

**Executive Summary:** Mentored 8 graduate students and 18 undergraduate researchers. Published 21 total peer review products. Five new federal grants and 2 new non-federal grants. Nine invited seminars at external institutions or conferences. One paper recieved an award. I was elected to a community leadership role by my peers. Total course enrollment flat in a year when overall graduate enrollment declined. My 2020 mentoring and teaching FTE was 27% exceeding my position description target of 18%.

**2020 Narrative:** Every member of my lab came through 2020 alive and safe. Students whose progress towards graduation depended on the 2020 field season got the data they needed. During the shutdown of campus, when university policy encouraged us to lay off undergraduate researchers, members of the lab instead pulled together to support our undergraduates and were able to train students in new computational tasks. No one was forced to miss a paycheck during the lockdown (many of the undergraduates in my lab depend on their income from lab to help make rent on a month to month basis), and the process even resulted in a new publishable research project which is now posted to bioRxiv, including undergraduate student authorship. We don't have a mechanism for reporting on preprints in our annual evaluation process but I expect to be able to report it on my five year publication list in 2021. Over the summer, after first figuring out how to work in the fields safely, we also coordinately closely with both Craig Chandler (University Communications) and Lana Johnson (our department), to publically the regular routines of our field research so that both the public and the state legislature would continue to see throughout the spring and summer that the shutdown did not mean that the research work – for which the project the substantial majority of IANKR's total operating budget – had ceased.

I'm really pleased at how well the lab has come together, organizing virtual social events and emotional support over slack and zoom (including assistance from lab-alumni, which was unexpected and for which I was really grateful). Being a graduate student is hard at the best of times. Being a grad student during a pandemic, often hundreds if not thousands of miles from family is even harder. I'm also finding some students need more frequent meetings and others longer ones, both as a substitute for drop in conversations that used to happen at the office, and because people have many more sources of stress and worries about the future than they would in a normal year. It is hard for me to come up with metrics that will let you assess the quality of the mentoring I have provided to the eight graduate students (6 PhD; 2 MS) who I mentored or co-mentored in 2020. If the peer evaluation committee has ideas about what type of metrics they'd like to see on mentoring quality that could serve as leading indicators for final outcomes for my students I'd be happy to collect and provide them in future years.

In addition, we engaged a total of eighteen undergraduates in research into plant biology, agronomy, and/or computer science in 2020, including both students enrolled here at UNL and an REU student who participated in a remote research experience over the summer. Three undergraduate researchers were authors on three separate published papers in 2020, including one current undergraduate researcher and two who graduated in 2019. Computational biology and agronomy are both fields that have struggled to recruit and retain diverse candidate pools. Among the undergraduate researchers in my lab in 2020, six of eighteen were female, twelve of eighteen were male, and four of eighteen came from groups historically underrepresented in STEM fields. Among graduate students in my lab in 2020, three of eight were female, five of eight were male, and three of eight were from groups historically underrepresented in STEM fields.

In 2020 my research group published eighteen peer reviewed journal articles and three peer reviewed conference papers in 2020 (21 total peer reviewed products). This represents a significant increase from eleven peer reviewed papers and five conference papers in 2019, which was in turn an increase from 2018. Of papers published in 2020, ten of eighteen included a first and/or last author from my research group with six total trainees publishing one or more first author papers. Papers lead by trainees in my lab were published in journals including Molecular Plant (IF=12.1) and Plant Physiology (IF=6.9), and collaborative projects in which my lab participated published in journals including Nature Plants (IF=13.2) and The Plant Cell (IF=9.6).

In 2020 I recieved funding as PI or co-PI for five additional federal grants up from four new federal grants funding in 2019. In total work in my lab in 2020 was supported by thirteen different active federal grants, including four from USDA-NIFA, four from the National Science Foundation, three from ARPA-E, one from FFAR, and one from the Department of Energy. The new grants recieved this year included two USDA-NIFA grants for high intensity phenotyping (\$3.0M and \$2.7M), an ARPA-E grant for monitoring soil organic carbon content (\$1.9M), a USDA-NIFA grant for predictive phenomics to guide agronomic decisions (\$1.05M) and an ARPA-E supported project to use machine learning to predict agronomic out-

comes in corn from molecular data (\$620k). In addition to these five new federal grants I also recieved a small \$50k linkage grant from ICRISAT (Hyderabad, India) to extend our machine learning framework for predicting loss of function phenotypes in sorghum (supported by my ongoing DOE grant) to pearl millet using field trials conducted by ICRISAT in India and Africa, and recieved a compentitive annual renewal from the Nebraska Corn Board to support my participation in Genomes to Fields. More details and links to grant summaries (when publicized) are provided in my abbreviated five year CV submitted as part of this annual report.

In 2020, I gave a total of 9 invited seminars at external institutions (5) or conferences (4). Seven were delivered remotely as a result of COVID travel restrictions. For comparison, I had 7 invited talks in 2019. I was also elected by the maize genetics community to the board of directors for our scientific community (The Maize Genetics Cooperation) and a paper in The Plant Phenome Journal recieved that journal's Paper of the Year Award. In 2020, I recieved a total of 1,027 citations, an increase of 300 (41%) from 2019.

#### **2021 Objectives**

**Progress towards a multi-omic model to predict maize and sorghum phenotypic outcomes in the field:** If successful, this will both help to accelerate the rate of genetic gain in plant breeding and aid growers in making and unpdating decisions about crop management throughout the growing season based on weather, crop development, and (eventually) changes in the cost of inputs (fertilizer and energy costs) and the value of outputs (crop prices). In 2020 we collected dense multi-trait datasets from large association panels of maize and sorghum at a single location. In 2021 my goal is to generate transcriptomic and metabolomic data from frozen tissue samples collected in the field last summer to provide additional variables for the predictivive models, repeat the 2020 experiment in 2021 to capture another environment, and collect data from smaller sets of lines grown across multiple locations in Nebraska. The resources for these activities will come from the new grant funding my group recieved in 2020.

**Identification of genes controlling variation of 3D traits in maize and/or sorghum:** Crops grow, interact with their environments, capture resources, and produce harvestable outputs in 3D space. However, many of the approaches we take to measuring the phenotypes of plants, either by hand or in high throughput imaging systems, simplify them to 2D objects. In 2020 I collaborated with a computer graphics expert at Purdue University to generate and validate an approach to reconstruct the 3D structure of corn and sorghum from 2D images (see pub #61 and conference paper #10 on my five year publication list). In 2021 I hope to use this newly developed approach map gene controlling natural variation in leaf positioning in 3D space as canopy architecture is a trait of particular importance to crop yield and resource use efficiency.

**Expand enrollment in the Integrated Plant Biology graduate track:** The Integrated Plant Biology PhD track provides students with the opportunity to rotate across multiple labs and increases the odds of finding good "fit" between a mentor and mentee, leading to better outcomes. At the same time, the Integrated Plant Biology track provides an opportunity to tap into pools of students currently largely inaccessible to our department. These include students from biology backgrounds where the academic culture emphasizes direct-to-PhD graduate programs. Direct to PhD is technically possible through our internal graduate program. However, the admissions committee has been historically reluctant to sign off on direct-to-PhD applications, putting faculty who are already trying to competitively recruit a PhD student who has already secured a PhD admission offer at another university at a competitive disadvantage. In 2020 I organized and held an online recruitment event for students interested in the program with a number of faculty both in and outside the department, an approach which can be expanded in 2021.

**Pilot shared graduate instruction across institutions:** This spring, Michael Tross, a graduate student I mentor, will be taking "Breeding for Quantitative Traits in Plants" remotely with Rex Bernado of the University of Minnesota, one of the world leaders in the field. At the same time he will recieve UNL credit for the course through AGRO 896. Similarly, in 2020 UNL and Federal University of Minas Gerais students enrolled in a common course taught remotely, a collaboration with my former PhD student Daniel Carvalho. In an era of shrinking enrollments and state support, I think it is critical to explore ways we can expand these practices so our graduate students can continue to recieve world class education as our department faces the need to scale down.

**A Small Request:** If the peer evaluation committee feels this annual report missing information I should have provided, please also tell me what I can safely omit. I'm up against length limits. Similarly, if the committee feels I should be do new or more things in 2021, please also tell me what I can safely do less of. I'm up against my physical and mental limits as a human being (as I suspect many of us are).