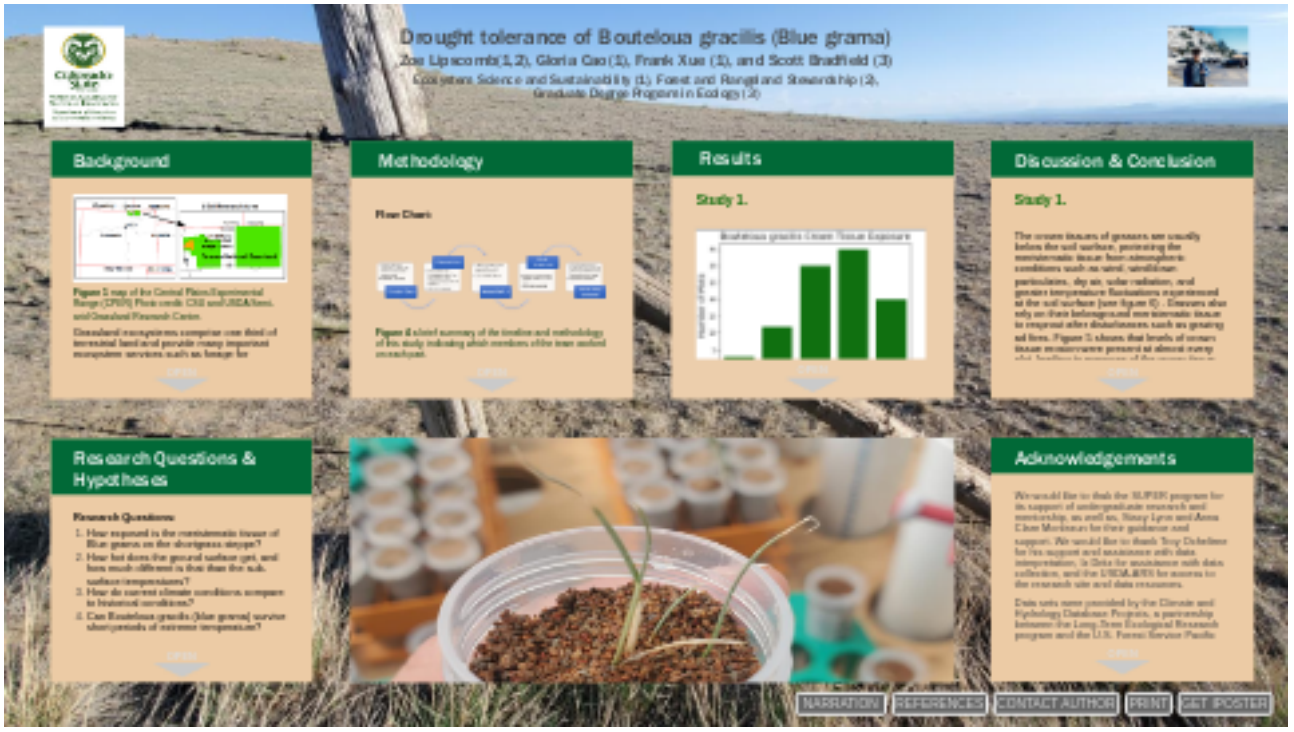
Drought tolerance of Bouteloua gracilis (Blu grama)



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COLORADO STATE UNIVERSITY

CELEBRATE UNDERGRADUA
RESEARCH AND CREATIVI

BACKGROUND

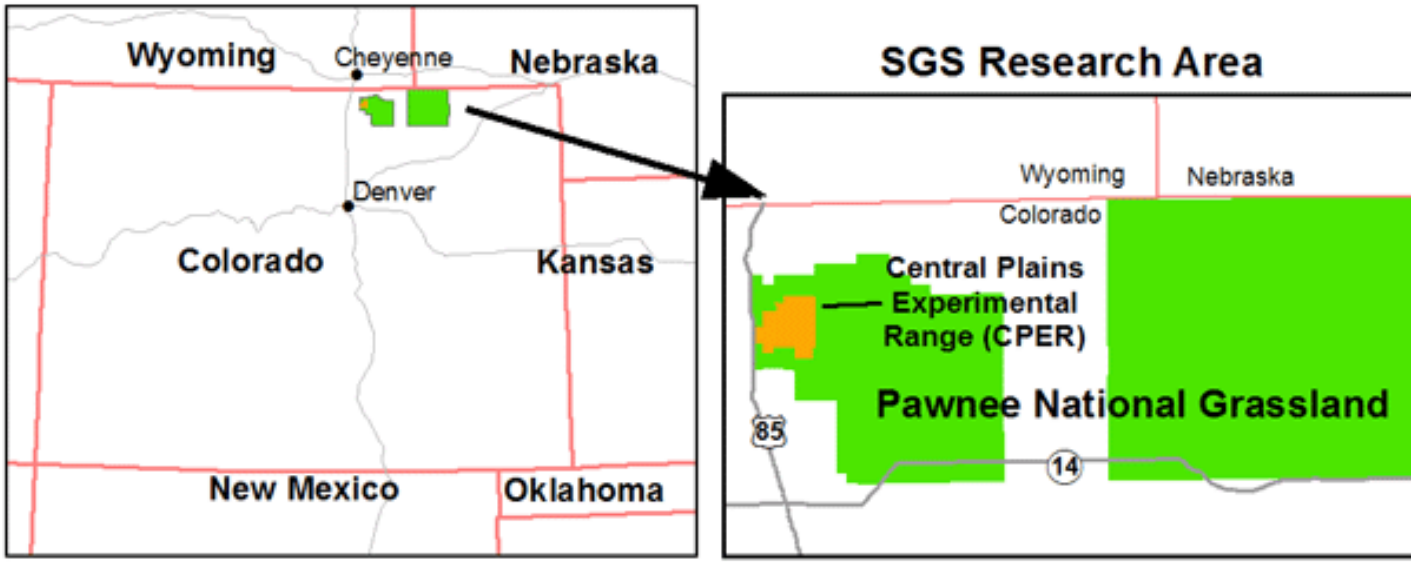

Figure 1 map of the Central Plains Experimental Range (CPER) Photo credit: CSU and USDA Semi-arid Grassland Research Center.

Grassland ecosystems comprise one third of terrestrial land and provide many important ecosystem services such as fo for livestock, native herbivores, and support biodiversity.[1,2] In Colorado, the livestock industry makes up 67% of the t agricultural income[3], and the productivity of perennial grasses on the shortgrass steppe are necessary to support this agriculture.

By the end of the century, it is predicted that drought intensity and frequency will increase in the Central U.S [4], and much of the shortgrass steppe in the U.S. is located in areas that will experience an increase in temperature of 2.5-4.3 ° during this timeframe[4].

Grasses are able to regrow quickly after disturbances and stresses, partially because their meristems are kept under the surface, protected by the crown tissues. These tissues are the location from which new growth is initiated, and because they are located beneath the soil surface, they are protected from disturbances and harsh atmospheric conditions. Howe heavy grazing treatments can lead to erosion[5], which can cause the crown tissues to be exposed above the soil surface (figure 2).

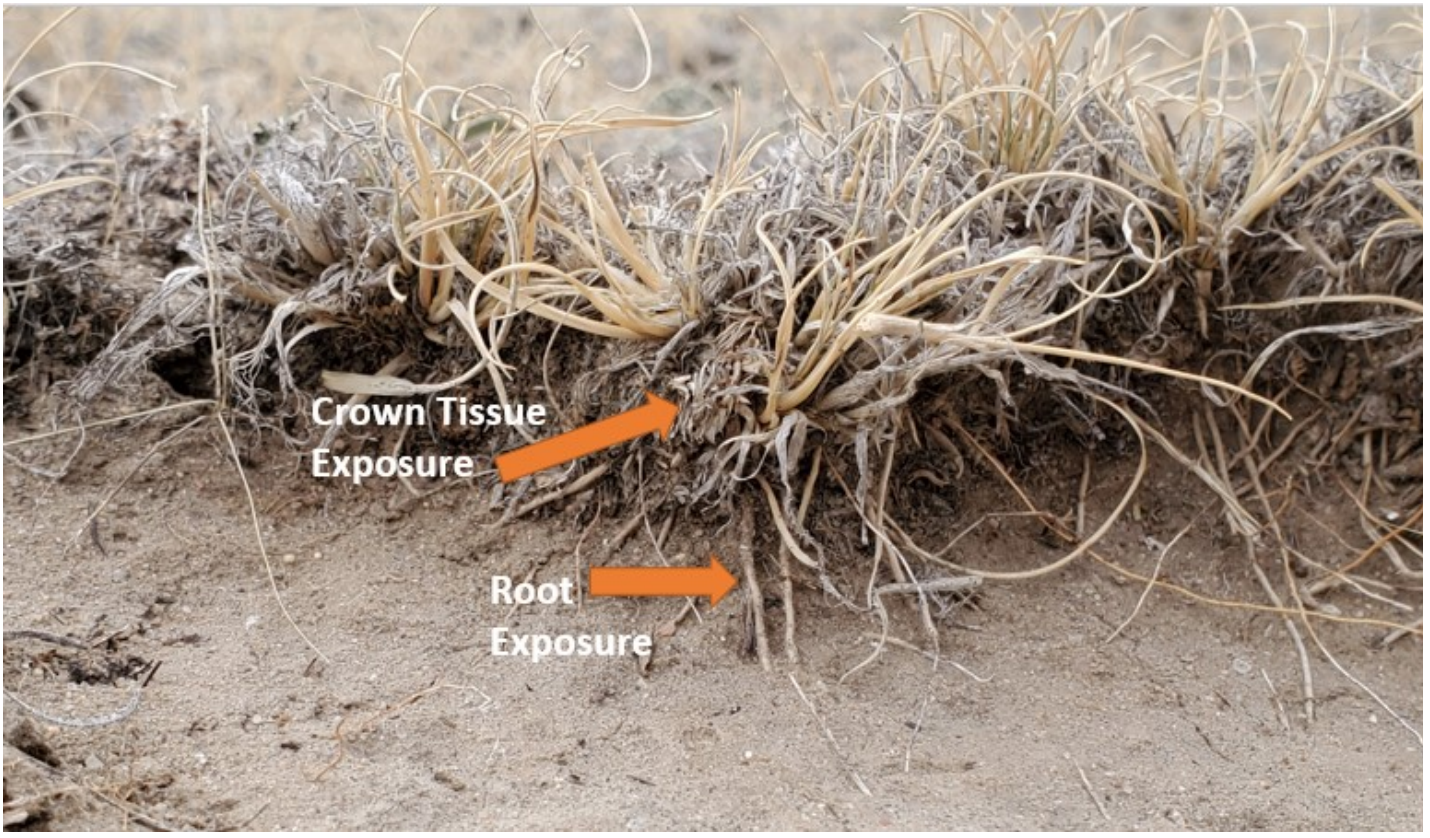

Figure 2 a visual of crown tissue and root exposure of Blue grama, the dominant perennial grass on the shortgrass steppe in Northern Colorado. Photo captured by Bradfield and edited by Lipscomb.

Drought conditions cause a combination of drought and water stress in plants, leading to increased levels of mortality. There is a knowledge gap on the responses of perennial grasses subjected to a combination of heat and water stresses. Moreover, the majority of previous research focused on woody plants, which have different adaptations and thresholds relation to drought stress[1,6]. As drought prevalence and severity increase, it is important to understand how the combination of these variables will affect common perennial grasses.

The crown exposure data, and grass test subjects were collected at the Central Plains Experimental Range (CEPR) (see figures 1 and 3). This site has been highly managed under the same grazing treatment for 75 years, and data records ha been kept throughout this timeframe. The results from studies at this site can be generalized across semi-arid perennial grasslands.

Figure 3 a landscape view of the Central Plains Experimental Range field site. Photo captured by Scott Bradfield

METHODOLOGY

Flow Chart:

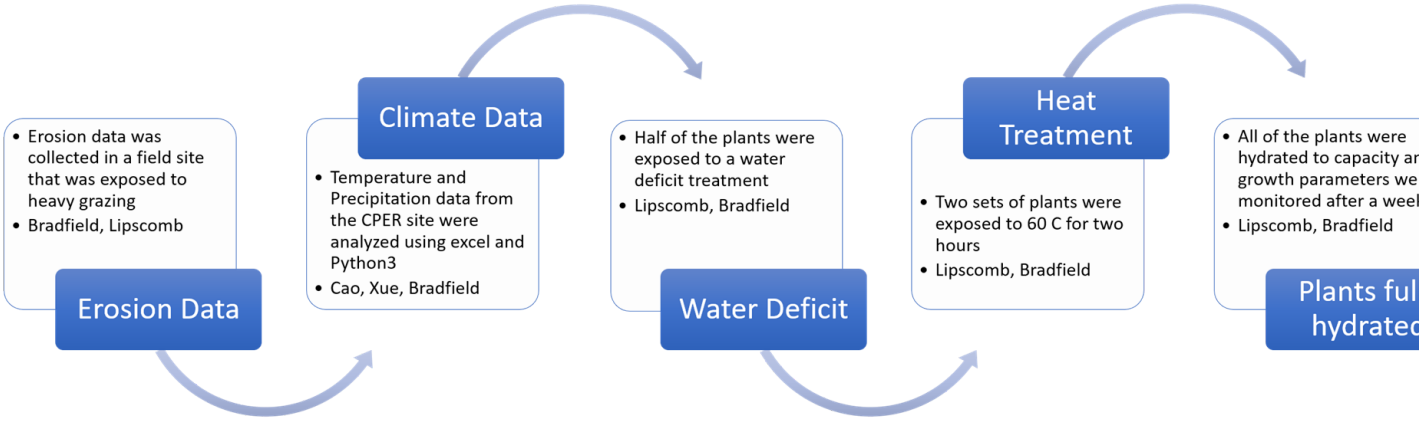

Figure 4 a brief summary of the timeline and methodology of this study, indicating which members of the team worked on each part.

Summary of Methods

Study 1: Crown and root tissue exposure (Lipscomb and Bradfield):

- Data was collected at the Central Plains Experimental Range (CPER) in Northern Colorado (see figure 1)
- The data was quantified using a numerical system to represent the prevalence and severity of erosion.
- Plots with an area of 0.125 m^2 were established every 10 m along 100 m transects; there were 5 transects in both an upland and lowland area and transects within each region were spaced 10 m apart
- Visual estimations were used to determine the ranking for severity of exposure

Study 2: Climate data analysis (Cao, Xue, and Bradfield)

- Data were obtained from National Ecological Observatory Network, USDA Ag data commons, USDA-NRCS Soil Climate Analysis Network, and Climate and Hydrology Database Projects[7,8,9,10]
- The data were analyzed by removing missing data fields, aligning data across databases (based on date and time), consolidating data, and generating visual representations
- Statistical analysis consisted of two-way ANOVA's and regressions performed with Spyder 4.5 (Python3.7)

Study 3: Drought Tolerance Study (Lipscomb and Bradfield):

- Samples of Blue grama were collected from CPER, and these grasses were kept fully hydrated in the CSU foothills greenhouse until they had come out of dormancy.
- Tillers were separated from ramets (groups of genetically identical tillers), creating two/three groups of genetically identical replicates. Each of these replicates received a different stress treatment.
- 50L falcon tubes with 35 g of fritted clay
- Plant roots were cut to limit root depth and ensure consistency between individuals[11], and the plants were potted in 50mL falcon tubes with 35 grams of fritted clay.
- All plants received an unintentional water deficit stress due to inclement weather conditions. After this, half of the plants were rehydrated while the other half were left dehydrated. Half of each of these groups were subjected to the heat treatment.
- Following this initial stress, half of the plants were fully hydrated in preparation for the heat stress treatment.
- Growth parameters of each plant were measured prior to and one week after heat treatment. These consisted of plant height, number of leaves, and number of tillers.
- A heat stress treatment was imposed by exposing half of the saturated and water deficit plants to a temperature of 60°C for two hours, a length of time determined during the climate data analysis conducted by Cao and Xue.
- Following the heat treatment, the plants were fully hydrated.
- The data were analyzed by Bradfield using Spyder 4.5 (Python3.7)

RESULTS

Study 1.

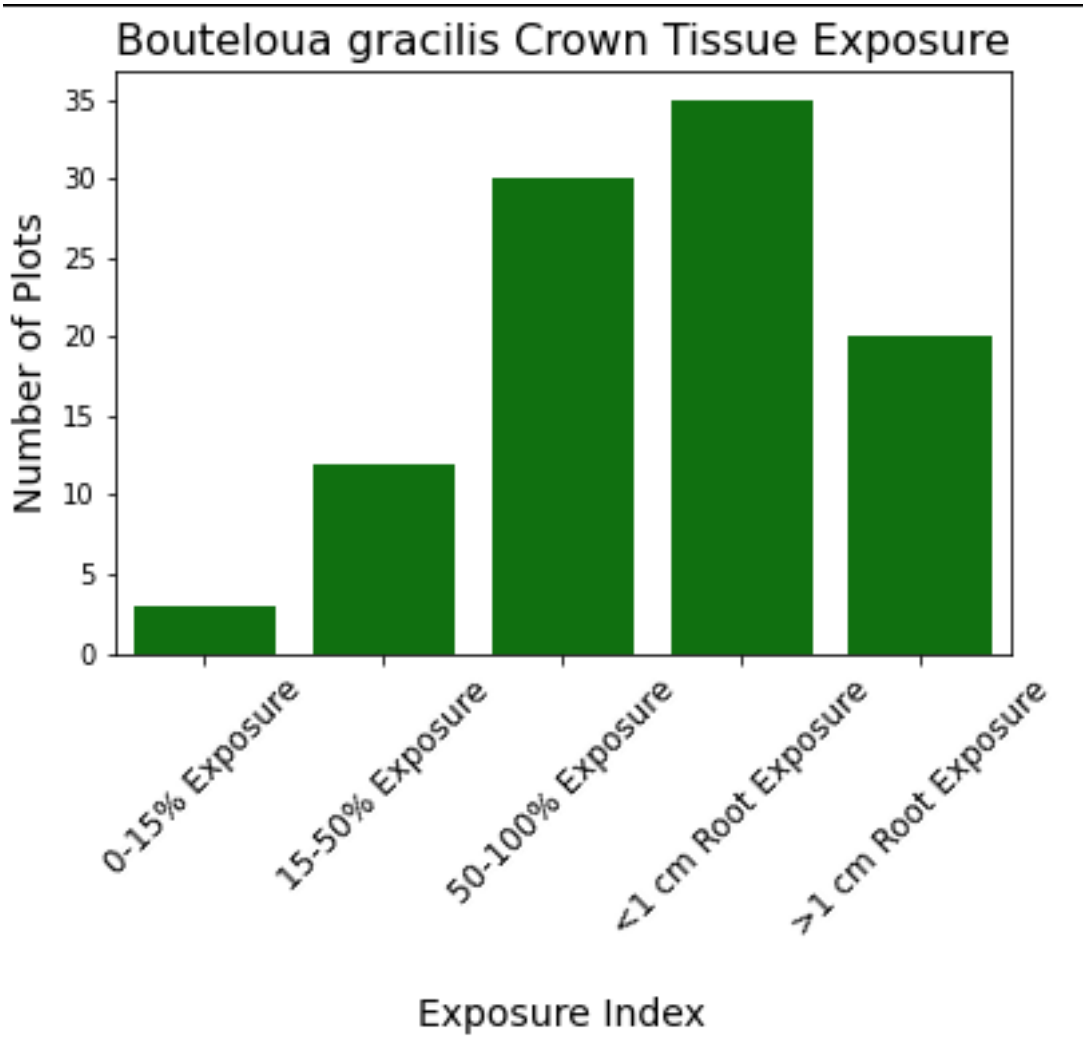

Figure 5. The occurrence of microsite erosion presence in plots based on visual quantification of plots established within a heavy cattle grazing treatment at the Central Plains Experimental Range (n=100). The horizontal axis shows the presence and degree of exposure.

Almost all plots showed some degree of erosion, in which the crown tissue for Blue grama is above the soil surface, exposing the meristematic tissues to conditions it is normally protected from under the soil surface. While crown expos was often experienced by the majority of the plant, the root exposure only occurred along the edge of the plant.

See visual examples of crown and root exposure in the slide deck at the bottom of the poster, and in figure 2.

Study 2.

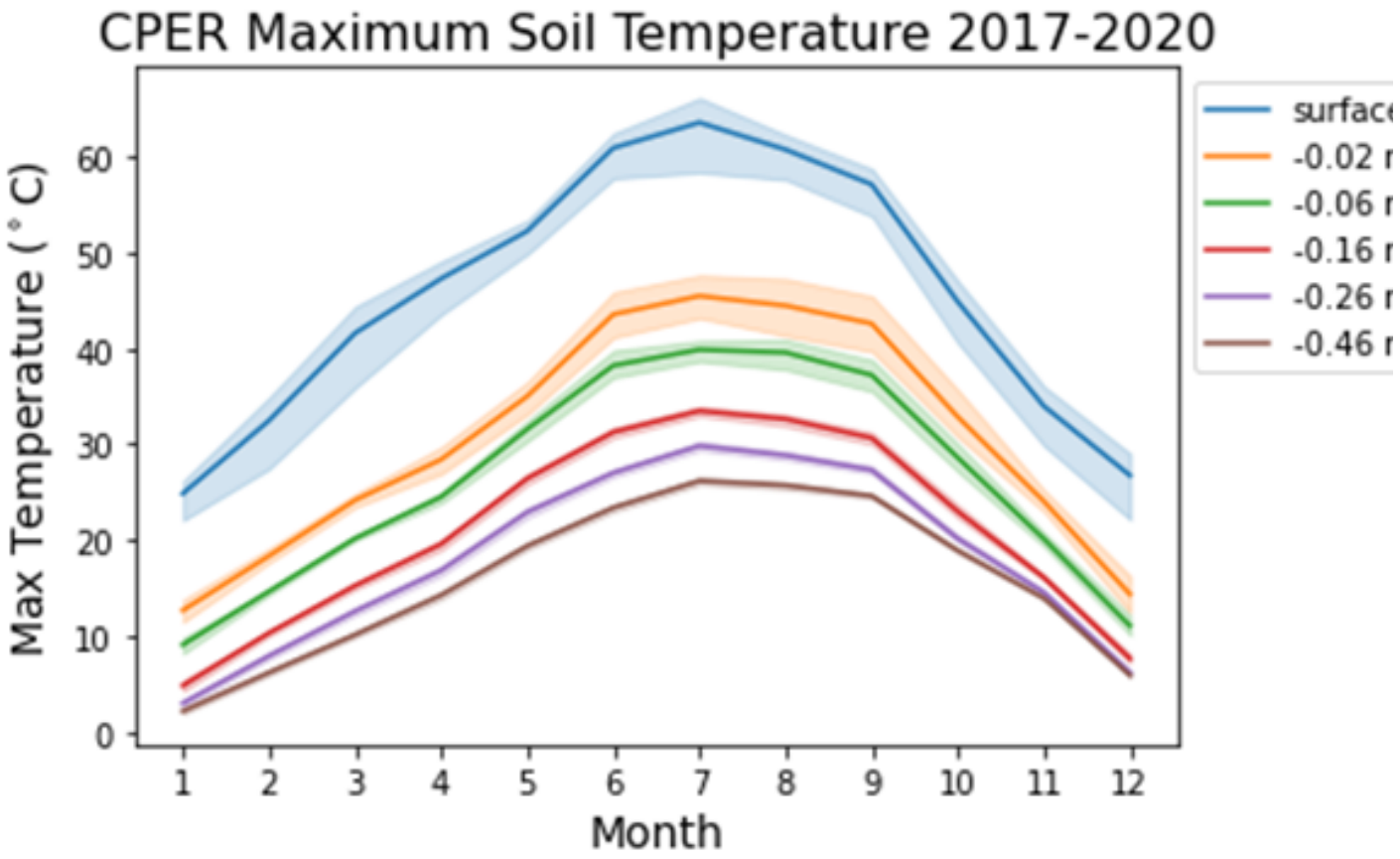

Figure 6. The maximum temperature experienced at the soil surface and within the soil profile for CPER.

Temperatures at the soil surface were hotter than temperatures just 2 cm beneath the surface, and heat steadily decreas with depth in the soil profile.

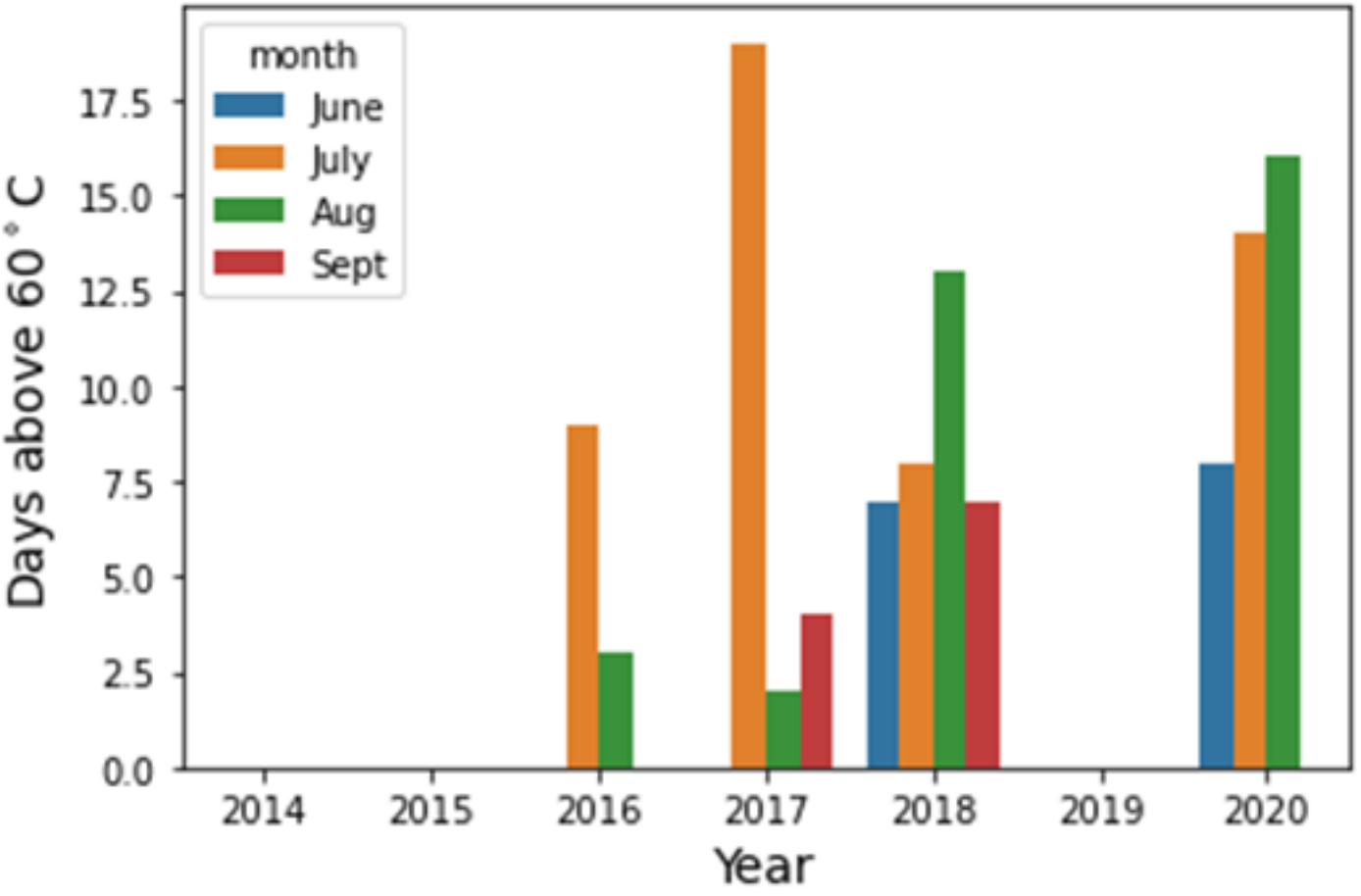

Figure 7. Number of days per month that experienced temperatures greater than 60°C at the soil surface.

Extreme temperatures (of 60°C) were experienced throughout the entire growing season, which suggested that warm season grasses experienced extreme temperatures at nearly every phenological stage.

Days that experienced 60 degrees did not occur every year, but can occur frequently within a growing season. Also, fi 7 showed that the number of days that experience temperatures above 60 are increasing.

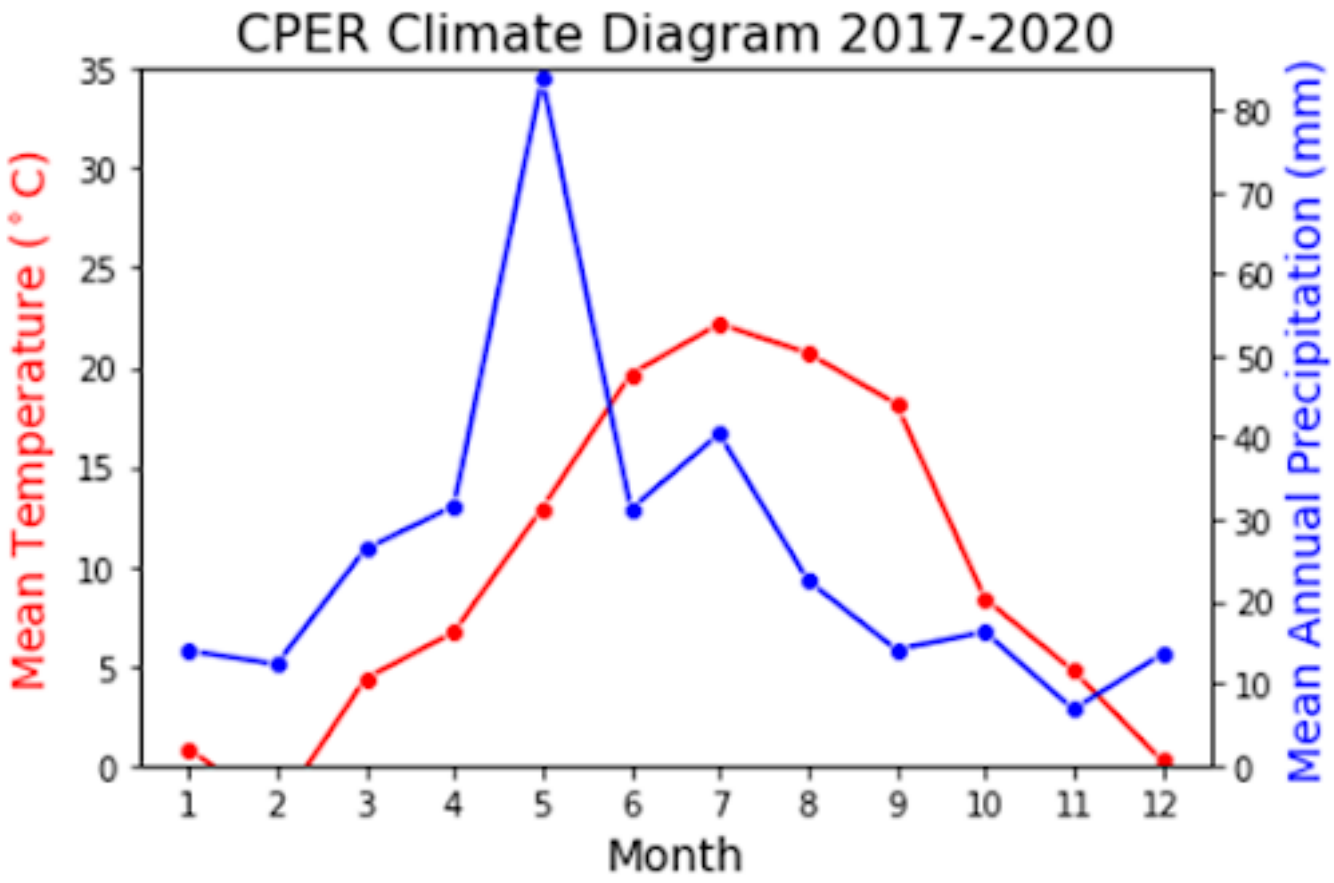

Figure 8. Short term climate data showing monthly averages for temperatures and precipitation of Shortgrass Station 11 from 2017 to 202((CLIMDB, 2021).

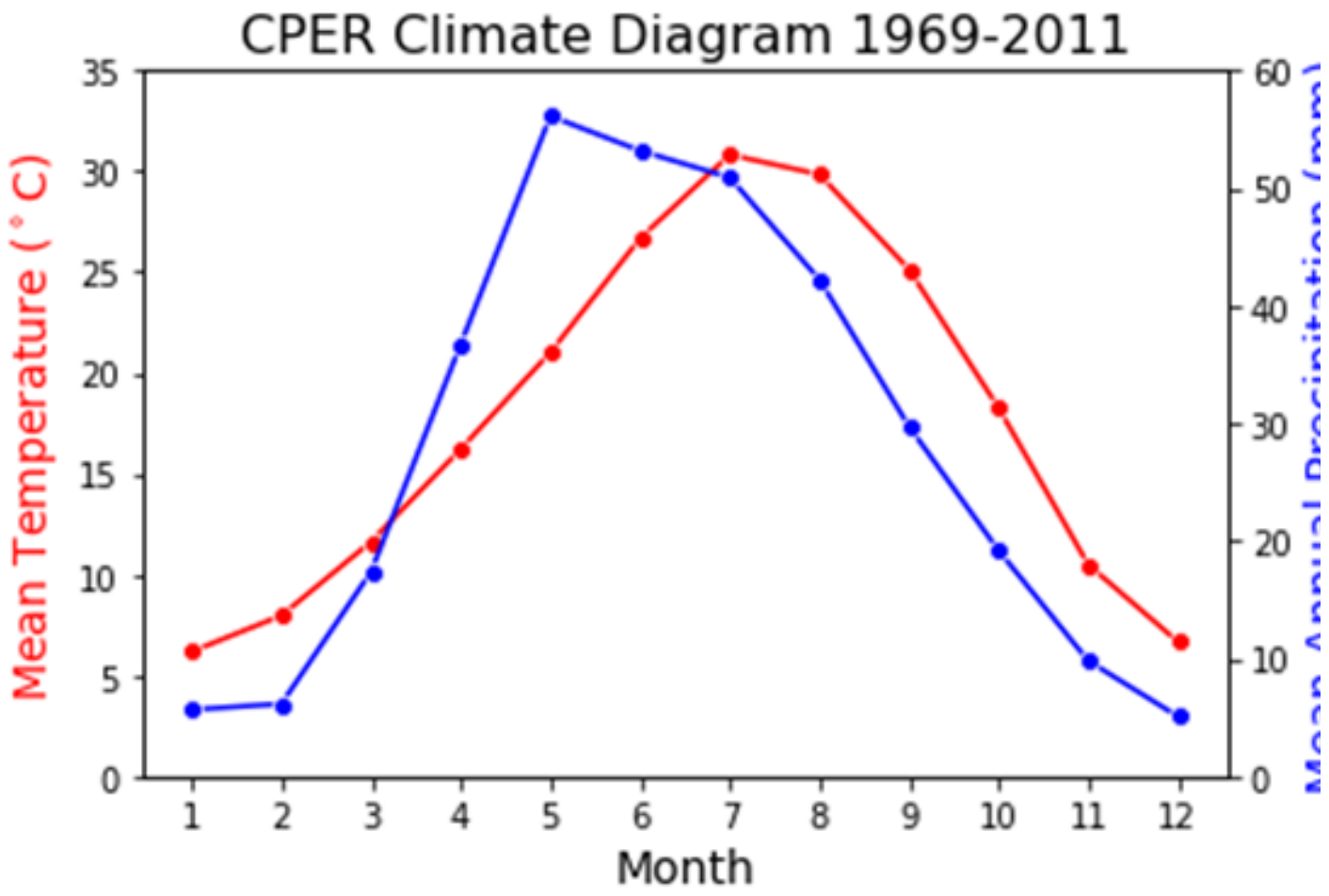

Figure 9. Long term climate data showing monthly averages for temperature and precipitation of Shortgrass Station 11 from 1969 to 2011 (CLIMDB, 2021).

In recent years, May experienced the greatest amount of precipitation, with a sharp decrease in June and July (see figu 8), compared to historic data which showed high levels of precipitation in May, June, and July (see figure 9).

Study 3:

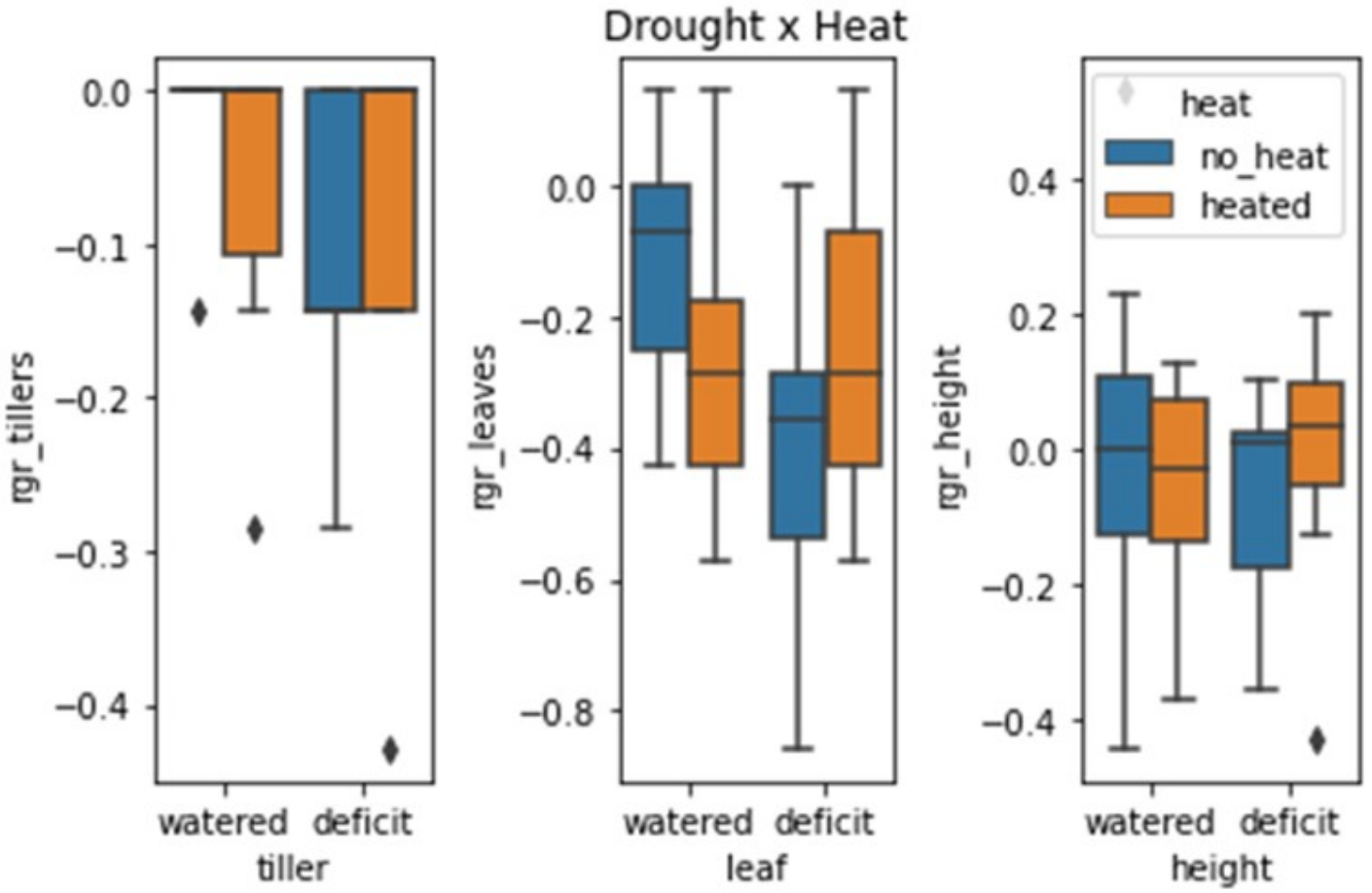

Figure 10. The relative growth rate of Bouteloua gracilis following the combinations of water and heat treatments.

This study found no statistical relationship between the interaction of heat and water stresses on plant growth. No plant developed new leaves or tillers in the week following the heat and water stress treatments. While there were slight increases or decreases in height, the mean was close to zero for all treatments.

Following the heat and water stresses, high levels of mortality were observed across all treatments, as the initial water stress that the plants experienced seemed to result in a high rate of mortality

DISCUSSION & CONCLUSION

Study 1.

The crown tissues of grasses are usually below the soil surface, protecting the meristematic tissue from atmospheric conditions such as wind, windblown particulates, dry air, solar radiation, and greater temperature fluctuations experien at the soil surface (see figure 6) . Grasses also rely on their belowground meristematic tissue to resprout after disturban such as grazing ad fires. Figure 5 shows that levels of crown tissue erosion were present at almost every plot, leading t exposure of the crown tissue, and in over half of the plots, roots of Blue grama individuals were also exposed.

After observing this exposure, it is important to know the conditions that the crown tissue will experience above the so surface determine if it is capable of surviving under conditions where it has been exposed.

Study 2.

The comparison of long term and short term climate data showed that the amount and timing of precipitation during th growing season is changing. While historically May, June and July were the months that received the most precipitatio (see figure 9), between 2017 and 2020, there has been a slight increase in precipitation during the month of May, and l in the months of June and July (see figure 8).

The climate data suggests that the soil surface and aboveground vegetation regularly experienced temperatures of 60°C (figure 7), showing that the plants living on the shortgrass steppe can likely withstand temperatures greater than 60 degrees, which is usually considered the maximum temperature for plant cell survival[12]. However, these temperatures only result in the death of aboveground vegetation, which the grasses would be adapted to given their tolerance to defoliation. However, the exposure of the crown tissue may result in heat induced mortality.

Study 3.

The data showed no significant correlation between the heat and water treatments on growth. The water deficit of all plants prior to the treatments likely caused high mortality rates. This suggests that at early phenological phases, Blue grama has a low dehydration tolerance. The data suggested a high level of mortality due to water stress, however the plants will need to be monitored for a longer period of time before coming to a definitive conclusion, as the buds could recover and stimulate new growth.

Limitiations:

During this study, the grasses were not kept at sufficient water saturation after they were transplanted. The saturated treatments were fully hydrated but had been exposed to a brief water deficit, as a snow storm restricted access to the facilities. The plants had a very low rooting depth and couldn't access water past the first couple centimeters of soil in falcon tubes. Time was another limitation, as the results may have been more conclusive if the study had monitored growth for longer than a week following the treatment. The grasses are currently being monitored, and the research tea will continue to measure growth parameters for two months.

Conclusion:

The majority of grasses are showing some kind of crown exposure, and the number of days with extreme heat are increasing, however this is only based on a 6-year data set. The combination of these two factors will likely lead to the mortality of a greater number of tillers. While this wasn't shown experimentally, the results of the third study did show the dehydration tolerance of the dominant species (blue grama) seems to be very low, and likely relies on access to dee soil water.

Moving forward, the research team will repeat the experiment using the knowledge gained from this preliminary study test for dehydration tolerance[1]. Additionally, the heat treatment will be repeated without the initial heat treatment and v expand to include phenology and additional heat treatments at higher temperatures.

RESEARCH QUESTIONS & HYPOTHESES

Research Questions:

1. How exposed is the meristematic tissue of Blue grama on the shortgrass steppe?
2. How hot does the ground surface get, and how much different is that than the sub-surface temperatures?
3. How do current climate conditions compare to historical conditions?
4. Can Bouteloua gracilis (blue grama) survive short periods of extreme temperature?

Hypotheses:

1. There will be crown tissue exposure
2. The surface temperature will be much higher than the subsurface temperatures.
3. Current climate conditions will be different than the historical average, especially in terms of precipitation.
4. Blue grama will have an increased mortality rate after being exposed to short-term extreme heat.

Study 1 addressed the first research question, **study 2** addressed second and third research questions, and **study 3** addressed the fourth research question.

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REFERENCES

1. Volaire, F., Lens, F., Cochard, H., Xu, H., Chacon-Doria, L., Bristiel, B., Balachowski, J., Rowe, N., Violle, C., Picon-Cochard, C. (2018). Embolism and mechanical resistances play a key role in dehydration tolerance of a perennial grass Dactylis glomerata L. Annals of Botany, 122(2), 325–336. https://doi.org/10.1093/aob/mcy073
2. Poirier, M, Durand, J.l., Volaire, F. (2012). Persistence and production of perennial grasses under water deficits extreme temperatures: Importance of intraspecific vs. Interspecific variability. Global Change Biology, 18, 363 3646. https://doi.org/10.1111/j.1365-2486.2012.02800.x
3. Colorado Agricultural Statistics. (2020). United States Department of Agriculture.
4. IPCC. (2007). International Panel of Climate Changes. Cambridge University Press, Fourth Assesment Report (AR4).
5. Belsky, A.J., Blumenthal, D.M. (2002). Effects of Livestock Grazing on Stand Dynamics and Soils in Upland Forests of the Interior West. Society for Conservation Biology, 11(2), 315–327. https://doi.org/10.1046/j.1523-1739.1997.95405.x
6. Balachowski, J.A., Bristel, P.M., Volaire, F.A. (2016). Summer dormancy, drought survival and functional reso acquisition strategies in California perennial grasses. Annals of Botany, 118, 357–368. https://doi.org/10.1093/aob/mcw109
7. Cove Sturtevant, David Durden, Stefan Metzger (2021), AmeriFlux US-xCP NEON Central Plains Experiment Range (CPER), Ver. 3-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1579720
8. USDA-ARS Rangeland Resources and Systems Research. CPER Precipitation-Headquarters. Monthly Precipit Totals. https://www.ars.usda.gov/plains-area/fort-collins-co/center-for-agricultural-resources-research/rangelan resources-systems-research/docs/range/misc-pages/cper-precipitation/
9. Climate and Hydrology Database. https://climhy.lternet.edu/
10. USDA-NRCS SCAN. https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=2197
11. Volaire, F. (2008). Plant traits and functional types to characterise drought survival of pluri-specific perennial herbaceous swards in Mediterranean areas. Science Direct, 29(2–3), 116–124. https://doi.org/10.1016/j.eja.2008.04.008
12. Dickinson, M.B., and Johnson, E.A. 2004. Temperature-dependent rate models of vascular cambium cell morta Can. J. For. Res. 34: 546–559.