PROJECT TITLE:

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LEVEL OF 2018-2019 FUNDING: $50,000

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:
The goal of this research is to assist growers and breeders in selecting the most productive and profitable small grain varieties and to provide management insight for small grain growers in diverse California agroecosystems. To inform the process of small grain variety selection in California, the UC Statewide Small Grain Variety Testing Program evaluates commercial and advanced small grain varieties for yield, agronomic characteristics, disease & pest reactions, and grain quality in representative environments throughout California. The resulting information helps to identify where and under which conditions varieties are best adapted and to justify the release of advanced breeding lines from both public and private breeding programs. In addition, research on the interaction between small grain varieties and environmental variables such as water and nitrogen produces information that enables growers to improve resource use efficiency. Specific project objectives and experiments carried out during the 2017-18 growing season were as follows:

**Objective 1:** Measure the performance of commercially available small grain varieties and advanced breeding lines across a range of environmental and management conditions that represent California agroecosystems. Crop performance includes yield, agronomic characteristics, disease & pest reactions, and grain quality.

**Experiments to accomplish Objective 1:**
Statewide Variety Testing: Commercially available and advanced breeding lines of common and durum wheat, triticale, and barley were grown in 36 separate variety trials in 13 locations across
the state during the 2017-18 growing season (Figure 1). These trials represented over 1,400 unique genotype x environment combinations and over 5,700 plots measured across California. These included: fall-sown common spring wheat and triticale (50 varieties in 10 unique locations and 14 total environments); fall-sown durum wheat (30 varieties established in 5 locations); fall-sown common winter wheat (40 varieties in 2 locations); fall-sown spring barley (17 varieties in 5 locations); fall-sown wheat and barley, organic production system (23 varieties in 1 location); fall-sown common spring wheat elite nurseries (150 elite lines were evaluated in 2 locations for UC breeders and private breeding companies selecting lines for California markets); spring-sown common spring wheat (42 hard spring wheat varieties and 17 soft spring wheat varieties in 1 location); and spring-sown spring barley (6 entries). Trials were established at University of California Research and Extension Centers and in fields of cooperating growers. Randomized complete block designs with four replications were used. Each plot was six to nine drill rows wide (5 to 8-inch row spacing) and 15 to 20 feet long, with a target planted area of 100 ft². Grain was harvested with a Wintersteiger Seedmaster Universal 150 plot combine.

Grain yield, grain protein content, test weight, thousand kernel weight, plant height, and incidence of lodging at soft dough and harvest were estimated for all trials. In addition, when diseases were present, variety-specific rating of diseases were recorded, including stripe rust, septoria, and barley yellow dwarf virus during the 2017-18 season. In-season observations on the timing of heading and maturity were recorded at the Davis and Tulelake locations for various crop-types/planting timing combinations. Finally, to facilitate the interpretation of trial results, climate data and physio-chemical soil properties were recorded at all test locations.

Summary of major accomplishments, Objective 1:

All the plots established in the 2017 season were successfully harvested in 2018 with the exception of the fall planted wheat and triticale trial at a rainfed location in Tulare County, where a majority of plots were not harvested due to crop failure from prolonged early-season drought. Average trial yields were 6,111 lb ac⁻¹ for common wheat, 7,289 lb ac⁻¹ for durum wheat, 6,164 lb ac⁻¹ for triticale, and 4056 lb ac⁻¹ for barley. Initial yield results results from the fall-planted trials were made available on 8/7/2018 with subsequent updates as quality data was added to the data and trials results from the Intermountain Region became available. All trial results produced during the period between 4/1/2018 and 3/31/2019, including the comprehensive 2017-2018 Annual Report can be found at [http://smallgrains.ucanr.edu/Variety_Results/2018/](http://smallgrains.ucanr.edu/Variety_Results/2018/).
Wheat Quality (Statewide trials): During the 2016-17 and 2017-18 seasons, sufficient quantities of grain from wheat trials were collected, cleaned, and processed to permit more extensive evaluation of grain quality by the California Wheat Commission Quality Lab. In collaboration with the CWC and Jorge Dubcovsky, a quality classification system was developed during 2018-2019 based on the quality results obtained from these samples.

Wheat Quality (Collaborative trials): 9 fall-planted common spring wheat varieties and 4 fall-planted durum wheat varieties were grown alongside appropriate control varieties in large plots in two separate locations (Davis and Fresno for common wheat, and Fresno and Imperial for durum wheat). The larger scale plots permitted production of sufficient grain such that each variety could be cleaned, milled and distributed to a number of collaborating wheat quality labs for an unbiased assessment of wheat quality. The results obtained from these samples served as the focus of the annual California Collaborators Meeting in October 2018.

Objective 2: In a subset of trial locations, directly manipulate water and nitrogen availability and measure variety responses to these varying management conditions.

Experiments to accomplish Objective 2:

2017-18 was the second season that managed nitrogen (N) and water stress trials were included as part of the variety testing efforts. At 2 of the 10 trial locations for the fall-planted common wheat and triticale trials (Davis and Fresno), duplicates of the trials were grown under conditions of nitrogen (N) stress and terminal drought stress in addition to the trials grown under conventional management practices. Relative to the conventionally managed trial, the low water common wheat trial at Fresno received approximately 3.5 inches less irrigation than the conventionally managed trial, and the low water trial in Davis received approximately 8.5 inches less irrigation during the 2017-18 season. In the N stress trials at these locations, no N fertilizer was applied compared to the 200 lb ac\(^{-1}\) N applied in the conventionally managed trials.

Summary of major accomplishments, Objective 2:

As a result of the decreased water availability, yields in the low water trial decreased by 3,684 and 864 lb ac\(^{-1}\) in the Fresno and Davis trials, respectively. The difference in N availability resulted in a 2,173 and 2,662 lb ac\(^{-1}\) yield reduction in the Fresno and Davis trials, respectively. Changes in relative variety performance under stressed and non-stressed conditions in both the 2016-17 and 2017-18 seasons were quantified so
that wheat and triticale varieties could be classified according to their relative stability under conditions of terminal drought and N stress for grain yield, grain protein and grain protein yield (Figure 2). For more detailed information related to experimental work and results for Objective 2, please see the Stress Stability section of the 2018 results and the 2017-2018 Annual Report.

**Objective 3:** Measure in-season changes and variety-specific differences in growth directly and via crop phenotyping platforms.

**Experiments to accomplish Objective 3:**

Canopy spectral reflectance was measured throughout the growing season using both hand-held GreenSeeker NDVI meters and a DJI Matrice 100 small Unmanned Aircraft System (sUAS) with a Micasense RedEdge-M. At the Davis location, normalized difference vegetation index (NDVI), a quantitative measure of photosynthetic activity, was recorded for all plots in the conventionally managed common wheat and durum wheat regional trials. Measurements were also taken in conventional and low nitrogen management treatments of Blanca Grande 515 and Cal Rojo. Measurements were recorded at approximately weekly intervals from January to May 2018. At the Fresno location, NDVI measurements were taken in all plots of the low water common wheat regional trial at nine intervals: January 30th, February 9th, February 20th, March 5th, March 16th, April 6th, April 18th, May 2nd, and May 23rd. At the Colusa location, NDVI measurements were taken in all plots of SY Cal Rojo, SY Balnca Grande 51, Bag New Dirkwin, NS Camelot, UC 3183, UC 3184, WB Patron, Yecora Rojo, SY Summit 515, UC Patwin 515, LCS Atomo, WB Joaquin Oro, WB 7566, and UC Central Red at two intervals: January 29th and February 9th. NDVI measurement were taken from the same varieties at the Kings and Kern site on January 24th. NDVI measurement were taken from the same varieties at the Solano site at nine intervals: January 31st, February 12th, February 28th, March 9th, March 19th, April 5th, April 19th, May 2nd, and May 30th.

A RedEdge-M camera collects data centered at the blue (475 nm) green (560 nm), red (668 nm), red edge (717 nm), and NIR (840 nm) wavelengths. Data was collected from the Davis location on a 7-10 day basis; at the Fresno site on February 7th, April 4th, and...
April 18th; at the Kings site on April 19th; at the Delta site on May 30th; at the Colusa site on January 29th, March 28th, May 3rd, and May 24th; at the Tehama site on May 3rd; at the Kern site on April 19th; and at the Tulare site on April 19th. The software programs PIX4D, R, and QGIS were used to capture, compile, and extract plot-level spectral data from images using a modified method of Haghighattalab et al (2016).

**Summary of major accomplishments, Objective 3:**

Reflectance data are improving our understanding of site-specific environmental interactions and their differential effects on variety performance. For example, varieties with yields that are relatively stable under conditions of N stress demonstrate a distinct reflectance fingerprint across the season as compared to varieties with unstable yields under N stress. Furthermore, the reflectance phenotype manifests differently in trials where stress is/is not present (Figure 3). Analyses to date have not found as much information present in the reflectance data related to terminal drought stress tolerance as to N stress tolerance. However, these conclusions are initial and further analysis of these data is required to explore these interactions more fully and uncover other insight that these reflectance measurements may offer. Overall, the reflectance measurements taken from the platforms deployed during the 2016-17 and 2017-18 seasons and analyzed to date have produced data that is beginning to contribute to a more mechanistic understanding of differential variety performance in California’s variable agroecosystems. Now that we possess multiple seasons of reflectance data, we are in a strong position to quantify the value of these measurements and apply them to our understanding of variety performance moving forward.

**Objective 4: Apply multi-level statistical models to trial data to understand and communicate varietal differences due to genotypic, environmental and management effects.**

**Experiments to accomplish Objective 4:**

The variety testing experiments described above as well as the historical UC variety testing data produced in California over the past two decades have served as the basis for a comprehensive, multi-year analysis of the genotype-by-environment effects present in California small grain production. Using a combination of linear modeling and principal components analysis, we quantified the degree to which genotype x environment interactions exist within California wheat, the degree to which these patterns are stable across locations and years, and the minimum trial effort necessary to maintain similar levels of information on multi-year variety performance.

**Summary of major accomplishments, Objective 4:**

The results of these analyses indicate that genotype x environment patterns present in fall-planted common wheat varieties are unstable and inconsistent across seasons in California. Further, while the effect of variety selection and differences in variety performance across
heterogeneous environments are important sources of variation in wheat yield outcomes, together they account for only 23% of the overall variation in yield outcomes (Figure 4). This indicates that some of the instability in yield performance in California wheat is a function of how wheat is managed in response to within- and between-season variation in environmental conditions. As such, the managed stress gradients incorporated into our trials in recent years appear to be delivering disproportionate value per unit effort within our trial structure. We will soon report results from these analyses in the journal Crop Sciences and, moving forward, we will continue to tweak our experimental methods to return the most valuable information possible given resources available for statewide variety testing.

Objective 5: Report results of the research and analysis on our program website, in extension meetings and other agricultural forums.

Summary of major accomplishments, Objective 5:

Extension Events during 2017-18 season: In collaboration with CCIA and the California Wheat Commission, we hosted our annual Small Grains/Alfalfa-Forages Field Day on 17 May in Davis, with over 200 people in attendance. In addition, on 8 May we hosted a field tour of over 40 individuals across several farms in Yolo County where we were conducting experimental work related to small grain variety selection and N fertilizer management. In collaboration with the California Grain Foundation and the California Wheat Commission, we hosted the annual Wheat Collaborators Meeting on 3 October in Davis. There were approximately 100 people in attendance. In addition, during the past year we have delivered 19 public presentations prepared 10 written publications and reports related to our work in California grain cropping systems.

Web Development and Extension: During the reporting period, we successfully released a second interactive web-based variety trial data exploration tool (http://smallgrainselection.plantsciences.ucdavis.edu/explore) as part of ongoing improvements and developments on the UC Small Grains Research and Information Center website. The tool communicates single-location trial data in an interactive interface that permits user-customized results. This additional site complements the interactive variety selection tool released the previous year, which was designed to pinpoint small grain varieties that have performed well in particular regions and environments of California using data from multi-year, multi-location field trials. We also continue to provide results in tabular and pdf formats on our program website (eg. http://smallgrains.ucanr.edu/Variety_Results/2018/).

The http://smallgrains.ucanr.edu/ site and associated web tools were viewed over 13,000 times during 2018 with over 900 California-based users. In addition to the efforts to update the web reporting related to variety selection, we have continued to expand our UC Small Grains Blog (http://ucanr.edu/blogs/smallgrains/), which serve as
a place for field notes, announcements, and timely discussions of interest to growers, consultants, agronomists and others involved in the California small grain industry. We produced 13 posts in 2017-2018 season, and the blog was viewed over 2600 times by over 800 California-based users during 2018.

**PUBLICATION OR REPORTS (4/1/2018 – 3/31/2019):**


George, N. & Lundy, M.E. Quantifying genotype-by-environment effects in long-term common wheat trials from an agro-ecologically diverse production region. Crop Science (under review).


**Presentations and Trainings (4/1/2018 – 3/31/2019)**

Lundy, M., "Small grain diseases." Guest Lecture for UC Davis Graduate Plant Pathology Course (PLP 205A). 27 April, 2018

Lundy, M. & George N., "Updates on statewide small grain research and extension efforts, with comments on variety performance, pests and diseases, nitrogen management, and extension tools." 2018 UC Davis Small Grain and Alfalfa/Forages Field Day. 17 May, 2018, Davis, CA.


Lundy, M., "Quick tests for improved precision of N fertilization." Small Grains and Soil Health Field Meeting. 5 June, 2018. Staten Island, CA.


Lundy, M. "N-rich Strips for Improved N Fertilizer Management in California Small Grains." UC Small Grains Workgroup Annual Meeting. 7 September, 2018. Davis CA

Lundy, M. "UC Small Grains Regional Variety Testing and Agronomic Research Update." UC Small Grains Workgroup Annual Meeting. 7 September, 2018. Davis CA


Lundy, M., “Crop Nutrient Management and Input Use Efficiency.” Guest Lecture for UC Davis Growth and Yield of Cultivated Plant (PLS 100B). 27 February, 2019


Student Training and Development: The Grain Cropping Systems Lab supported 3 graduate students and 3 undergraduate students between 4/1/2018 and 3/31/2019. Taylor Nelsen, completed her MS degree in Horticulture and Agronomy at UC Davis during 2018. She led our UAV data acquisition and processing efforts across all our small grain variety trials in addition to completing her thesis research related to precision of N fertilizer management of California malting barley varieties. She has also been instrumental to the integration of sUAS into our research efforts. Taylor Becker is a MS student in Horticulture and Agronomy at UC Davis whose thesis research is aimed at developing an empirical relationship between crop evapotranspiration and N uptake in California corn crops. She also contributes to the field and lab based efforts associated with the statewide small grain testing efforts. Kalyn Diederich is a PhD student in Soil and Biogeochemistry whose thesis is measuring the above and belowground productivity of the perennial wheatgrass Kernza in comparison to annual wheat under varying water and nitrogen conditions. She also contributes to the statewide variety testing program efforts during busy periods of the field season. In addition, Leah Puro earned a MS degree in International Agricultural Development at UC Davis and worked in the Grain Cropping Systems Lab during the 2016-17. In the past year she completed work quantifying how ET demands from small grain crops grown with different harvest timing strategies interact with the spatially and temporally heterogeneous rainfall patterns across California. This work highlights some of the cost-benefits for various small grain harvest strategies in terms of both economic returns and returns to water in the state’s diverse precipitation environments and is in the final stages of preparation for submission to California Agriculture. We recruit the undergraduate students working in our group from degree programs in the agricultural and environmental sciences. These students are eager to gain exposure to the day-to-day details involved in agronomic research. Over the course of their typically year-long internship program, they contribute greatly to the plant and soil processing and analysis in our research as part-time employees.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

The California small grain crop in 2017-18 consisted of approximately 485 thousand planted acres of wheat, triticale and barley. Approximately 35% of the planted area of wheat was harvested for grain. Total small grain acres in California were at their lowest in a decade. The declines in grain acreage are due to low grain prices and opportunity costs associated with other cropping system options, including the market for small grain forage.

For fall-planted crops, the early season was marked by below average rainfall and infrequent precipitation events, which resulted in some early drought stress and weak stands, particularly in dryland areas. After a warmer than average early-season, from mid-February to early-March there were several multi-day periods with daily low temperatures below freezing for multiple hours. As a result, some frost damage was observed in the Northern San Joaquin Valley and the Sacramento Valley. Above average precipitation in March and April helped to return the annual rainfall total to within a few inches of normal in much of the state. Quantitative summaries of environmental conditions across the state and at the UC variety testing sites can be found on the UC Small Grain blog and the 2018 Annual Report. Relative to the previous season, disease incidence in the state was low, with minimal occurrence of barley yellow dwarf virus, stripe rust, and false black chaff. Statewide common wheat yields averaged 4,620 lb ac⁻¹, durum wheat yields averaged 5,700 lb ac⁻¹, and barley yields averages 1,710 lb ac⁻¹. Within UC Variety testing trials, average grain yields were 5,975 lb ac⁻¹, which is approximately 105% of the 5-year average.
Detailed results for yield, agronomic characteristics, disease resistance and quality evaluations are presented at the UC Small Grains Research and Information Center website:

http://smallgrains.ucanr.edu/Variety_Results/2018/

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Sincerely,

Mark Lundy

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