicki, M., Boggess, S. L., Staton, M., Teng, N. & Trigiano, R. N. (2018). Characterization of fifteen microsatellite loci and genetic diversity analysis for the Ghanaian food security crop *Solenostemon rotundifolius* (Frafra potato). *African Journal of Biotechnology*, 17(47), 1352-1357.

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Moss, R.H. (eds.]). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 517.

Kamvar, Z.N., Tabima, J.F. & Grünwald, N.J. (2014) Poppr: an R package for genetic analysis of populations with clonal, partially clonal, and/or sexual reproduction. *PeerJ* 2:e281 <https://doi.org/10.7717/peerj.281>

Nantui, M. F., Bruce, S. D., & Yaw, O. A. (2012). Adaptive capacities of farmers to climate change adaptation strategies and their effects on rice production in the northern region of Ghana. *Russian Journal of Agricultural and Socio-Economic Sciences*, 11(11).

Pritchard, J. K., Stephens, M., & Donnelly, P. (2000). Inference of population structure using multilocus genotype data. *Genetics*, 155(2), 945-959.

Sasson, A. (2012). Food security for Africa: an urgent global challenge. *Agriculture & Food Security*, 1(1), 2.

Tandon, S., Landes, M., Christensen, C., LeGrand, S., Broussard, N., Farrin, K., & Thome, K. (2017). *Progress and Challenges in Global Food Security* (No. 1476-2017-3897).

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Webb, P., Stordalen, G. A., Singh, S., Wijesinha-Bettoni, R., Shetty, P., & Lartey, A. (2018). Hunger and malnutrition in the 21st century. *British Medical Journal*, 361, k2238.

Summer Graduate Research Assistantship (GRA) Fund
Knoxville, TN 37996

26 February, 2020

Dear Committee,

I am writing to express my strong support and enthusiasm for the project proposed by Michelle Odoi and Dr. Denita Hadziabdic entitled "Hunger Solution in West Africa: Genetic Diversity and Spatial Distribution of Native Frafra Potato Plants."

Food insecurity is a global grand challenge. Frafra potato is an economically important, medicinal, and potential food security crop in Africa. I consider the proposed research as high impact, extremely relevant, and timely given the challenges we are facing regarding food insecurity and climate change. Results of the research will provide important foundational data on the distribution of genetic variation within Frafra, which will be important for understanding the adaptive potential of his plant under varying climatic conditions and for identifying new lines or variants that can be used in breeding programs for large-scale production. The research project research will enhance the dissertation research planned by Michelle Odoi, will help her learn novel molecular laboratory skills, population genetic data analyses, and basic and molecular plant pathology approaches, and will enable her to educate the next generation of scientists both in the U.S.A. and her home country of Ghana when she returns. I judge graduate student potential on academic ability, critical thinking, perseverance, and work ethic. Ms. Odoi excels in all of these areas. It is not surprising that the original idea for the project came from Michelle partly because of her working knowledge of Frafra through the years. Dr. Hadziabdic and I have committed to supporting Ms. Odoi with a graduate research stipend and tuition waiver for the remainder of the year. The project also will further strengthen Dr. Hadziabdic's research program, which focuses partly on contributing to hunger eradication efforts on the African continent by preserving biodiversity of indigenous and nutritional plants adapted to climate change. Ms. Odoi and Dr. Hadziabdic together form a great team, and I am confident the stated goals are achievable within proposed time frame. The results from Ms. Odoi's dissertation research will provide the important results that have the potential to be published in higher impact journals and to facilitate acquisition of research funding. Dr. Hadziabdic has the additional resources necessary to conduct this research.

I fully and enthusiastically support the funding of this research proposal. If you need more information, please contact me.

Sincerely,



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MICHELLE ESTHER ODOI

University of Tennessee, Knoxville, Tennessee, USA

Email: modoi@vols.utk.edu; Phone: (865) 203-8044

EDUCATION

B.S. Major in Crop Science

University of Ghana, Legon. May 2015

Second Class Upper [GPA (3.0-3.5)/4.0]

Advisor: Dr. Naalamle Amissah

M.S. Major in Floriculture

Leibniz University of Hannover, Germany. September 2019

Summa Cum Laude GPA- [3.9/4.0]

Thesis: Characterization of genetically modified *Kalanchoe blossfeldiana* and *Petunia hybrida* towards compact growth

Advisor: Prof. Dr. Margrethe Serek

Ph.D. Major in Entomology, Plant Pathology, and Nematology

Concentration in Bioinformatics, Genomics and Molecular Interactions

University of Tennessee, Knoxville, USA. January 2020 – Present

Dissertation: Genetics and genomics of endangered sunflower, *Helianthus verticillatus*

Advisors: Dr. Denita Hadziabdic and Dr. Robert N. Trigiano

EMPLOYMENT HISTORIES

Graduate Research Assistant

University of Tennessee, Knoxville, Tennessee, USA

Department of Entomology and Plant Pathology

January 2020 – Present

- Lab-based work focusing on population genetics of Western Africa food crop Frafra Potato (*Solenostemon rotundifolius*); data management, curation, and DNA extraction
- Basic plant pathology skills including media preparation, culture maintenance, identification, and molecular confirmation of fungal plant pathogens
- DNA isolation from plant and fungal tissues

Horticulture Intern

Westhoff Flower Company, Südlohn-Oeding, North-Rhine Westphalia, Germany

March 2018- April 2018

- Production and handling of plants in the floriculture industry
- Developed pest and disease management skills in flower production

Horticulture Intern

MDK Flower and Greens, Honselersdijk, Netherlands

September 2016 – November 2016

- Assisted with the production, processing and sales of cut foliage (*Monstera*, *Philodendron*, *Anthurium*, *Heliconia*) and pot plants (*Ficus*)
 - Delivered orders to customers, compared product quality, and attending trade fair to display and trade in ornamental plants
-

- Greenhouse management, plant propagation, post-harvest handling of ornamental plants

Horticulture Research Assistant

Department of Crop Science, University of Ghana, Legon

January 2014 – July 2015

- Established seed propagation protocols for the germination of *Bauhinia species*
- Assisted with the project “Propagation, cultural practices, genetic and biochemical diversity of two medicinal plant species, *Croton membranaceus* and *Cryptolepis sanguinolenta*”

TEACHING AND MENTORING EXPERIENCES

English Language Teaching Assistant

Language Center, Leibniz University of Hannover, Germany

September 2018 – September 2019

- Taught Two A level and three B level courses

Nursery Supervisor/Teaching Assistant

Department of Crop Science, University of Ghana, Legon

August 2015 – September 2016

- Mentored twenty student volunteers working in the ornamental and medicinal plant nursery.
- Trained students in ornamental species identification, propagation techniques and plant care.
- Facilitated training workshops for farmers, primary school and graduate students.

AWARDS AND HONORS

- First Class Honors (Summa cum laude) M.S. International Horticulture Class of 2019, Leibniz University of Hannover, Germany (2019)
- Outstanding Student and Valedictorian M.S. International Horticulture Class of 2019, Leibniz University of Hannover, Germany (2019)
- Deutsche Akademische Austauschdienst (DAAD) Scholarship, Leibniz University of Hannover, Germany (2017-2019)
- A three-month sponsored horticulture internship for outstanding students, MDK Flower and Greens, Honselersdijk, Netherlands (2016)

PRESENTATIONS/TRAINING WORKSHOPS/CONFERENCES

1. 6th International Academic Writing Symposium 2019: Writing at the crossroads language center, Leibniz University of Hannover Germany, March 28-30th, 2019. [*Workshop facilitator*]
2. Odoi, M.E., Serek, M. and Gehl, C. (2019) Characterization of genetically modified *Kalanchoe blossfeldiana* and *Petunia hybrida* towards compact growth. Floriculture Section Open House, Leibniz University of Hannover Germany, January 23rd, 2019. [*Poster Presenter*]
3. Webinar on the Deutsche Akademische Austauschdienst (DAAD) Development-related postgraduate courses (EPOS) and Helmut Schmidt Scholarship programs and application requirements, June 27th, 2018. [*Presenter*]
4. “Skill Building, Professional Development and Molecular Biology Workshop for Research Technicians”, USAID-Borlaug Higher Education for Agricultural Research and Development program with collaboration of the University of Ghana and West Africa Centre for Crop Improvement (WACCI). University of Ghana, Accra, Ghana. June 18-23rd, 2017. [*Assisted Workshop Facilitator*]

DENITA HADZIABDIC, PH.D.

Assistant Professor, Fulbright Scholar to Ghana
Department of Entomology and Plant Pathology
University of Tennessee
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Professional Preparation

Tennessee Technological University, Cookeville, TN	Horticulture	B.S.	2002
University of Tennessee, Knoxville, TN	Plant Pathology	M.S.	2005
University of Tennessee, Knoxville, TN	Plants, Soils & Insects (Population Genetics)	Ph.D.	2010

Appointments

Fulbright Scholar	University of Ghana, Accra, Ghana	May-June 2019
Fulbright Scholar	University of Ghana, Accra, Ghana	Nov-Dec 2018
Assistant Professor	University of Tennessee, Entomology & Plant Pathology	2017-present
Research Assistant Professor	University of Tennessee, Entomology & Plant Pathology	2011-2017
Postdoctoral Fellow	University of Tennessee, Entomology & Plant Pathology	2010-2011

Peer-Review Publications (selected)

Students and postdocs from Hadziabdic lab are underlined.

1. Spring, O, Gomez-Zeledon J, **Hadziabdic D**, Trigiano R, Thines M, Lebeda A (2018) Biological characteristics and assessment of virulence diversity in pathosystems of economically important biotrophic Oomycetes. *Critical Reviews in Plant Sciences* 37(6):439-495.
2. Gazis R, Poplawski L, Boggess S, Klingeman W, Boggess S, Trigiano R, Graves A, Seybold S, **Hadziabdic D** (2018) Mycobiota associated with insect galleries in walnut with thousand cankers disease reveals a potential natural enemy against *Geosmithia morbida*. *Fungal Biology* 122(4): 241-253.
3. Oren E, Klingeman W, Gazis R, Moulton J, Lambdin P, Coggeshall M, Hulcr J, Seybold S, **Hadziabdic D** (2018) A novel molecular toolkit for rapid detection of the pathogen and primary vector of thousand cankers disease. *PlosOne* 13(1): e0185087. <https://doi.org/10.1371/journal.pone.0185087>
4. Wadl P, Mack B, Beltz S, Moore G, Baird R, Rinehart T, Molnar T, Staton M, **Hadziabdic D**, Trigiano R (2019) Development of genomic resources for the powdery mildew, *Erysiphe pulchra*. *Plant Disease* 103:804-807. <https://doi.org/10.1094/PDIS-05-18-0719-A>
5. Mantooth K*, **Hadziabdic D***, Boggess S, Windham M, Miller S, Cai G, Spatafora J, Zhang N, Staton¹ M, Ownley, Trigiano R (2017) Confirmation of independent introductions of an exotic plant pathogen of *Cornus* species, *Discula destructiva*, on the east and west coasts of North America and subsequent population bottlenecks. *PlosOne* 12(7): e0180345 <https://doi.org/10.1371/journal.pone.0180345> *equal author contributors

Other Significant Products

1. Chahal K, Gazis R, Klingeman W, **Hadziabdic D**, Lambdin P, Grant J, Windham M (2019) Assessment of alternative candidate subcortical insect vectors from walnut crowns in habitats quarantined for Thousand Cankers Disease. *Environmental Entomology* 48 (4) 882–893.

<https://doi.org/10.1093/ee/nvz064>

2. Nowicki M, Zhao Y, Boggess S, Fluess H, Payá-Milans M, Staton M, Houston L, **Hadziabdic D**, Trigiano R (2018) *Taraxacum kok-saghyz* (Russian dandelion) genomic microsatellite loci: cross-species amplification and population genetics applications. *Scientific Reports* 9: 1915.
3. Blood B, Klingeman W, Paschen M, **Hadziabdic D**, Couture J, Ginzel M (2018) Behavioral responses of *Pityophthorus juglandis* (Coleoptera: Curculionidae: Scolytinae) to volatiles of black walnut and *Geosmithia morbida*, the causal agent of thousand cankers disease. *Environmental Entomology* 47(2): 412-421. <https://doi.org/10.1093/ee/nvx194>
4. Hatmaker A, Staton M, Dattilo A, **Hadziabdic D**, Rinehart T, Schilling E, Trigiano R, Wadl P (2018) Population structure and genetic diversity within the endangered species *Pityopsis ruthii* (Asteraceae). *Frontiers in Plant Science* 9: 943. doi: 10.3389/fpls.2018.00943.
Role: Co-author; contributed to data analyses, manuscript preparation and editing.
5. Daniels DA, Nix KA, Wadl PA, Vito LM, Wiggins GJ, Windham MT, Ownley BH, Lambdin PL, Grant JF, Merten P, Klingeman WE, **Hadziabdic D** (2016) Thousand cankers disease complex: A forest health issue that threatens *Juglans* species across the U.S. *Forests* 7(11):260. DOI: 10.3390/f7110260.

Synergistic Activities

1. Designed and implemented *USAID-BHEARD (Borlaug Higher Education for Agricultural Research and Development Program) Grant Writing Training Workshop* for graduate students and faculty at the University of Ghana, Accra, Ghana (Jan 8-9, 2018)
2. Designed and implemented portion of the *USAID-BHEARD Molecular Workshop and Professional Development*, University of Ghana/West Africa Centre for Crop Improvement, Accra, Ghana (June 19-23, 2017)
3. Faculty mentor for *Pre-College Upward Bound (PCUB) Project* at the University of Tennessee - six weeks long teaching and research program designed to help low-income, potential first-generation college students to graduate from high school and to enroll in a postsecondary institution of their choice that aligns well with their educational and professional goals (mentored 6 high school students during summer 2014-2016)
4. *USDA-NIFA-Women and Minorities in Science, Technology, Engineering and Mathematics Outreach* at the University of Tennessee. This was a 2-day camp titled - Fostering aGIRLculture: a girls STEM camp solving the Grand Challenges of the 21st Century (summer 2016)
 - a. Presented lecture related to epidemiology and worldwide distribution of vector-borne diseases
 - b. Organized and participated in two different modules – soil diversity and epidemiology with a focus on Zika
5. *Gadget Girls Adventures in STEM* - provided a day of hands-on science to middle school aged girls. Co-taught a module entitled “Cracking the Code” that teaches the central dogma of molecular biology (DNA to RNA to protein) with pencil, paper and beads to make a “protein” bracelet (summer 2012)

Funding

Since December 2011, I received a total of \$1,799,457 (internal institutional funding, external federal research/teaching competitive funding, and gift, contracts and cooperative agreements) – 24 as principal, 3 as co-principal investigator, and one as cooperator. Since my tenure-track position in 2017, I have received a total of \$1,193,902 in grants (\$460,040 was allocated for my research program).