Winter Wheat: Climate Change Effects on Yield & Physiological Changes

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FOOD SECURITY AND CLIMATE CHANGE

With wheat being the third most commonly grown crop in the world for the past 30 years[1], studies that focus on wheat response to climate change are key players in eliminating food insecurity. This project investigates how rising atmospheric carbon dioxide concentration and variability in precipitation affect yield and physiological performance of rainfed California winter wheat in a 23-year field experiment[2]. Isotopic signatures of archived wheat are proxies for changes in stomatal conductance, a water stress indicator. The analyses indicate **wheat yields have not been affected by abiotic pressures** (i.e. variable seasonal precipitation or atmospheric CO_2 concentration) suggesting **changes in water use efficiency are tolerated** by current wheat varieties. Wheat's resilience to unfavorable climatic factors indicates that the threshold drought limits for yield decline were not met within the experimental period. This phenomenon is confirmed by the lack of separation in isotopic signatures between normal and dry years. **Nitrogen input had the largest effect on yield** in this system.

YIELD UNAFFECTED BY ABIOTIC FACTORS

DROUGHT CONDITIONS AND RISING CO_2

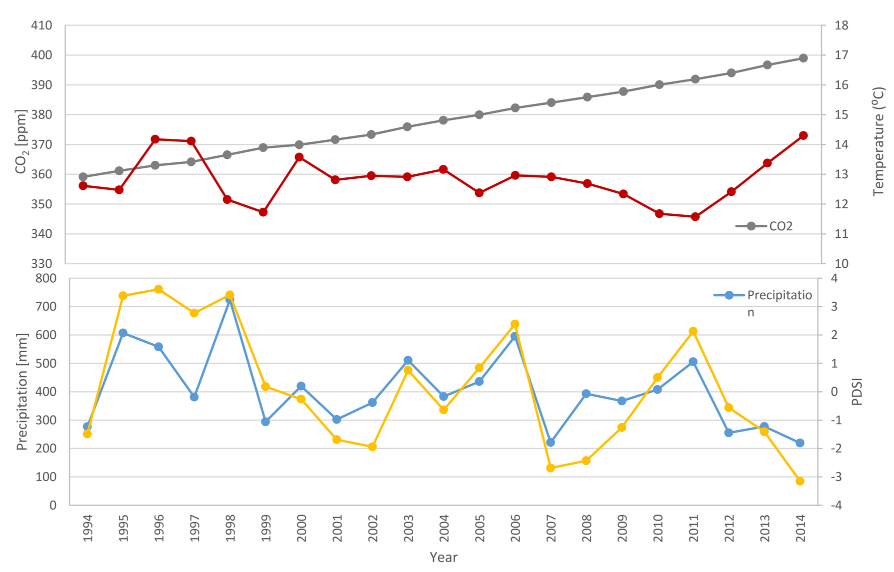
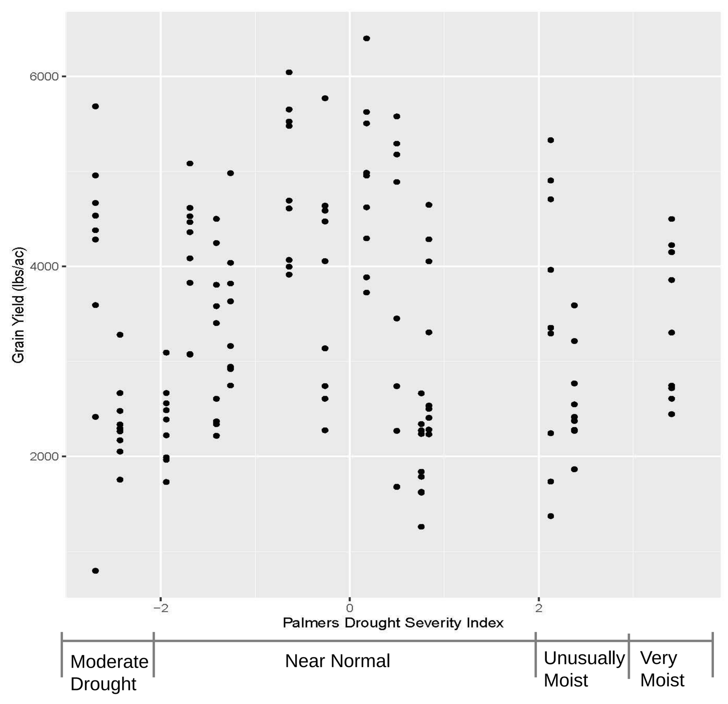


Figure 1. (Left) General trend of atmospheric carbon dioxide[3], temperature[4], precipitation[4], and the Palmer's Drought Severity Index (PDSI)[5] over the study period. All measurements are growing season averages (November-June) from monthly data. (Right) Wheat in hand. All rights reserved. Emberson 2016.

No relationship between drought, CO_2, and yield

PDSI is a drought severity index that estimates available soil water.



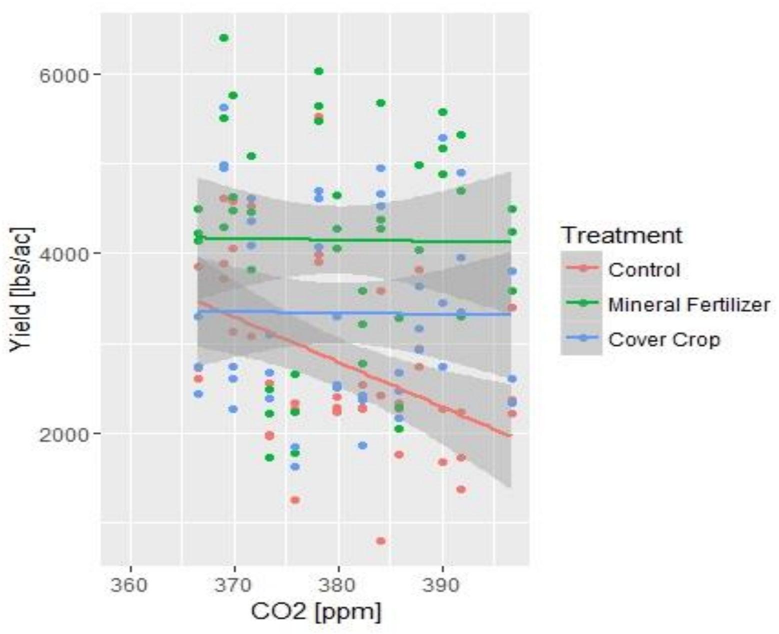


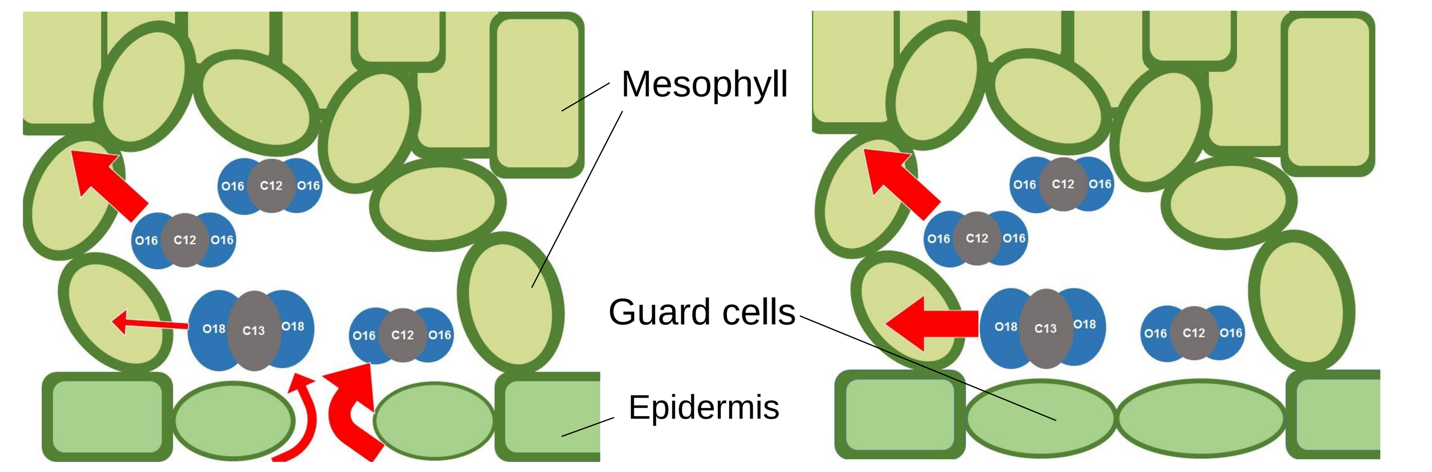
Figure 2. (Left) nearly even spread of yield [lbs/ac] through all drought conditions. Palmer's Drought Severity Index (PDSI) does not effect yield (p=0.69). (Right) Even spread of yields at all carbon dioxide levels, CO_2 does not effect yield (p=0.12). Decline in yield of control treatment with increasing CO_2 is not statistically significant (p=0.10).

METHODS

Agronomic **data** was accessed through the UC Davis Russell Ranch Database on the Century Experiment, conducted in Yolo County, beginning in 1993. Climate data was collected from CIMIS[4], FOA[1], and NOAA[3]. Isotope analysis was preformed at the Stable Isotope Facility at UC Davis. Each year there were a total of 18 plots under two year soil **treatments**, rainfed only. In a given year half the plots grew wheat and the other half were fallow or grew legume cover crops. The treatments are as follows: Mineral Fertilizer- received synthetic fertilizers, pesticide applications, and a fallow alternate year. Cover Crop- received no fertilizer, no pesticide, and a legume cover crop was planted the alternate year. Control- received no fertilizer, no pesticide, and a fallow alternate year. Winter wheat **cultivars** changed from Serra Wheat planted in 1994-2003, Summit Wheat planted 2004-2006, and Cal Rojo Wheat planted 2008-present. Mixed linear **models** were used to assign variation to factors and ANOVA test results determined significance of those factors.

References [1]Food and Agriculture Organization of the United Nations (2016). Statistics Division. http://faostat3.fao.org/compare/E. [2]University of California, Davis (2015). Russell Ranch Sustainable Agriculture Facility. http://asi.ucdavis.edu/programs/rr/data/data-use-agreement. [3]T. Pieter (2015). National Oceanic and Atmospheric Administration. Earth Systems Research Laboratory. Atmospheric CO_2 Concentration. ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt. [4]California Department of Water Resources (2015). California Irrigation Management Information System. Davis, Sacramento Valley, Yolo Station. http://www.cimis.water.ca.gov/WSNReportCriteria.aspx. [5]National Oceanic and Atmospheric Administration (2016). National Climatic Data Center. Palmer Drought Severity Index. http://www1.ncdc.noaa.gov/pub/data/cirs/climdiv/.

YIELD UNAFFECTED BY WATER USE EFFICIENCY

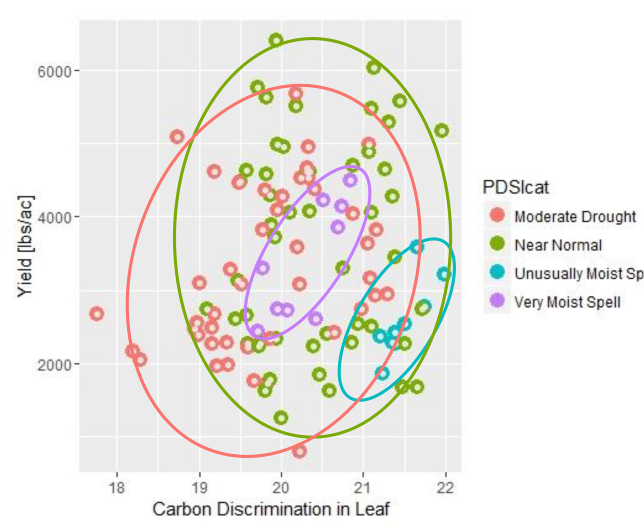


Carbon-13 discrimination in the leaf ($D^{13}C$) is a proxy for drought stress because under normal conditions carbon assimilation preferentially fixes light carbon isotopes. However when a plant is under water stress, stomata close to reduce transpiration and maintain cell turgor pressure. Consequently, light carbon dioxide molecules are not available and **less discrimination occurs during assimilation**. Therefore, a smaller $D^{13}C$ value indicates more stress.

Diffusion accounts for 4‰ of heavy isotope discrimination during photo-synthesis. Carbon assimilation accounts for 23‰ of discrimination.

Isotope signatures do not indicate drought stress

Overlapping $D^{13}C$ of PDSI categories indicate that **moderate drought does not produce physiological signs of stress** in winter wheat.



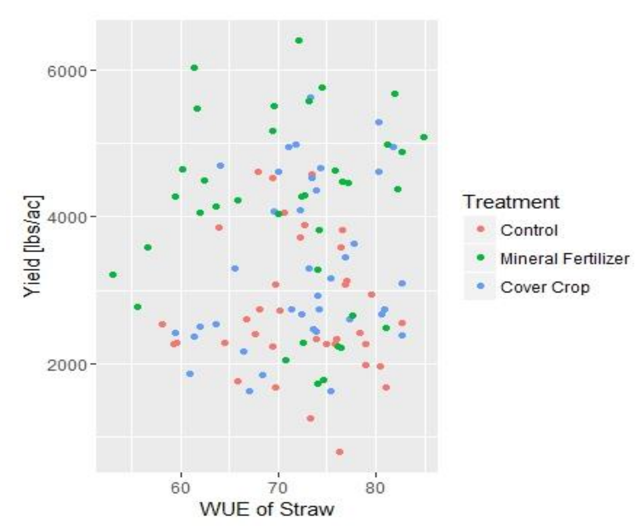


Figure 3. (Left) No relationship between carbon discrimination, PDSI category, and yield. Carbon discrimination, in moles ‰, PDSIcat are the categorical separations of the Palmer's Drought Severity Index. (Right) No relationship between water use efficiency (umols C/mol H_2O) and yield. Both models were non-parametric, neither ANOVA nor cluster analyses were done.

Water use efficiency (WUE) is unrelated to yield

WUE is the amount of carbon assimilated per amount of water transpired, and it is directly related to $D^{13}C$. Lower WUE values are expected to have lower yields. The **expected trend is not upheld** in this dataset.

NITROGEN FERTILIZATION IINCREASES YIELDS

Mineral fertilizer and cover crops treatments increase yields over time and **new cultivars do not increase yields**.

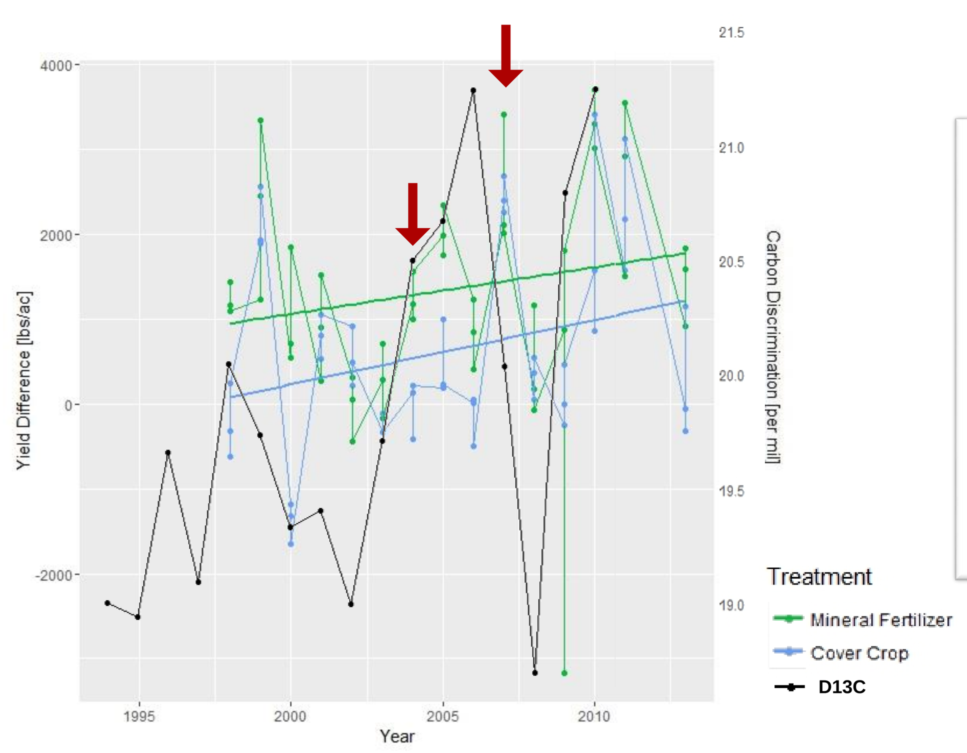


Figure 4. (Left) The yield of each treatment is subtracted from the average control yield within each year. The graph shows that both mineral fertilizer and legume cover crop additions produce higher yields than the control over time ($p=1.56x10^{-5}$ and p=0.025, respectively) . $D^{13}C$ does is non-parametric, however spread of Figure 3 indicates it is not correlated to yield. Red arrows point out the year of new cultivar introductions. The graph indicates that cultivar has no effect on yield over time. (Right) Soil moisture expected effect. All rights reserved. Emberson 2016.