Research Statement

I study the patterns of crop genetic diversity that can influence interactions between crops and their environment, farmers, or other organisms. My program focuses on two broad areas of research: I) Adaptation to environmental change and II) Interdisciplinary inquiries into agricultural sustainability.

I. Adaptation to environmental change

Rapid climate change threatens agricultural systems and requires immediate basic research on tolerance to abiotic stresses in cultivated species. I study how genetic variation responds to changes in climatic and landscape factors in centers of crop diversity. These centers have hosted the evolution of a diverse mix of wild, landrace, and improved varieties across a range of environments. This diversity, often adapted to local abiotic conditions, may differentially respond to environmental changes (Mercer and Perales 2010). Focusing on (a) chile pepper and (b) maize, my work investigates local adaptation using quantitative and molecular genetic approaches based on extensive georeferenced collections of wild and crop populations from Mexico.

*I.a. Genetics of abiotic stress tolerance in chile peppers (*Capsicum annuum *and others)*

Chile peppers were domesticated in Mexico, are now grown throughout the world, and contain significant quantitative and molecular genetic diversity (Taitano et al. 2019; Kantar et al. 2016). Since 2014, I have led a collaborative US-Mexico research team studying chile peppers in Mexico to explore genetic diversity and tolerance to abiotic stress. This research has unfolded over two stages. First, with funding from the OARDC Competitive Grants Program in 2016 (on which I was PI; see Research section 5a, #5), I led an investigation of chile pepper phenotype and genotype related to water stress using collections of wild and landrace chile pepper made in the Mexican states of Oaxaca and Yucatan (these collections were the product of an earlier Center for Applied Plant Sciences project led by Dr. Esther van der Knaap). We found that seeds from accessions collected in drier areas reduced germination in response to water deficit more than those from wet areas, possibly indicating a sharper adaptation to remain dormant when conditions are dry (Bernau et al. submitted to *PLOS ONE* June, 2020). We further discovered that, while most accessions reduced fruit production when watering was reduced, the degree to which they did so varied by accession and some actually increased production (Bernau et al. In preparation). Additionally, using environmental and regular genome-wide association studies (GWAS), we revealed loci that may be relevant to drought tolerance phenotypes and that may have alleles whose frequency is differentiated across accessions from wetter and drier areas (Bernau et al. In preparation).

For the second stage of this research, I have built a team to expand our collections to encompass all environments in Mexico in order in order to explore environmental, phenotypic, and genetic attributes associated with responses to abiotic stress—particularly drought. Here my aim is to clarify the genetic basis and fitness implications of traits critical for climate adaptation. This research, funded by AFRI in 2018 (see Research section 5a, #3) has three goals: (i) To illuminate the degree to which environment structures genetic diversity in chile pepper (using population genetic analyses, such as STRUCTURE analysis and analyses of identity by environment; to be performed by collaborators in Mexico). (ii) To clarify loci that appear to have responded to environmental selection (using outlier approaches, including FST; to be performed by collaborators in Hawaii). (iii) To identify loci that are related to various phenotypic responses to water deficit (using QTL analysis here at OSU in the Mercer and McHale laboratories). As we work towards these goals, we have evaluated a number of collections from environmentally extreme parts of Mexico (as well as select US varieties) in the greenhouse to compare their drought tolerance phenotypes (McCoy et al., In preparation). To ensure we are studying relevant traits, my graduate and undergraduate students and I are measuring seed characteristics, gas exchange traits, root architecture, as well as whole plant parameters. With the broader group of collaborators, we are also mining our extensive collection of chile peppers in Mexico to produce maps of expected distributions of wild, weedy, landrace, and cultivated chile peppers in Mexico, as well as to describe their climate envelope and how that envelope may shift with climate change (Kantar et al., In preparation; see Khoury et al., 2019 for previous collaboration on related work). In the future, I hope to expand my chile pepper research to better understand the role that adaptation to abiotic stresses may have played in facilitating the spread of wild chile pepper from tropical forests into more open environments typical of production. To this end, with my Mexican collaborator, I recently took environmental data and collected germplasm in Yucatán, Mexico.

*I.b. Local adaptation of maize (*Zea mays *ssp.* mays*)*

Since domestication in southern Mexico, farmers have continuously grown maize as evolving landraces. Reciprocally moving landraces from where they evolved to new locations across elevational gradients (up or down a mountain) provides a model for response to climate change (substituting space for time). Since 2005, my research has shown that maize along an elevational gradient in the southern Mexican state of Chiapas is locally adapted, although moving down in elevation to warmer climes takes a larger toll on productivity than moving up in elevation (Mercer et al. 2008). Since my promotion in June 2015, I have led and expanded research on this theme to clarify the patterns of the genetic variation and identify traits that underlie adaptation. We have found that an array of landraces from a single elevation are similar in the ways their productivity responds to environment and that flowering characteristics play an important role in adaptation (Mercer and Perales 2019). I have also advised students using physiological, biochemical, and molecular genetic approaches to uncover traits underlying adaptation. Using RNA-seq to generate a global gene expression dataset from landraces originating at different elevations (but grown together), we identified loci related to abiotic and biotic stress tolerance that share patterns of differential expression correlated with environmental gradients—promising candidates for local adaptation (Kost et al. 2017). We also learned that highland and lowland landraces are differentiated for the expression of genes involved in UV-B protection, indicating that maize from different elevations may use different adaptation strategies (Kost et al. 2020). Moreover, biochemical adjustments to UV-B changes involved in shifting elevation are hard to discern, but may also be induced by biotic stress (Pace et al. In preparation). Using a physiological approach, we learned that there is some adaptive phenotypic plasticity occurring in physiological traits (i.e., some non-local plants change trait values to those similar to the local type under local conditions)—plasticity that is likely constrained (Pace et al. Resubmitted June 2020). In my new research in this area, I have begun to explore adaptations by

Mexican landraces to handle low nutrient soils, including symbiosis with a nitrogen-fixing bacteria on aerial roots coated with mucilage (see recent AFRI proposal and Mercer and Kayafas 2020).

I.c. Effects of domestication on evolution of abiotic stress tolerance (sunflower, Helianthus annuus*, and wild chili pepper,* C. annuum *var.* glabriusculum*)*

Novel genetic variation from crop to wild gene flow can make wild species weedy or invasive. As an extension of my past research into the impacts of gene flow from crop to wild sunflower, in 2016 I initiated an international collaboration to work on invasive sunflower in Argentina where crop-wild gene flow appears to have enhanced weediness. Thus far, we have investigated phenotypic selection on crop traits as affected by environmental conditions (Presotto et al. 2019) and methods to discern differences in heat and cold stress tolerance in seedlings of wild and crop sunflower for use in breeding (Hernández et al. 2020). As a result of this collaboration, I am now co-advising a student in Argentina assessing selection and evolutionary change in crop-wild sunflowers exposed to various cropping systems.

II. Interdisciplinary inquiry into agricultural sustainability and philosophy of science

Interdisciplinary explorations into complex agricultural issues that require both natural and social scientific scrutiny have been a cornerstone of my scholarship since 2000. My recent work since promotion in June 2015 has focused on two projects. (II.a.) I have worked in southern Belize with indigenous Maya community collaborators and an interdisciplinary team of researchers (led by a geographer, including agroecologists, a soil scientist, an aquatic ecologist, an ecologist, a city planner, and remote sensing experts). We explore how traditional and non-traditional land management strategies affect land use and agroecosystem characteristics, such as cultivation intensity (Wainwright et al. 2015), soil quality and weed composition (Peller et al. In preparation), and changing systems of food provisioning (Cleary et al., Submitted June 2020). (II.b.) I collaborate with a geographer and science studies expert to explore how science can be leveraged for humanity's benefit. We have inquired into how economic systems, the changing role of the university, and the shifting funding environment affect the choices researchers make (Mercer and Wainwright 2018). We also continue to explore how conceptions of science can influence its practice and social effects (Wainwright et al., In preparation).