

ASSESSING SEED DENSITY OF BLUE WILDRYE (*ELYMUS GLAUCUS*) FOR
RESTORING NATIVE FLORA IN BURN PILE SCARS
IN NORTHERN CALIFORNIA

A Thesis

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by

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DEDICATION

This thesis is dedicated to my friends and family, whose unwavering support and encouragement have been invaluable throughout my academic journey. Your belief in me has inspired me to persevere.

I also dedicate this work to the Big Chico Creek Ecological Reserve. May it recover and thrive in the aftermath of the Park Fire, serving as a testament to nature's resilience and the importance of conservation.

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ABSTRACT

This thesis examines the addition of native Blue Wildrye (*Elymus glaucus*) seeds to burn scars left behind after pile burning to aid the establishment of native flora post-fire. To achieve this, piles were built 1.5 meters tall and 1.5 meters wide and burned in the fall of 2023. Piles were composed of various understory species such as Toyon (*Heteromeles arbutifolia*), Deerbrush (*Ceanothus integerrimus*), Grey Pine (*Pinus sabiniana*), Common Manzanita (*Arctostaphylos manzanita ssp. manzanita*), and White-leaved Manzanita (*Arctostaphylos viscida ssp. viscida*). In December of 2023, the half-meter by half-meter quadrat in the center of each burn scar was hand-seeded with four different quantities of seeds: no seed (control), 0.5 grams of seed, 1.0 grams of seed, and 1.5 grams of seed. In May of 2024, all above-ground shoots were collected at each pile; then, they were dried and weighed for the biomass. Tukey multiple comparisons of means test showed significant differences between no addition of seeds and 0.5 gram to 1.5 gram densities at an alpha level of 0.05. This study found that at all densities, adding *E. glaucus* seeds in the burn scars produced more biomass of native vegetation than the control piles. These results suggest that using native perennial grass seeds, such as *E. glaucus*, as a restoration tool positively impacts burn scars. The research contributes to growing knowledge around post-fire restoration practices in oak woodlands.

CHAPTER I

INTRODUCTION

Background

In recent years, the Sierra Nevada foothills in Northern California have had a changed outlook from policies of active fire suppression to using fire as a tool to help prevent future wildfires (Stephens et al., 2007). For decades, the view on fire was suppression, meaning if any fire were to start, it would be put out as soon as possible. Fire suppression efforts by the US Forest Service have cost over 1 billion dollars annually in three out of the last six years (Stephens et al., 2007). The lack of fire from the 20th and 21st centuries throughout the landscapes of Northern California allowed fuels to build up, causing mega-fires, which are larger than typical fires, when fire inevitably spread through the area (Calkin et al., 2015). The increased gap in the fire return interval and the time between fires in a particular area in the Sierra Nevada foothills of Butte County have created the need for more research on fire, fire behavior, and vegetative succession after fire in oak woodlands.

There are a handful of ways a fire can occur on the ground: wildfire, broadcast burn, and pile burns. A broadcast burn refers to intentionally putting fire on the ground in a predetermined area under specific weather conditions to burn excess fuel. This study looked at reseeding Blue Wildrye (*Elymus glaucus*) in the scars of pile burns, piles built out of slash resulting from mechanical or hand thinning of a forest. Theoretically, this study could also be applied to wildfire and broadcast burn scars. Burn piles were chosen for this study because

wildfires can't be easily manipulated, meaning you cannot decide when and where they start, and broadcast burns are not guaranteed to happen and run the risk of being shut down at a moment's notice. However, as of fall 2023, once fire season is officially declared over, a permit is no longer needed to burn on your property, including burn piles in Butte County (California Department of Forestry and Fire Protection, 2024a). Burn piles are piles built out of slash resulting from mechanical or hand thinning of a forest; when these piles are burned, the heat from the fire is concentrated, damaging the soils below and leaving few to no viable seeds (Korb et al., 2004). In a coniferous-dominated forest, burn pile scars take roughly seven years for the plant cover to get back to the state of unburned areas (Halpern et al., 2014). The lapse in vegetation cover leaves the scars susceptible to invasive species that take over the bare soil and out-compete the native species (Korb et al., 2004). Reseeding with native plants post-disturbance leads to long-term species establishment and, at the same time, suppresses the establishment of invasive species (Kerns et al., 2020).

Blue Wildrye (*Elymus glaucus*) is a native California perennial grass that resprouts every spring. It is a rapidly developing bunchgrass that favors disturbances such as burning (Stannard et al., 2005), making it an ideal native plant to seed in this study. It should be mentioned that *E. glaucus* is one of many possible candidates for land management in Northern California. Burn scars that remain bare for decades (Rhoades et al., 2015) need active restoration of native seeds to help promote succession after fire. The results of this study aim to assist property owners in enhancing the ecosystems they live in by recommending how many *E. glaucus* seeds they could place in their burn scars to restore native plant coverage.

Statement of the Problem

Using fire as a fuel management tool has become increasingly popular across the United States since the 1970s after the Forest Service policies shifted to “let-burn” allowing naturally caused wildfires to burn on their own (U.S. Forest Service, 2024a). With fire comes the aftermath, a black burn scar. Burn scars have been shown to leave the area without ground vegetation for years afterward (Creech et al., 2011). There is a gap in the research on fire effects and behavior in California, specifically reseeding in burn or slash piles to restore native flora species in oak woodlands of the Sierra Nevada foothills. This study assesses the optimal density of planting *E. glaucus* seeds in burn pile scars under Black Oak (*Quercus kelloggii*) canopies.

The Big Chico Creek Ecological Reserve conducts pile burns throughout the wildfire offseason, November through May, leaving behind black charred circles on the ground that can be seen driving through the reserve. Land stewards of the reserve cut and burn debris as a fuel management plan. The reserve’s botanist, along with a longtime senior volunteer, started to disperse a mixture of native seeds into burn pile scars after seeing the result of intense fire on the vegetation (M. Bamford & P. Maslin, Big Chico Creek Ecological Reserve, personal communication). In the piles where native seeds, such as *Elymus glaucus* and *Bromus carinatus var. carinatus*, were added, a positive response from native seeds was seen. Although these trials were not rigorously documented, they can be used as starting points for further research.

Purpose of Study

This study measures the optimal density of Blue Wildrye (*Elymus glaucus*) seeds planted in burn pile scars. Scientists in Northern California have done little research on fire restoration efforts. Studies in other western states have shown success in adding native seeds to burn scars to promote native cover (Creech et al., 2011; Albrecht et al., 2022).

Theoretical Bases and Organization

As California starts to switch its fire management strategies from the old suppression tactics to a more recent approach of prescribed burning, there is a need for further research in the field of study. Broadcast burns and pile burns are the common ways to dispose of built-up fuel to mitigate potentially disastrous wildfires. Setting intentional fires is no new concept, as records show California's indigenous people used fire to keep the forest healthy (Purcell & Stephens, 2005). Once a megafire burns through, landscape regeneration can become difficult for native flora. The accumulation of fuels caused by years of fire suppression increases the severity of these megafires, making it harder for vegetation to regenerate afterward. The gap in vegetation following a fire leaves the area susceptible to invasive annual species like Medusa-head (*Elymus caput-medusae*) and Yellow star-thistle (*Centaurea solstitialis*) by creating a bare landscape that is easy for competitive species to dominate (Pyke et al., 2013; Getts, 2021). Reseeding with native species in burn scars is a potential restoration strategy to increase the regeneration of native flora (Creech et al., 2011; Albrecht et al., 2022).

Pile burning is a cost-effective alternative to broadcast burning, which helps reduce unwanted fuels (Delač et al., 2021). Broadcast burns differ from pile burns regarding the resources needed and the amount of landscape being burned. Broadcast burns are defined as intentionally putting fire on the ground in a predetermined area under specific weather conditions to burn excess fuel. In contrast, pile burns are described as the process of collecting woody materials that are produced from cutting understory brush, placing the materials in piles, and then burning the piles. Pile burns often burn for multiple hours with concentrated heat on the soil, raising soil temperatures up to 400 °C and can adversely affect the soils and the previously existing vegetation by changing the soils' pH, phosphorus, carbon, and nitrogen content (Halpern et al., 2014; Creech et al., 2011). The intensity of the burns can damage the roots of existing plants and possibly cause mortality to the seed bank (Creech et al., 2011). The burn severity, however, depends on the piles' construction and the types of fuels used (Busse et al., 2013).

Past studies have shown mixed outcomes from reseeding in burn scars, although most studies have different forest types, pile sizes, seeds used, and treatments. In pine forests, pile burning can lead to fire scars with little to no flora, indicating a possible need for reseeding after conducting pile burns (Creech et al., 2011). In Midwestern oak woodlands, the addition of seeds did increase the native cover and reduced the invasive cover in burn scars in comparison to control locations; this was also found to be true in upper montane forests in Colorado (Fornwalt & Rhoades., 2011; Albrecht et al., 2022). However, in the grasslands of Oregon Cascades, a study found that even without the addition of seeds on the edge of burn scars, only native species came back, which was comparable with adjacent

control areas. Still, the richness of the cover in the scar center was lower (Halpern et al., 2014). Reseeding native plants has the potential to help discourage invasive plants as well as increase native cover in burn scars.

Limitations of the Study

There are a few limitations to this study, one being the short timeline of the study overall. The growing time for the *E. glaucus* is a few months, December through April; the aboveground biomass was collected on May 24th, 2024, just as the *E. glaucus* was seeding. As mentioned earlier, *E. glaucus* is a perennial grass, meaning the aboveground biomass will die off and return year after year (Garnier, 1992). Another possible limitation is the six different locations where the study occurred. The sites are as similar as possible, all on the same aspect (west-facing), with a comparable slope (roughly 5 to 15 degrees) and canopy cover, predominantly consisting of Black Oak (*Quercus kelloggii*), and the vegetation within the piles is also similar. Each pile's location affected fire safety differently, so it was crucial to position them in areas with minimal risk of unwanted fire spread.

Definitions of Terms

I hereby provide definitions of terms relevant to this study.

Active Restoration

A restoration technique where land managers intervene to aid in the recovery of ecosystems.

BCCER

Big Chico Creek Ecological Reserve (BCCER) is a 7,835-acre reserve with diverse canyon and ridge habitats, including 4.5 miles of Big Chico Creek. It is home to many species of plants and animals.

Broadcast Burn

Broadcast burns involve intentionally putting fire on the ground in a predetermined area under specific weather conditions to burn excess fuel.

Burn Scar

The mark left on the ground after a wildfire, broadcast burn, or pile burn, leaving behind black charred vegetation.

Fuel

Any vegetation or materials in a landscape that can be burned. For example, downed trees, logs, dried grass, etc.

Invasive Species

A species not native to BCCER that out-competes the native species, harming the ecosystem's overall health. For example, Yellow star-thistle (*Centaurea solstitialis*).

Megafire

A larger than normal-sized wildfire that is the result of fuel build-up that happens over time in the absence of fire.

Non-Native Species

A species that is not native to BCCER but does not harm native species or the overall health of the ecosystem.

Pile Burn

The process of collecting woody materials that are produced from cutting understory brush, placing the materials in piles, and then burning the piles. The size of the piles varies from organization to organization.

Quadrat

A square frame used in ecology to sample and count organisms within a defined area.

Secondary Succession

Secondary succession occurs when a disturbance is severe enough to remove most, if not all, vegetation from an established ecosystem. For example, when a wildfire moves through a forest, secondary succession occurs, and perennial forbs appear first. Unlike primary succession, which occurs on bare or newly formed land, secondary succession occurs in areas where vegetation can regenerate from remaining surviving seeds or other propagules after a disturbance.

CHAPTER II

LITERATURE REVIEW

Overview

Eighty years ago, there were two outlooks on setting fire to a forest (McCulloch, 1944): the first outlook believed starting fires that leave a clean burn was good for the forest, and the other argued that fire would put the forest at risk for the future and advocated for no fire at all (McCulloch, 1944). This is not shocking; since the late 1800s, Anglo-Americans have been frightened of fires and considered fires destructive and unwelcome forces on ecosystems that do more harm than good (Raison, 1979). However, recently, studies have shown that fire, specifically prescribed fire, is beneficial in reducing wildfire damage (Jose et al., 2023). Intentional burning in forests and high-fire-risk ecosystems reduces long-term hazards, creating a safer environment with less fuel build-up (McCulloch, 1944). Nevertheless, if hot enough, fire can leave the soil without vegetation for over five years (Creech et al., 2011). The addition of native seeds has been found to help ground vegetation recover after an intense fire (Korb et al., 2004). Blue Wildrye (*Elymus_glaucus*) is commonly used in California restoration efforts (Balachowski, 2015). California has seen an increase in wildfires since the average temperatures during summer have risen by 1.4 degrees Celsius since the 1970s (Williams et al., 2019), and due to its ideal fire conditions, with dry and hot summers and various dead fuels, there will be a need to help restore the burned areas (Jose et al., 2023). Looking at fire data

from 2003 until 2017, it was found that California would benefit from increasing the acreage burned in prescribed fires, which would be more cost-effective (Jose et al., 2023).

Pile Burning

Pile burning is a commonly used method for fuel reduction among land managers. Land managers and property owners often have fuel management plans to reduce the number of unwanted fuels, debris, dead vegetation, snags, etc., to reduce the risk of a wildfire (California Department of Forestry and Fire Protection, 2024a). Pile burning consists of making piles from the slash left after a forest is mechanically cut and thinned and then burning the piles (U.S. Forest Service, 2024b). Burning brush and slash in piles allows a contained fire to be made on large and small scales for property owners. Unlike broadcast burns, which are predetermined areas with clear boundaries and appropriate weather conditions where the fire on the ground can move throughout the region, burn piles are contained in a single pile, ideally with no fire movement from the pile itself (Jose et al., 2023). Broadcast burns often move quickly across the landscape, spending minimal time burning a single spot, making the fire lower intensity (Minore, 1986). The opposite occurs with pile burns; the heat of the burn is concentrated on a specific spot of soil, intensifying the fire and potentially damaging the soil, as mentioned in the following section (Minore, 1986). It is important to note that with any fire on the ground, the fuel's composition significantly impacts the burn's severity (Busse et al., 2013), meaning the size and type of materials burning can influence the intensity and energy of the burn.

Pile burning is a cost-effective way to clear unwanted fuels compared to broadcast burns (Delač et al., 2021). It can be done with limited resources outside fire season, roughly

November through May, in Northern California (Cart & Gedy, 2024). Fire season in California is typically April through October (Cart & Gedy, 2024). April is considered the start of fire season because vegetation generally starts to dry out as the summer heat begins. California begins to receive more consistent rainfall in October, and the temperature cools off, signifying the end of the wildfire season. Reducing the fuels on the landscape better prepares the area for future wildfires. Fire suppression efforts, extinguishing any and all fires, made by the US federal agencies from 2000 to 2013 cost over \$24 billion, which does not account for state or local suppression efforts (Calkin et al., 2015). If burning is done to remove invasive plant species and fuels, it is easier to rehabilitate small burn scars compared to large ones from a management standpoint (Rhoades et al., 2015). Burning in piles can also be used to eliminate invasive species on the ground under the piles (Halpern et al., 2014). However, burning with too high-intensity fire can leave the ground bare of all vegetation, leaving it open to invasive plant species to re-establish. It is crucial to know the restoration objectives before burning. Burn pile scars can be bare of vegetation for six years [as found in a study] (Creech et al., 2011). During this period of slowed vegetation growth, competition is diminished, giving invasive species a greater advantage over the native flora (Haskins & Gehring, 2004).

Fire and Flora Relationship

The flora-fire relationship has existed for 400 million years, with evidence of fire first appearing during the Silurian period and the first land plants (Keeley & Pausas, 2022). During the Cretaceous period, there was an increase in the diversification of environments housing plants, leading to an increase in fire activity (Keeley & Pausas, 2022). Flora and fire have co-

occurred for millions of years, leading plants to adapt to the presence of fire. Fire adaptations have been documented from the Cretaceous period and, most recently, the Neogene period (Keeley & Pausas, 2022). These adaptations are still present in species today.

Adaptations are characteristics found in species that provide a fitness benefit (Gittleman, 2022). When applied to fire, they can vary depending on the fire regime standard in their ecosystem. Fire adaptations are categorized into traits that facilitate survival during a fire and support regeneration afterward (Keeley & Pausas, 2022). For instance, woody species like *Quercus spp.* in California have evolved the ability to resprout after fires, responding to frequent fires typical of Mediterranean climates. Another adaptation that is prominent in fire-prone ecosystems is heat-stimulated germination; the germination process is started by heat cracking the more rigid outer shell of a seed in the seed bank, which is common in the Anacardiaceae or the serotinous cone of *Pinus sabiniana* (Pinaceae), which requires heat to open up (Keeley & Pausas, 2022). An additional common trait in fire-prone ecosystems is smoke-stimulated germination. Organic molecules in smoke, specifically butanolides, can trigger germination in various plant species (Keeley & Pausas, 2022). All previous adaptations mentioned above are physiological changes species have undergone to coexist with fire. However, it should be noted that the fire regimes that triggered the adaptations occurred before the increase in the fire return interval due to anthropogenic impacts, and species in fire-prone regions may not be equipped for accelerated climate change.

Soil Effects

Studies have shown that fire can change soil's physical and chemical properties.

Physically, fire exposes the bare mineral soil in the burn scars, leaving the landscape vulnerable to erosion and can make the soil hydrophobic (Alexander, 2022), preventing water absorption. Past studies demonstrate that the chemical composition of soils in the center of burn piles, where the heat is concentrated, and compared to the soils outside of the burn scars, the pH of the soils is significantly increased, and the nitrogen and carbon levels are decreased (Korb et al., 2004). However, nitrogen levels in the top 15 cm of soils burned in a burn pile may increase compared to soils outside the burn scars (Jiménez Esquilín et al., 2007).

Changes in soil chemistry and physical characteristics also impact the seed bank. Burn piles create high-intensity and concentrated fire on the soils beneath them, leading to lower seedling growth than do broadcast burns (Minore, 1986). Intense fires have been shown to produce soil temperatures that are hot enough to cause water loss in the soils, which leads to root death of preexisting vegetation and seed mortality (Jiménez Esquilín et al., 2007). Plant communities rely on the soil and microbial communities found within them, which disappear during intense heat, creating a challenging environment for the re-establishment of plants (Haskins & Gehring, 2004). Soil three meters outside of the burn scar has more viable seeds when compared to soil inside the burn scar and on its edge (Korb et al., 2004). Of the viable seeds that remain, most are of invasive species, which can outcompete native plants, reduce biodiversity, and alter the fire regime (Keeley, 2001). The fire regime encompasses the type of fire (crown or ground), frequency, intensity, and timing (Lambert et al., 2010). In July of 2021,

the Dixie Fire burned for 104 days over 389,837 hectares and across five counties: Butte, Plumas, Shasta, Lassen, and Tehama (California Department of Forestry and Fire Protection, 2022). In the aftermath of the Dixie Fire, the first species to return in the burned areas were medusa-head (*Elymus caput-medusae*), Canada thistle (*Cirsium arvense*), and yellow star-thistle (*Centaurea solstitialis*) (Getts, 2021). Medusa-head (*Elymus caput-medusae*) and yellow star-thistle (*Centaurea solstitialis*) are considered invasive in the BCCER.

Addition of Native Seeds

Burn scars have been shown to take roughly seven years to go from ash and bare mineral soil back to the same vegetation cover as unburned areas when using pile burns as a treatment to resolve conifer encroachment on native grasslands (Halpern et al., 2014), in some cases cutting the total count of species in half (Creech et al., 2011). Studies have been conducted in Arizona, Colorado, Georgia, Missouri, and Oregon on various types of ecosystems, pile compositions, and sizes. One of the five studies referenced (Albrecht et al., 2022) was conducted in the oak woodlands of the Midwest, making this study essential in advancing post-fire seed amendment knowledge as it is the only study conducted in ecosystems similar to the one examined in the present paper. Even in different ecosystems, similar effects were found on the soil and vegetation recovery from burning piles of debris without amendment of native seeds. Burn scars created from pile burning were discovered to have little to no viable plant seeds (Korb et al., 2004), leading to a lack of vegetation and making the soil more susceptible to invasive species with a seed bank composed of mainly invasive seeds. Haskins and Gehring

(2004) found that invasive species were four times more prevalent in burned sites compared to unburned sites, thereby altering the composition of understory vegetation.

In efforts to reduce the abundance of invasive species shown to establish in burn scars, native seeds have been planted after burning. In Arizona (Korb et al., 2004), restoration efforts focused on improving burn scars by planting native species, making soil amendments, and combining both seed and soil amendments. Based on the results, the authors suggest that in severely burned scars, the addition of native seeds aids in the recovery of native plant cover. Another restoration project in Oregon focused on the long-term effects of reseeding native plants in skid trails as well as burn scars in a conifer forest (Kerns et al., 2020). Similar to the previous study in 2004, the results indicate that planting native seeds in disturbed areas can lead to the long-term establishment of those species and decrease the number of invasive species in the area. In Missouri's oak woodlands, where pile burning is commonly employed for fuel management, restoration ecologists compared the passive recovery of burn scars to the active recovery achieved by adding native seeds (Albrecht et al., 2022). Passive recovery would allow the burn scar to recover over time without intervention, whereas active recovery involves intervention on biotic and abiotic levels (Atkinson & Bonser, 2020). The addition of seeds increased the native plant cover by roughly 70 percent, further suggesting that the addition of native seeds can promote the establishment of native cover in burn scars. More specifically, seeds of perennials such as *E. glaucus* are more likely to become established and they have a remarkable ability to stabilize the surface soils, retain nutrients, and to facilitate nutrient cycling (Menke, 1992). In Southern Oregon, the addition of perennial grasses was examined after a fall and spring burn as well as seeding after no burn, and it was found that following a fall burn, the

establishment of the grasses was successful, including *E. glaucus* (Coulter et al., 2010). Not only did *E. glaucus* have the most significant increase in cover after the fall burn, out of the three perennial grasses in this study, but the presence of perennial grasses reduced invasive cover significantly.

Addition of Blue Wildrye (*Elymus glaucus*)

Elymus glaucus is a perennial bunchgrass native to North America. It is commonly used in restoration efforts and is found in every region of California except the low desert (California Native Plant Society, 2024; Balachowski, 2015). The Sierra foothill populations of *E. glaucus* has significantly higher standardized biomass recovery post-drought, compared to coastal populations (Balachowski, 2015), suggesting greater drought tolerance. The Sierra Nevada foothills populations have a deeper root system than the four other *E. glaucus* populations, allowing access to soil moisture, which is unavailable to other species, including invasive annual grasses. Deeper and more extensive root systems are a common trait of perennial grasses (Garnier, 1992). As climate change increases the overall temperature in California, so does the number of invasive annual species, which can adapt quickly to new warmer grasslands (Finch, 2021); it is crucial to mitigate this by planting drought-tolerant native perennial species (Balachowski, 2015).

Six different Poaceae species and their germination rates were observed when exposed to smoke-water containing butanolides (Ely, 2016). Out of the six species, only *E. glaucus* had significantly increased germination after being exposed to smoke, suggesting *E. glaucus* responds positively to fire. As the number of prescribed fires increase in Butte County (Jiang,

2024), it is essential to note that *E. glaucus* is a fire-tolerant species; smoke increases seed germination, it is drought tolerant, and it can compete with annual invasive species.

Wildfires can be destructive when fuels are allowed to build up over time, leaving behind scorched landscapes that can lie barren for years, resulting in ecological and economic damage. Pile burning is a more feasible route of prescribed fire, which is more cost-effective and can be done by land managers and property owners. However, the intensity of burn piles can leave the soils depleted of nutrients and barren of seeds, leaving them vulnerable to invasive species. Fortunately, studies have tested and confirmed that adding native seeds into burn scars has been shown to reduce the establishment of invasive species and help promote the return of native cover. This study seeks to build on existing research by demonstrating that adding native *E. glaucus* seeds enhance the recovery of native flora in burn scars.

CHAPTER III

METHODOLOGY

Overview

This study aimed to measure the biomass and growth of Blue Wildrye (*Elymus glaucus*) in burn scars. From December 2023 to June 2024, the growth was monitored bi-weekly and quantified by aboveground biomass. This chapter will cover the study's population, experimental design, different treatments, experimental limitations, and the statistical tests used.

Population

The sample population used in this study is *E. glaucus* at BCCER in Butte County, California. *E. glaucus* was chosen as the species because it is a native perennial grass that is already found in BCCER. A perennial grass is the optimal species choice due in part to its ability to reach maturity within a year (Luna et al., 2008). Unlike an annual grass, it is established and returns year after year. *E. glaucus* is a generalist that can grow in varying types of soils and canopy cover (Stannard et al., 2005; Balachowski, 2015; Majerus, 1997) with deep soil roots, making it a suitable species for burned soils. Some sites used already had *E. glaucus* present. The seeds used in the study were collected by hand by stripping the seeds off the seedhead located on the stem (Cooper & Atkins, 1957) at BCCER on August 18th, 2023. Seeds were

haphazardly collected when they became light tan, and the florets were weak, making the seeds easy to remove.

Experimental Design

The study site is BCCER in Forest Ranch, California, just east of Chico. The reserve is roughly 3,200 hectares of diverse canyons and ridge habitats, with elevations ranging from 200 to 610 meters above sea level and numerous species of flora and fauna. The ecological reserve prides itself on supporting the educational mission of California State University, Chico, by providing a site with natural resources to support research, teaching, conducting public outreach, and education. Chico State Enterprises, the non-profit research auxiliary that serves the mission of Chico State, currently owns the land. Still, it should be acknowledged that BCCER is on land that historically belonged to the Mechoopda Tribe.

All six site locations at BCCER (see Figure 1 below) are on the eastern side of Big Chico Creek, which runs through the reserve. The six sites are located under a majority California Black Oak (*Quercus kelloggii*) canopy, on a West-facing aspect and of a similar slope of 5-15 degrees. California Black Oaks are deciduous oaks, meaning their leaves will drop during the winter. However, the piles were constructed from October 16th through October 30th before the oaks dropped their leaves. They were located under 90 to 100 percent canopy cover and at least six meters from each other.

The piles themselves were constructed using materials cut at each site from the understory vegetation consisting of mostly Toyon (*Heteromeles arbutifolia*), Deerbrush (*Ceanothus integerrimus*), Grey Pine (*Pinus sabiniana*), Common Manzanita (*Arctostaphylos manzanita ssp. manzanita*), and White-leaved Manzanita (*Arctostaphylos viscida ssp. viscida*). To make the study applicable to all homeowners, land managers, and property owners, the piles were 1.5 meters in width and 1.5 meters in height; when the pile reached 1 meter in height, a sheet of forestry paper, a large sheet of waxed paper, was placed, covering the entire top of the pile. Forestry paper was used during pile construction to keep the heart of the pile dry if it rained before the piles were burnt. Piles were kept 1.5 meters by 1.5 meters to make the results of this study applicable to homeowners who cannot build piles any larger without permits (California Department of Forestry and Fire Protection, 2024a). Woody materials over 7.5 centimeters in diameter were not added to the piles; these materials are classified as 100-hour fuels (see Table 1). It is vital to avoid building piles on stumps near the base of trees and to position piles at least six meters apart (Dunning, 2019). I started with small kindling and fine fuel when building the heart of the pile, then layered larger materials, making sure to alternate the direction of the fuels; after the pile was one meter in height, a large sheet of forestry paper roughly two meters by two meters was placed and I finished the pile with larger, heavier fuels to keep the pile compressed.

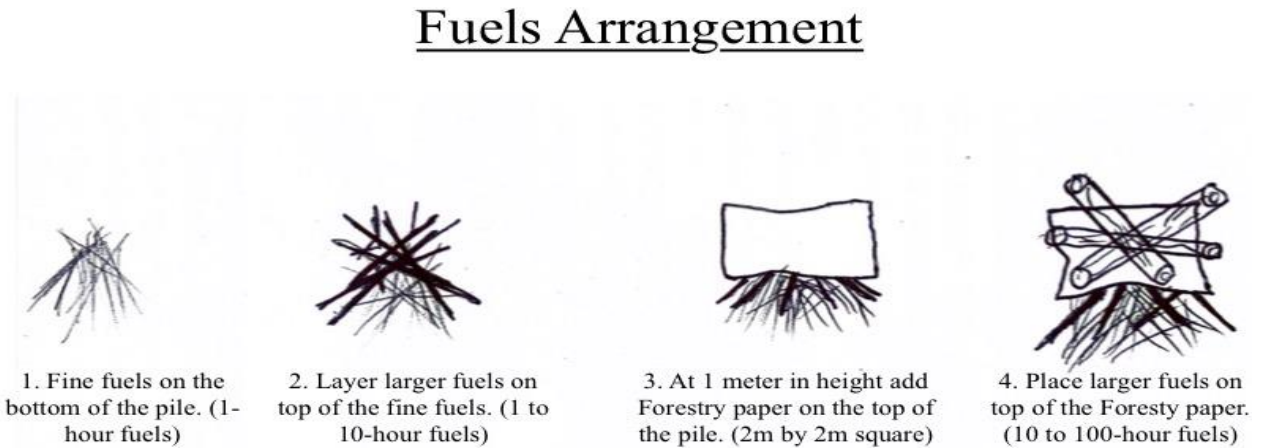
Table 1. Fuel Class

Table of fuels class describing the size and impact on fire behavior fuels have. The fuel category refers to how long in hours the fuel could stay ignited. The table has been converted from inches into centimeters. The table is made based on a fuels chart from Oregon State University (Cowan et al., 2023).

Fuel Category	Diameter (centimeters)	Description	Impact on Fire Behavior
1-hour	Less than 1	Needles, twigs, moss, lichens, small shrubs and grasses	Easily ignitable, these fuels facilitate the initial spread of fire and help heat and ignite larger fuels. In dry conditions, they are considered flashy, allowing surface fires to spread rapidly.
10-hour	1 - 2.54	Small branches and shrubs	Facilitates the spread of fire and the heating and ignition of larger fuels. In extremely dry conditions, fires can spread rapidly.
100-hour	2.54 – 7.62	Medium-sized branches	Aids in the spread of fire as well as the heating and ignition of larger fuels.
1,000-hour	7.62 – 20.32	Large branches and small logs	Supports fires spread. Leads to a longer duration of fire and intensity, depending on the amount in the area.
10,000-hour	Greater than 20.32	Large, downed logs that are solid or slightly decayed	Catches fire after initial fire has passed. Does not increase the spread of fire, but can increase the duration, burning hours after initial burn. High fuel loading, like that from beetle-killed trees, can lead to widespread fire severity, increased control difficulties, and longer burning duration.

The piles were burned on November 15th and on November 27th. Small pieces of pitch wood were the only fuel added to the piles to ignite them. Pitch wood or fatwood is wood harvested from cut pine stumps with high quantities of sap or resin, making it easy to ignite and sustain a flame. A small piece of pitch wood was ignited and placed in the heart of the pile; no other fuels were added once the pile was ignited (Figure 2). Piles were allowed to burn themselves out. All piles were constructed by the first of November 2023, and burnt by November 27th, 2023.

Figure 2. Fuels Arrangement



A diagram of how the fuels were arranged within the piles. Molly Lea made this diagram based on an image by Robert W. Gray, a Wildfire Ecologist.

On December 6th, 2023, seeds were distributed into the piles at all six BCCER sites. Less than two centimeters of rain fell between the burning of the piles and planting (Regional Climate Centers, 2024). At each site, 90-95% of the white ash was scraped away from the pile before the seeds were distributed (see Figures 3 and 4). It has been observed that planting directly into white ash can reduce the recruitment of the seedlings (M. Bamford & P. Maslin, Big Chico Creek Ecological Reserve, personal communication).

One of four treatment types was administered to the piles in a half-meter by half-meter quadrat in the pile's center. The half-meter square was placed in the center of the pile where the heat was the most intense, indicated by the amount of white ash left behind. The seeds

Figure 3. Image of Ash Left After Pile Burning



An example of a burned pile that still has the white ash that remains after burning.

Figure 4. Image of 90-95% of Ash Removed



An example of a pile in which 90-95% of the white ash was scraped away from the half-meter square, seen in white, using a fire tool called a McLeod.

were distributed by hand to get the most even distribution, starting at the upper left corner of each quadrat and moving to the bottom right corner, dropping seeds as uniformly as possible; spacing varied for each treatment. In treatment two, the seeds were spaced the farthest apart at approximately five-centimeter intervals. In treatments three and four, where larger quantities of seeds were used, the spacing was reduced to about two centimeters or less. After the treatment was placed, the piles were left alone to be monitored once germination began, and sprouts were subsequently visible above the soil. The first signs of germination occurred

the last week of December 2023, after the reserve received roughly thirteen centimeters of rain (Regional Climate Center, 2024).

From January 2024 through June 2024, the six locations were monitored, and data was collected on the number and height (to the nearest cm) of *E. glaucus* individuals within the half-meter square. To avoid recounting individuals, two metal rods were placed to section off the quadrat to keep track of already counted stems (see Figures 5 and 6). Stems were counted systematically from the upper left corner of the quadrat to the bottom right corner. The number of individuals per quadrat for each treatment was averaged.

$$\text{Average \# Individuals (Treatment 1)} = \frac{(\text{Location 1 \#})+(\text{Location 2 \#})+(\text{Location 3 \#})+\dots}{\text{Total \# of Locations}}$$

Figure 5. Image Displaying Metal Rods
Used to Count Sprouts



The metal rods, highlighted in yellow, keep track of *E. glaucus* while counting individuals.

Figure 6. Closer Image of Metal Rods

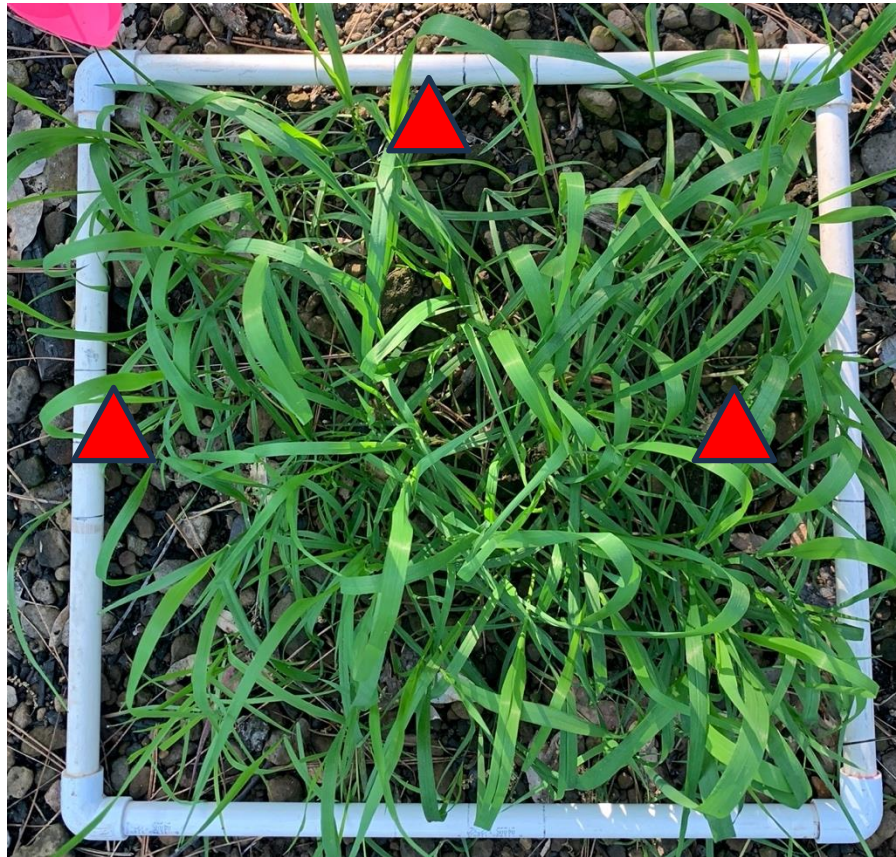


A closer look at the metal rods, highlighted in yellow, used in counting *E. glaucus* individuals.

The height of the individual *E. glaucus* stems was measured once the plants reached twelve centimeters in height in April. The height of the individuals within the quadrat was taken at three different points, a protocol adapted from BCCER's RX Fire Research team (Figure 7). The three heights were then averaged for each pile.

$$\text{Average Height (Centimeters)} = \frac{(\text{Height 1})+(\text{Height 2})+(\text{Height 3})}{3}$$

Figure 7. Example of Where the Heights were taken at each Sprouts



Example of where the heights (cm) were taken in each quadrat.
Photo by Molly Lea.

On May 24th, 2024, all aboveground biomass was collected from every pile in the six locations (Pieper, 1988). The aboveground biomass is all greenery of *E. glaucus* above the soil (see Figures 8 and 9). This was then cut at the base and placed into a paper bag labeled with the treatment type, date collected, location, and pile number. After the aboveground biomass was collected, it was weighed in the field where the “fresh” weight was recorded; the “fresh” weight is the weight in grams of the plant before it has been dried (University of Idaho, 2009). The paper bag was placed on the balance and then tared, giving the weight of just the *E. glaucus* trimmings (to the nearest 0.1 g). The paper bag of trimmings was then placed in an incubator at 60 degrees Celsius for at least 48 hours. After 48 hours in the incubator, the

Figure 8. Image of Location One, Pile Three's Aboveground Biomass



Location 1, Pile 3 before the above-ground biomass is collected.

Figure 9. Image of Location One, Pile Three's after Collecting Aboveground Biomass



Location 1, Pile 3 after collecting the above-ground biomass.

E. glaucus cuttings were weighed again and recorded as “dry” weight 1. The “dry” weight was taken every 24 hours after the initial 48 hours until the weight was constant, meaning it was within 0.1 grams of the previous weight. After the weight reached equilibrium, that weight was recorded as the final “dry” weight. Biomass was calculated using this formula:

$$\frac{\text{Final "dry" weight (g)}}{\text{"fresh" weight (g)}} \times 100 = \text{Biomass (\%)}$$

Treatments

This study used four different treatments of varying quantities of seeds in a half-meter by half-meter quadrat. The treatments were as follows:

Treatment 1: The control (no seed)

Treatment 2: 0.5 grams of seed (approximately 147 seeds)

Treatment 3: 1.0 grams of seed (approximately 293 seeds)

Treatment 4: 1.5 grams of seed (approximately 443 seeds)

The varying weights of the seeds were selected to create a more substantial distinction between the quantities. A stratified random sample was used to determine the treatment, or the quantities of seeds, each pile received. The piles were stratified into six different locations, and random.org was used to assign treatments randomly. Each treatment was used only once at a given location (see Appendix B).

Experimental Limitations

The study's timeline limits the data collected. Collecting aboveground biomass after one growing period may not allow the grass to drop seeds and fully establish. Fortunately, as mentioned before, *E. glaucus* is a perennial with a quick germination period and a realistic possibility of establishment (Stannard et al., 2005). The piles were placed strategically to keep the surrounding trees safe from unintentionally being burned.

As the *E. glaucus* plants grew, site six and piles one and three showed signs of grazing starting March 8th, 2024. It is possible that Columbian black-tailed deer (*Odocoileus hemionus columbianus*) fed on the grass. Sites two and three also showed signs of grazing, but less intensely than site six (see page 21 or Appendix A). This affected the biomass for the treatments and possibly skewed the data. However, grazing is also a sign of the ecosystem function perennial grass provides.

Data Analysis

An analysis of variance (one-way ANOVA) statistical test was run to see if there were significant differences between the four treatments at a 0.05 significance level. A Tukey multiple pairwise comparison was also run to see which treatments differed significantly. A Levene's test was run to evaluate the homogeneity of variance, and residuals were plotted against the means from each group. Lastly, a Shapiro-Wilk Test was run to check for normality of the data. All statistical analyses were run in R version 2024.04.2+764 (see appendix D). Graphs and tables were made using R and Microsoft Excel.

Chapter Summary

E. glaucus collected from BCCER on August 18th, 2023, was distributed into burn scars in six locations across the reserve. These burn scars resulted from 24 different burn piles consisting of cut debris from the understory of Black Oaks (*Quercus kelloggii*). From December of 2023 until May of 2024, the growth of plants in these replicates was monitored until they began to go to seed and potentially lose biomass from desiccation. The aboveground biomass

was collected, and their mass was recorded. All data were analyzed using R version 2024.04.2+764.

CHAPTER IV

RESULTS

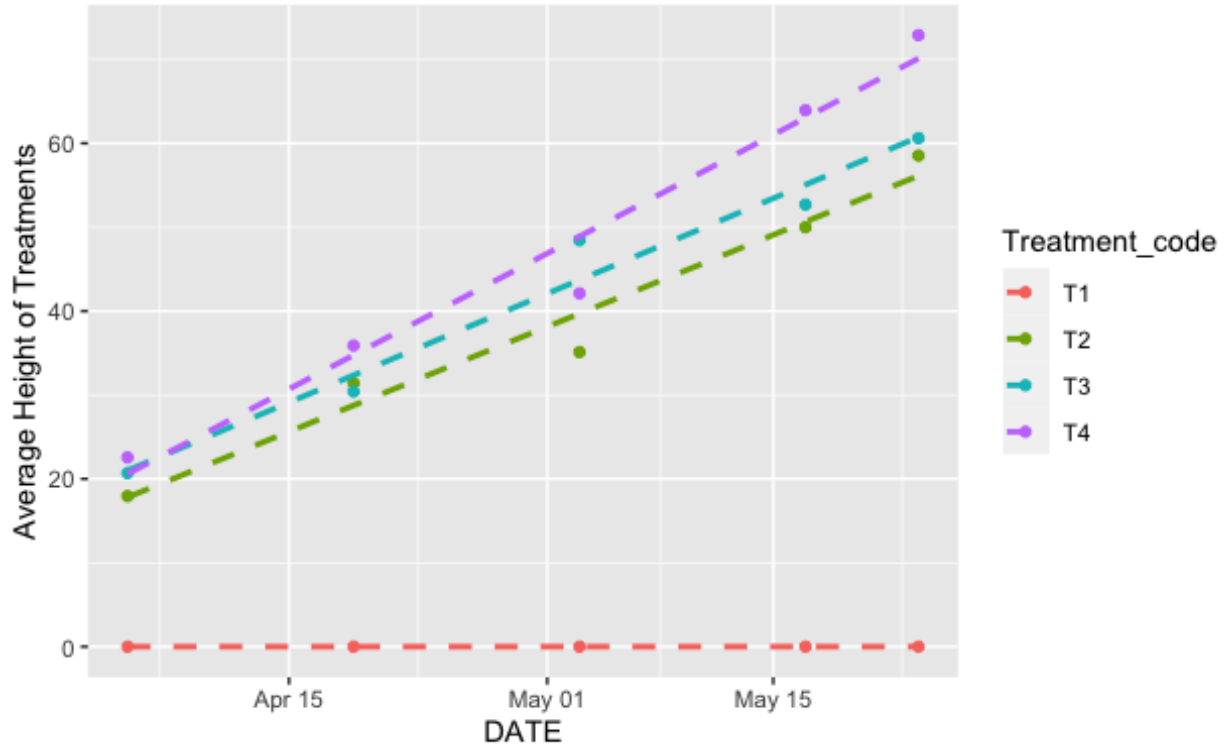
Introduction

This chapter covers the findings and results from the statistical analysis of the data collected over the growing season and the aboveground biomass from this study's *E. glaucus* trials. All statistical analysis was conducted in R version 2024.04.2+764. Tables and figures were made using Microsoft Word and R. All raw data available upon request.

Growth Data

The average heights and the number of individual sprouts of *E. glaucus* were collected over the December 2023 through May 2024 growing season. The heights were averaged by treatment type: T1 = no seed, T2 = 0.5 grams of seed, T3 = 1.0 grams of seed, T4 = 1.5 grams of seed, and plotted along time as seen below (Figure 10).

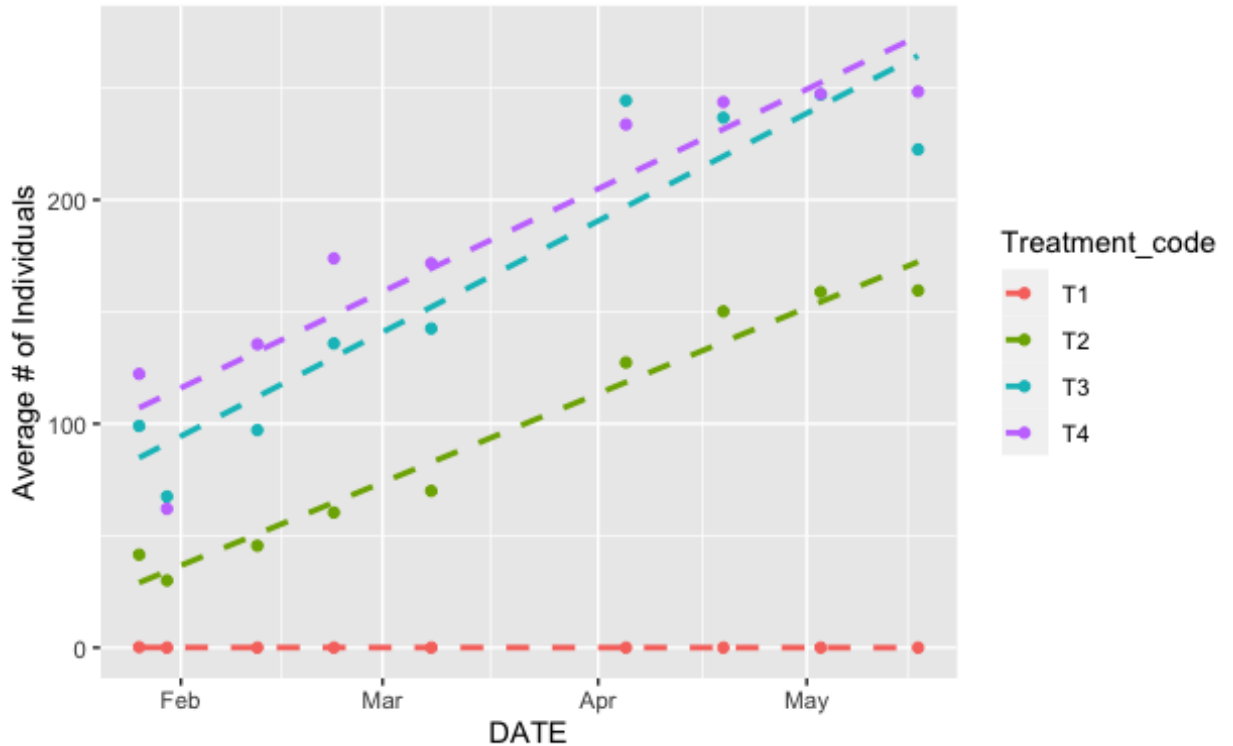
Figure 10. Plot of Height versus Date by Treatment Code



This figure plots the average heights (y-axis) for each treatment across time (x-axis). The average heights for each treatment are the heights from all six locations. Treatments are: T1=control (no seed), T2=0.5g of seed, T3=1.0g of seed, T4=1.5g of seed.

Once the plots had germinated, on January 26, 2024, the number of individual seedlings from each pile was counted. This data was collected until the aboveground biomass was collected in May 2024. The number of individuals was averaged by treatment type: T1 = control, T2 = 0.5g, T3 = 1.0g, T4 = 1.5g, and plotted along time as seen below (see Figure 11).

Figure 11. Plot of Individual Sprouts versus Date by Treatment Code



This plot shows the average number of individuals (y-axis) across time (x-axis). The average number of individuals is the number of sprouts for each treatment across the six locations for the date indicated. The treatments are: T1=control, T2=0.5g, T3=1g, T4=1.5g.

Biomass Data

After one growing season, December to May, the experimental trials of *E.*

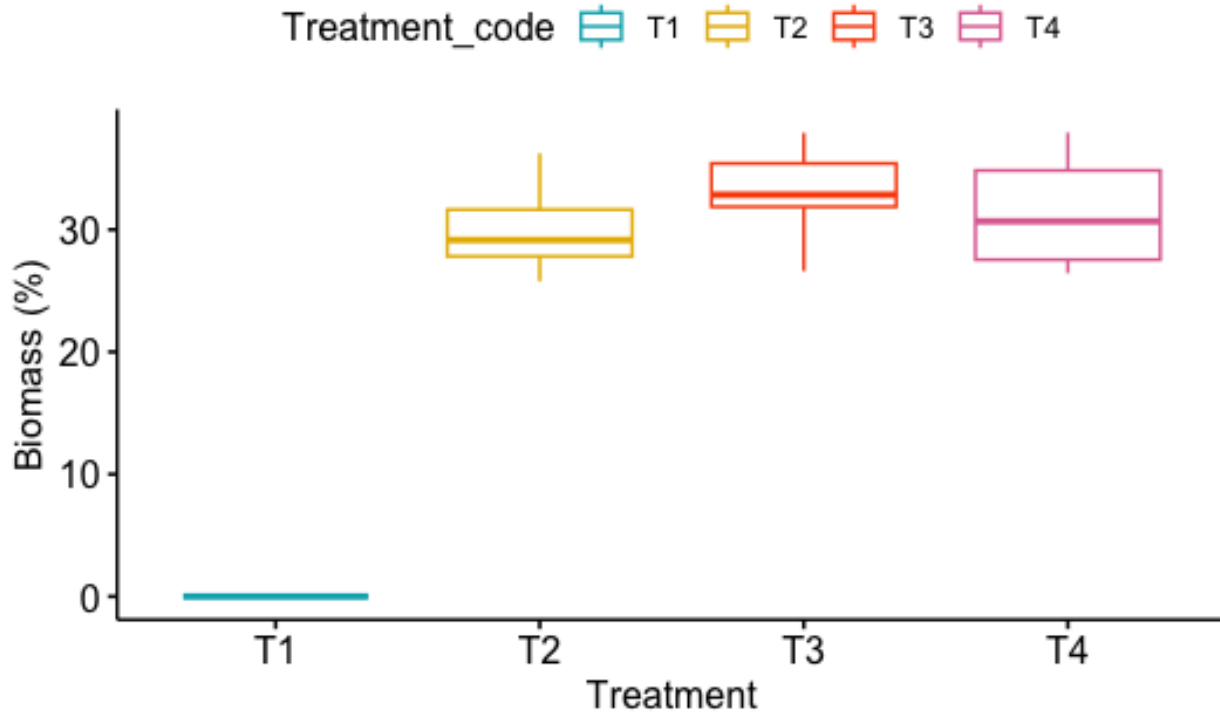
glauca were cut one centimeter above the soil. The samples were then weighed, dried, and weighed again to calculate biomass. The biomass data was put into a Microsoft Excel sheet and run in R. The data was then sorted to find the mean biomass in grams for each treatment (see Table 2 and Figure 12). This is the average of the six biomasses from each location.

Table 2. Mean Biomass per Treatment Code

An output from R compressed all the raw data and gave only the mean percent of biomass in grams for each treatment. Treatment types: T1= control (no seed), T2= 0.5g of seed, T3= 1.0g of seed, T= 1.5g of seed.

Treatment Code	Mean Percent Biomass (g)
T1	0.000
T2	30.024
T3	33.002
T4	31.407

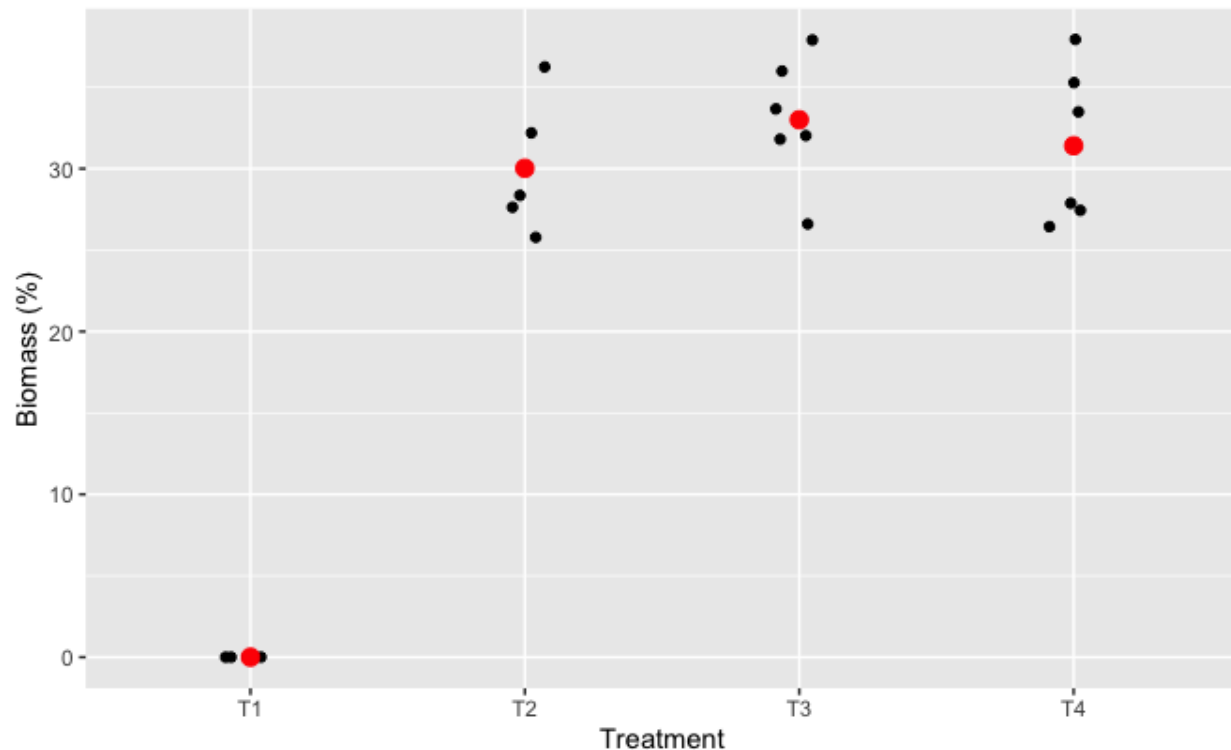
Figure 12. Boxplot of Biomass versus Treatment



A boxplot made in R showing the mean biomass of *Elymus glaucus* (y-axis) across the different treatments (x-axis). The boxplot summarizes the data by showing the median percent of biomass in grams, the maximum and minimum values, the lower and upper quartiles, and outliers. The data shown above has no outliers. T1 is significantly different from the other treatments at alpha level 0.05. The treatments are: T1=control, T2=0.5g, T3=1g, T4=1.5g.

Separate biomass estimates for each treatment are shown in Figure 13.

Figure 13. Plot of Biomass versus Treatment Showing each Data Point



This plot shows the six different biomass (y-axis) points from each treatment (x-axis). The red point indicates the mean biomass for each treatment. The treatments are: T1=control, T2=0.5g, T3=1g, T4=1.5g.

After visualizing the four means in a boxplot, an analysis of variance was run in R. A one-way ANOVA test was run to find there was a difference in the means at the significance level of 0.05 (p -value < 0.05). The one-way ANOVA test, however, does not distinguish which means differ from each other significantly. A Tukey multiple comparisons of means test was run to see which means were significantly different from one another (Table 3).

Table 3. Statistical Summary: Comparison of Differences in Mean Percent Biomass (g)

This table is an output from R that was exported into Excel for formatting. The Tukey HSD test shows which treatments are statistically significant from one another at the significance level of 0.05. This is true if the p-value number is less than 0.05.

Treatment Code	Difference in % Means (g)	Lower	Upper	P-Value
T2-T1	30.024	24.179	35.868	<<0.01
T3-T1	33.002	27.158	38.847	<<0.01
T4-T1	31.407	25.563	37.252	<<0.01
T3-T2	2.978	-2.856	8.823	0.498
T4-T2	1.383	-4.461	7.227	0.909
T4-T3	-1.595	-7.439	4.249	0.869

As seen above, treatments T2, T3, and T4 significantly differ from T1 at the significance level of 0.05. However, treatments T2, T3, and T4 are not substantially different from one another at the significance level of 0.05.

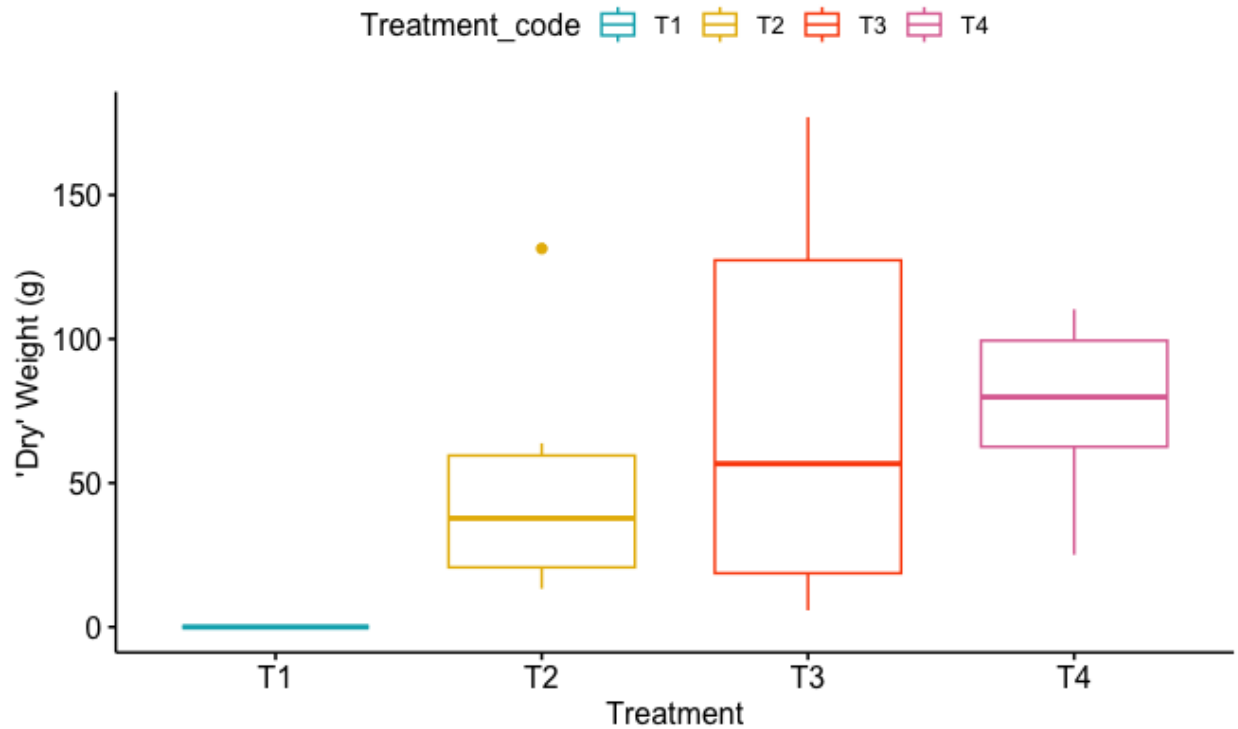
The data was then sorted to find the mean “dry” weight in grams for each treatment (see Table 4 and Figure 14). This is the average of the six biomasses from each location.

Table 4. Mean “Dry” Weight (g) per Treatment Code

An output from R compressed all the raw data and gave only the mean “dry” weight in grams for each treatment. Treatment types: T1= control (no seed), T2= 0.5g of seed, T3= 1.0g of seed, T= 1.5g of seed.

Treatment Code	Mean “Dry” Weight (g)
T1	0.000
T2	50.333
T3	75.517
T4	76.317

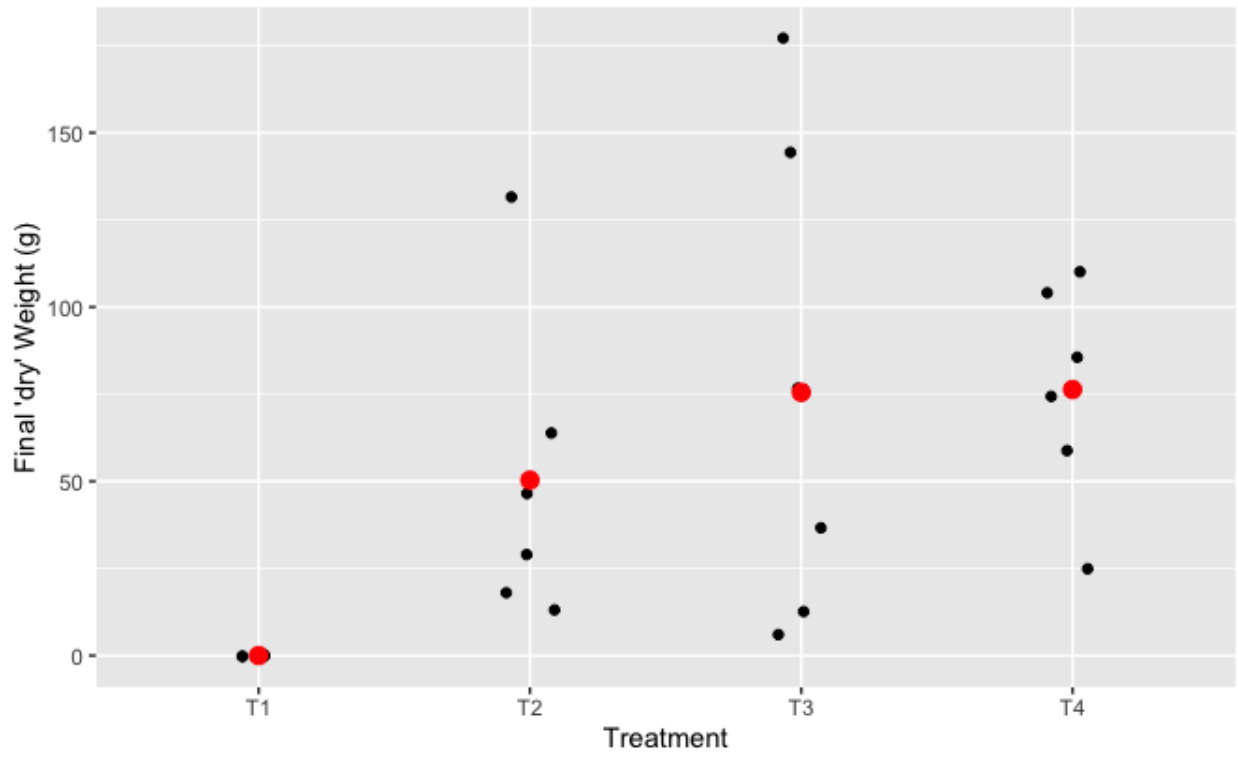
Figure 14. Boxplot of Mean “Dry” Weight versus Treatment



A boxplot made in R showing the mean “dry” weight of *Elymus glaucus* (y-axis) across the different treatments (x-axis). The boxplot summarizes the data by showing the median percent of biomass in grams, the maximum and minimum values, the lower and upper quartiles, and outliers. The data shown above has no outliers. T1 is significantly different from the other treatments at alpha level 0.05. The treatments are: T1=control, T2=0.5g, T3=1g, T4=1.5g.

Separate weight estimates for each treatment are shown in Figure 15.

Figure 15. Plot of Mean “Dry” Weight versus Treatment Showing Data Points



This plot shows the six different “dry” weights (y-axis) points from each treatment (x-axis). The red point indicates the mean biomass for each treatment. The treatments are: T1=control, T2=0.5g, T3=1g, T4=1.5g.

After visualizing the four means in a boxplot, an analysis of variance was run in R. A one-way ANOVA test was run to find there was a difference in the means at the significance level of 0.05 (p -value < 0.05). The one-way ANOVA test, however, does not distinguish which means differ significantly from each other. A Tukey multiple comparisons of means test was run to see which means were significantly different from one another (Table 5).

Table 5. Statistical Summary: Comparison of Differences in Mean “Dry” Weights (g)

This table is an output from R that was exported into Excel for formatting. The Tukey HSD test shows which treatments are statistically significant from one another at the significance level of 0.05. This is true if the p-value number is less than 0.05.

Treatment Code	Difference in Means (g)	Lower	Upper	P-Value
T2-T1	50.333	-21.876	122.543	0.239
T3-T1	75.517	3.307	147.726	0.038
T4-T1	76.317	4.107	148.526	0.036
T3-T2	25.183	-47.026	97.393	0.764
T4-T2	25.983	-46.226	98.193	0.747
T4-T3	0.800	-17.409	73.009	1.000

As seen above, treatments T3 and T4 significantly differ from T1 at the significance level of 0.05.

However, treatments T2, T3, and T4 are not substantially different from one another at the significance level of 0.05, and T1 and T2 are not significantly different from one another either.

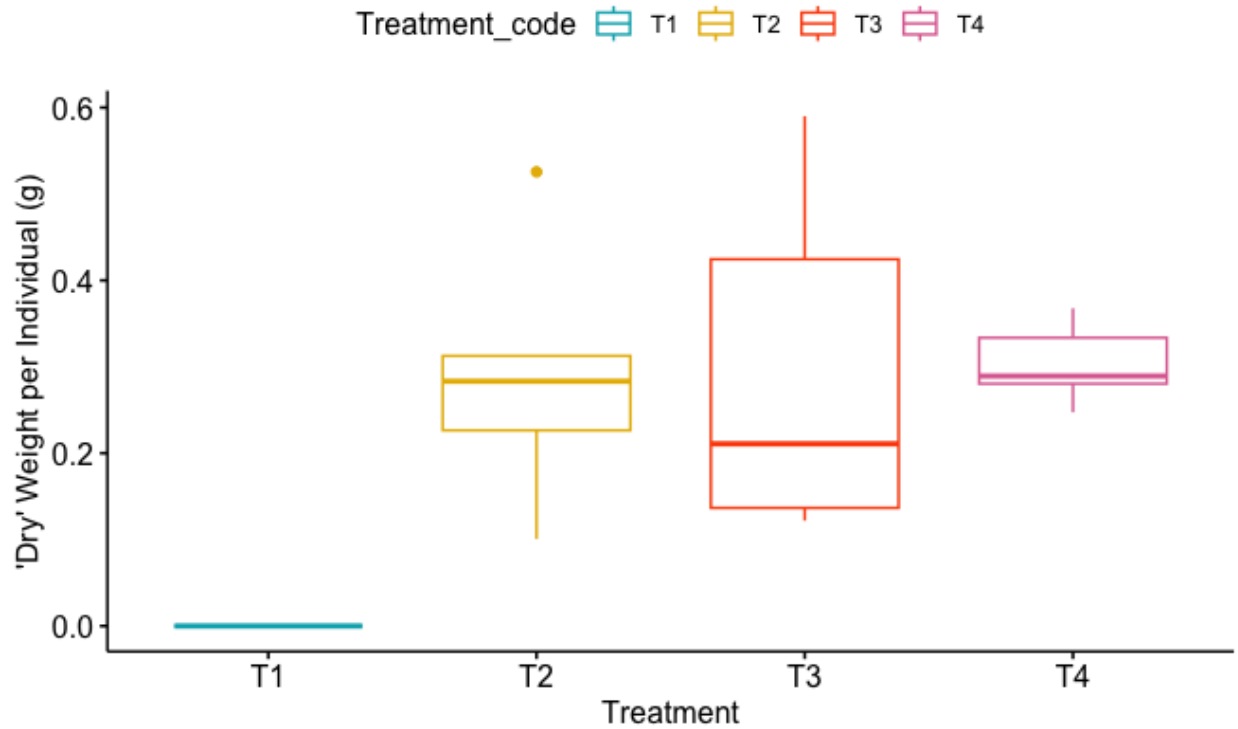
The data was then sorted to find the “dry” weight in grams per total number of individuals for each treatment (see Table 6 and Figure 16). The maximum number of individuals was 300. This is the average of the six “dry” weights per individual from each location.

Table 6. Mean “Dry” Weight (g) per Individual by Treatment Code

An output from R compressed all the raw data and gave only the mean “dry” weight per individual in grams for each treatment. Treatment types: T1= control (no seed), T2= 0.5g of seed, T3= 1.0g of seed, T= 1.5g of seed.

Treatment Code	Mean “Dry” Weight (g) per Individual
T1	0.000
T2	0.287
T3	0.290
T4	0.303

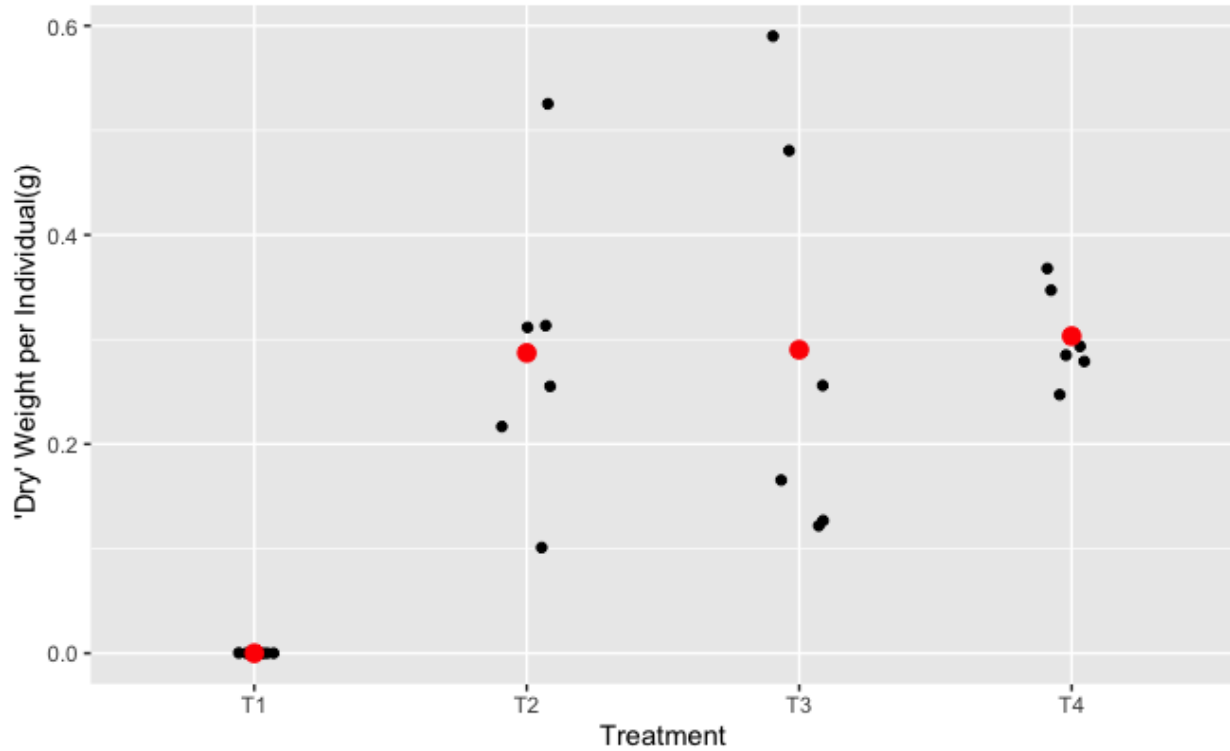
Figure 16. Boxplot of Mean “Dry” per Individual versus Treatment



A boxplot made in R showing the mean “dry” weight per individual (g) of *Elymus glaucus* (y-axis) across the different treatments (x-axis). The boxplot summarizes the data by showing the median percent of biomass in grams, the maximum and minimum values, the lower and upper quartiles, and outliers. The data shown above has no outliers. T1 is significantly different from the other treatments at alpha level 0.05. The treatments are: T1=control, T2=0.5g, T3=1g, T4=1.5g.

Separate biomass estimates for each treatment are shown in Figure 17.

Figure 17. Plot of Mean “Dry” per Individual versus Treatment Showing Data Points



This plot shows the six different “Dry” weights per individual (y-axis) points from each treatment (x-axis). The red point indicates the mean biomass for each treatment. T1 is significantly different from all other treatments. The treatments are: T1=control, T2=0.5g, T3=1g, T4=1.5g.

After visualizing the four means in a boxplot, an analysis of variance was run in R. A one-way ANOVA test was run to find there was a difference in the means at the significance level of 0.05 (p -value < 0.05). The one-way ANOVA test, however, does not distinguish which means differ from each other significantly. A Tukey multiple comparisons of means test was run to see which means were significantly different from one another (Table 7).

Table 7. Statistical Summary: Comparison of Differences in Mean “Dry” Weights (g) per Individual

This table is an output from R that was exported into Excel for formatting. The Tukey HSD test shows which treatments are statistically significant from one another at the significance level of 0.05. This is true if the p-value number is less than 0.05.

Treatment Code	Difference in Means (g)	Lower	Upper	P-Value
T2-T1	0.287	0.087	0.487	0.003
T3-T1	0.290	0.090	0.490	0.003
T4-T1	0.303	0.103	0.503	0.002
T3-T2	0.003	-0.197	0.203	1.000
T4-T2	0.016	-0.184	0.216	0.996
T4-T3	0.013	-0.187	0.213	0.998

As seen above, treatments T2, T3, and T4 significantly differ from T1 at the significance level of 0.05. However, treatments T2, T3, and T4 are not substantially different from one another at the significance level of 0.05.

CHAPTER V

DISCUSSION AND CONCLUSION

Discussion

The addition of native Blue Wildrye (*Elymus glaucus*) seeds to the burn scars of cut debris under a Black Oak (*Quercus kelloggii*) canopy successfully established colonies of this perennial grass. The statistical analysis showed no significant difference in biomass between the three treatments: T2= 0.5g, T3= 1.0g, T4= 1.5 g of seeds at the significance level of 0.05 (p -value < 0.05). However, there was a significant difference between the control (no seeds) and all three treatments. The control, which was not seeded, had no regrowth of perennial native or annual invasive flora. This aligns with the results of a study on the burn scar of the Dixie fire located in Lassen National Forest (Getts, 2021). Other forbs were seen early on but died off as the *E. glaucus* plants grew taller and their density increased, effectively crowding out competitors. Fifteen of the 18 plots with seeds added post-fire had great success, leading to an increase in *E. glaucus* at those locations. The addition of seeds from this study agrees with findings in Arizona and the midwestern United States, in which both studies found an overall increase in native cover after using native seeds as an amendment to burned areas (Albrecht et al., 2022; Korb et al., 2004). Although treatments of 0.5 grams, 1.0 grams, and 1.5 grams of *E. glaucus* produced noteworthy biomass, there was no significant difference in final biomass density among these, suggesting an attenuation of the effect of increasing the density of planting seeds in burn scars. Two additional analyses were conducted to specifically assess the "Dry" weight, defined as the total weight (in grams) of all plant matter harvested per treatment.

The first analysis examined the total “Dry” weight per treatment, while the second calculated the “Dry” weight per individual plant by dividing the total dry weight by the number of individuals within each quadrat. Both analyses revealed no statistically significant differences between treatments, with the exception of the control group. Clearly, the addition of seeds visibly improves the outcome of burn trials, as compared with controls (Figures 18-21). Based on the data collected, all seed amounts yield roughly the same mass of *E. glaucus*; thus, it can be suggested using no more than 0.5 grams of seeds per half-meter square is optimal. The prolonged heat generated by pile burning may have similar effects to those observed when larger fuels, such as downed logs, burn in a broadcast burn. As a result, these areas may be important targets for seeding native plants after a broadcast burn.

Figure 18. Image of Treatment One, Location One, on May 17th, 2024



Image of Treatment 1 (no seeds added) on May 17th, 2024, at site location one at BCCER.

Figure 19. Image of Treatment Three, Location One, on May 17th, 2024



Image of Treatment 3 (one gram of seeds added) on May 17th, 2024, at site location one at BCCER.

Figure 20. Image of Treatment One, Location Two, on May 17th, 2024



Image of Treatment 1 (no seeds added) on May 17th, 2024, at site location two at BCCER.

Figure 21. Image of Treatment Three, Location Two, on May 17th, 2024



Image of Treatment 3 (one gram of seeds added) on May 17th, 2024, at site location two at BCCER.

Limitations and Further Research

The *E. glaucus* plants grew during one growing season only. The aboveground biomass was collected as the seeds were beginning to be produced. This study would have benefited from allowing the perennial grasses to drop their seeds (probably in August 2024) and continuing monitoring until the following spring, as this would ensure the establishment of *E. glaucus*. With a population of *E. glaucus* established, the competition might increase as the plants will increase in size over time. The higher density of seeds can reduce invasives in the short-term but may find competition amongst themselves in the long term, possibly weakening the population. A previous study demonstrated long-term beneficial results when planting in burn scars and disturbed soils (Kerns et al., 2020). In this study, there was evidence of grazing starting in April 2024 in two of the six locations, likely affecting the total biomass produced. Grazing by black-tailed deer and other consumers may complicate estimates of productivity, but it also raises the possibility of carrying out additional studies to estimate compensatory growth in response to grazing. Nevertheless, erecting exclusion cages around the trials would minimize or prevent browsing by vertebrates such as deer.

Results in this study could be extended by monitoring the plots over additional growing seasons to estimate the success of establishment by *E. glaucus*. Ideally, well-established plants may spread beyond the half-meter square trial plots. Future studies could focus on the higher density plots to examine the seed bank, identifying seeds that haven't germinated and assessing how long they persist in the soil. Future research could examine seeding at densities less than 0.5 grams per half-meter quadrat; it is possible at lower densities, there is a drop in

biomass production. This study could also be done using different species, for example, California Brome (*Bromus carinatus var. carinatus*), another native grass species found at BCCER. This study was done under the Black Oak (*Quercus kelloggii*) canopy, and the methodology could also be used under a different *Quercus* species canopy.

Conclusion

More research is needed on the effects of fire in the Sierra Nevada foothills, more specifically, oak woodlands. This study, with its findings and implications, has the potential to serve as a bridge for future research and continued exploration of the effect and behavior of fire in oak woodlands. While there was no significant difference between the quantity of seeds (0.5 g, 1.0g, and 1.5g) on the final aboveground biomass of *E. glaucus* at BCCER, it does not negate the impact of adding native perennial seeds to burn scars, as the addition of *E. glaucus* did increase the cover of native grass in the trial plots. However, it is not recommended to use more than 0.5 grams per half-meter square. The findings of this study can allow land managers to reduce seed costs by 66%, as 0.5 grams of seed will produce the same biomass as 1.5 grams. This study should be used as a stepping stone to continue the research that can be done on the seed bank and the actions we can take to help promote the recovery of native vegetation after fire.

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https://www.fs.usda.gov/detail/arp/landmanagement/resourcemanagement/?cid=fsm91_058

[291#](#)

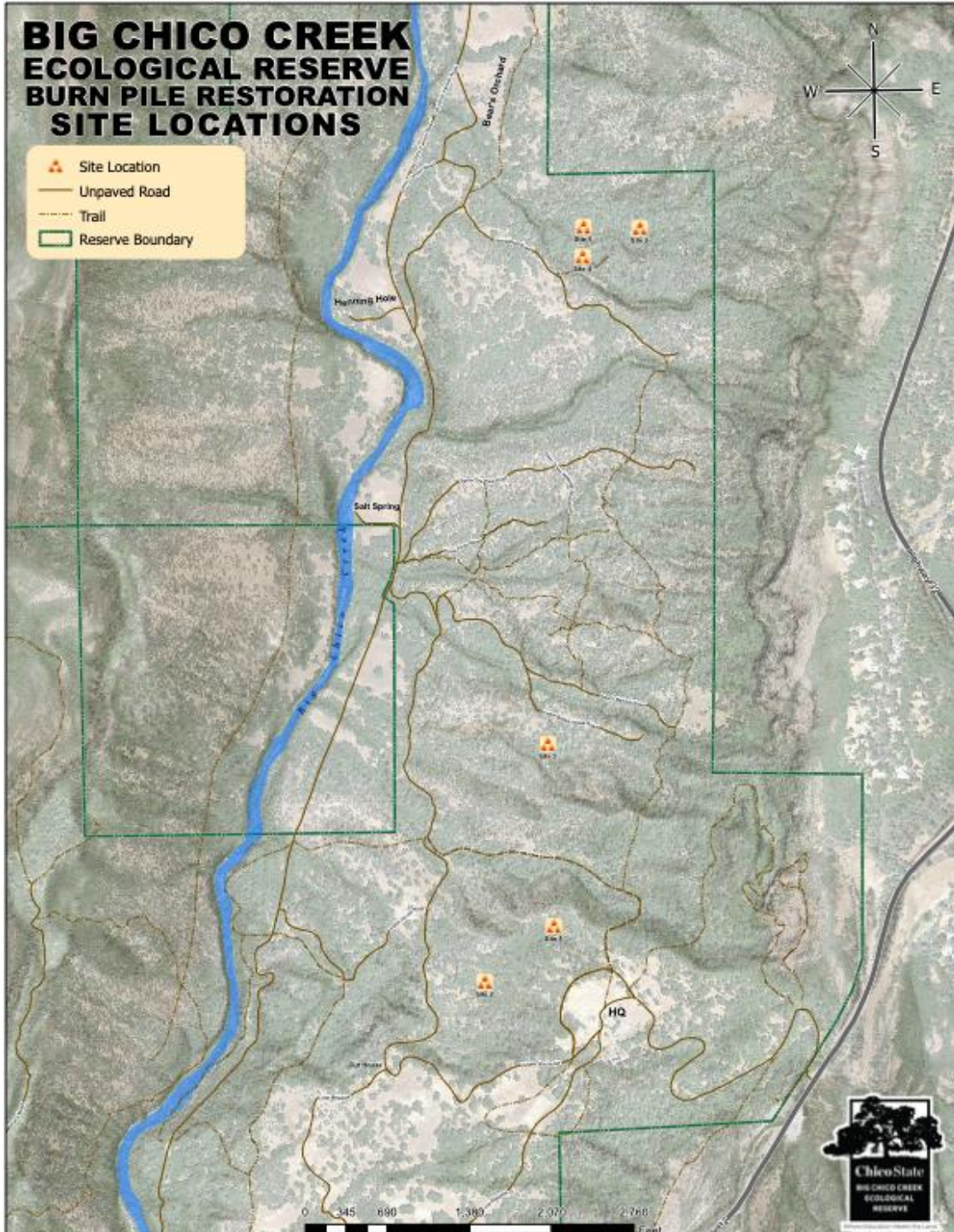
Williams, A. P., Abatzoglou, J. T., Gershunov, A., Guzman-Morales, J., Bishop, D. A., Balch, J. K., & Lettenmaier, D. P. (2019). Observed impacts of anthropogenic climate change on wildfire in California. *Earth's Future*, 7(8), 892-910.

APPENDICES

APPENDIX A

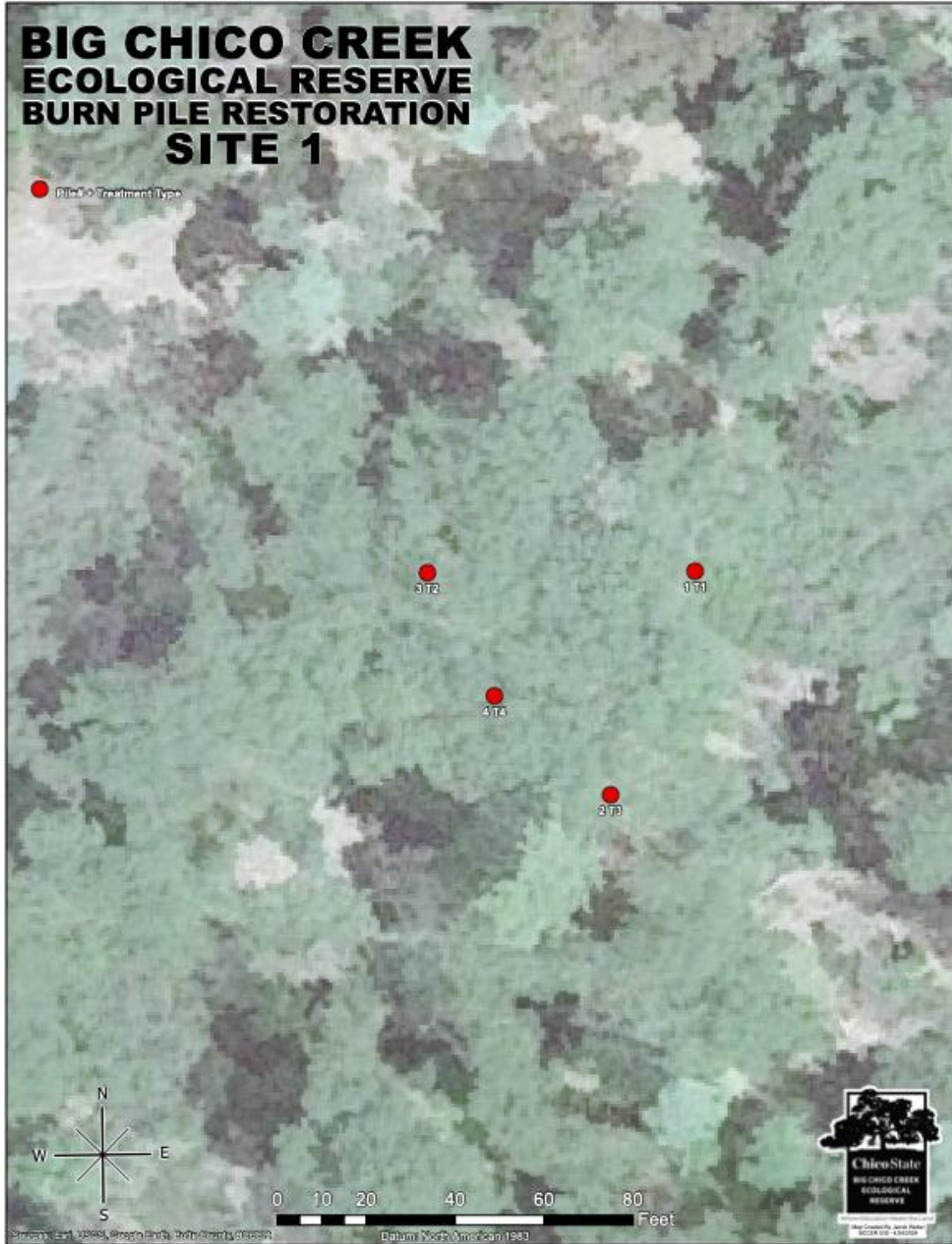
Map of all six project locations on the Big Chico Ecological Reserve. All maps were done by Jacob Weber.

Map 1



Map 1- Map of BCCER boundaries with the six site location indicated by triangles.

Map 2



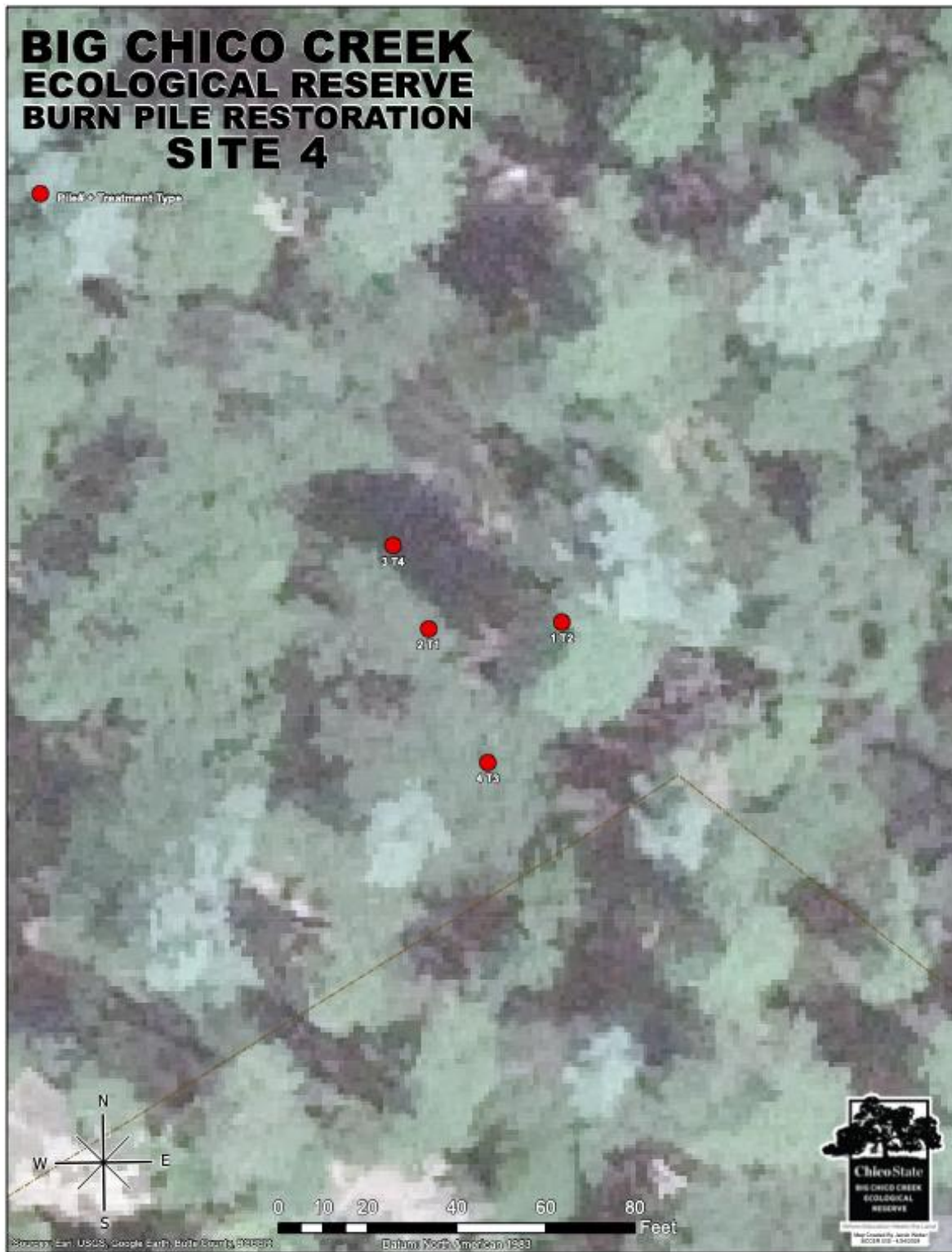
Map 2- Map of location one; individual piles are marked by red dots and labeled with the treatment type.

Map 3



Map 3- Map of location two; individual piles are marked by red dots and labeled with the treatment type.

Map 5



Map 5 -Map of location four; individual piles are marked by red dots and labeled with the treatment type.

Map 7



Map 7- Map of location six; individual piles are marked by red dots and labeled with the treatment type.

APPENDIX B

Pile Treatment Schematic

<https://www.random.org/sequences/?min=1&max=4&col=1&format=html&rnd=new>

Treatments 1= no treatment, 2= 0.5 g, 3= 1.0 g, 4= 1.5 g

Location 1

Pile 1
1

Pile 2
3

Pile 3
2

Pile 4
4

Location 2

Pile 1
1

Pile 2
2

Pile 3
4

Pile 4
3

Location 3

Pile 1
4

Pile 2
2

Pile 3
1

Pile 4
3

Location 4

Pile 1
2

Pile 2
1

Pile 3
4

Pile 4
3

Location 5

Pile 1
3

Pile 2
1

Pile 3
4

Pile 4
2

Location 6

Pile 1
2

Pile 2
4

Pile 3
3

Pile 4
1

APPENDIX C

The complete code run in R Studio. Raw data is available from the author upon request.

title: "Untitled"

author: "Molly Lea"

date: "`r Sys.Date()`"

output: html_document

```
``{r setup, include=FALSE}
```

```
knitr::opts_chunk$set(echo = TRUE)
```

```
``
```

```
``{r}
```

```
library(dplyr)
```

```
library(tidyr)
```

```
library(ggplot2)
```

```
library(scales)
```

```
library(ggpubr)
```

```
``
```

```
``{r}
```

```
View(EglacusBIOMASS)
```

```
``
```

```
``{r}
```

```
mean_by_treatment = EglacusBIOMASS %>%
```

```
  group_by(TREATMENT_code) %>%
```

```
  summarise(meanmass=mean(BIOMASS))
```

```
mean_by_treatment
```

```
```
```

```
A tibble: 4 × 2
```

| <b>TREATMENT_code</b> | <b>meanmass</b> |
|-----------------------|-----------------|
| <chr>                 | <dbl>           |
| T1                    | 0.00000         |
| T2                    | 30.02423        |
| T3                    | 33.00291        |
| T4                    | 31.40763        |

```
```{r}
```

```
st.err <- function(x) {  
  sd(x)/sqrt(length(x))  
}
```

```
```
```

```
```{r}
```

```
SE <- mean_by_treatment %>%  
  group_by(TREATMENT_code) %>%  
  summarise(SE=st.err(meanmass))
```

```
SE
```

```
```
```

```
A tibble: 4 × 2
```

```
TREATMENT_code
```

```
<chr>
```

SE

<dbl>

T1 NA

T2 NA

T3 NA

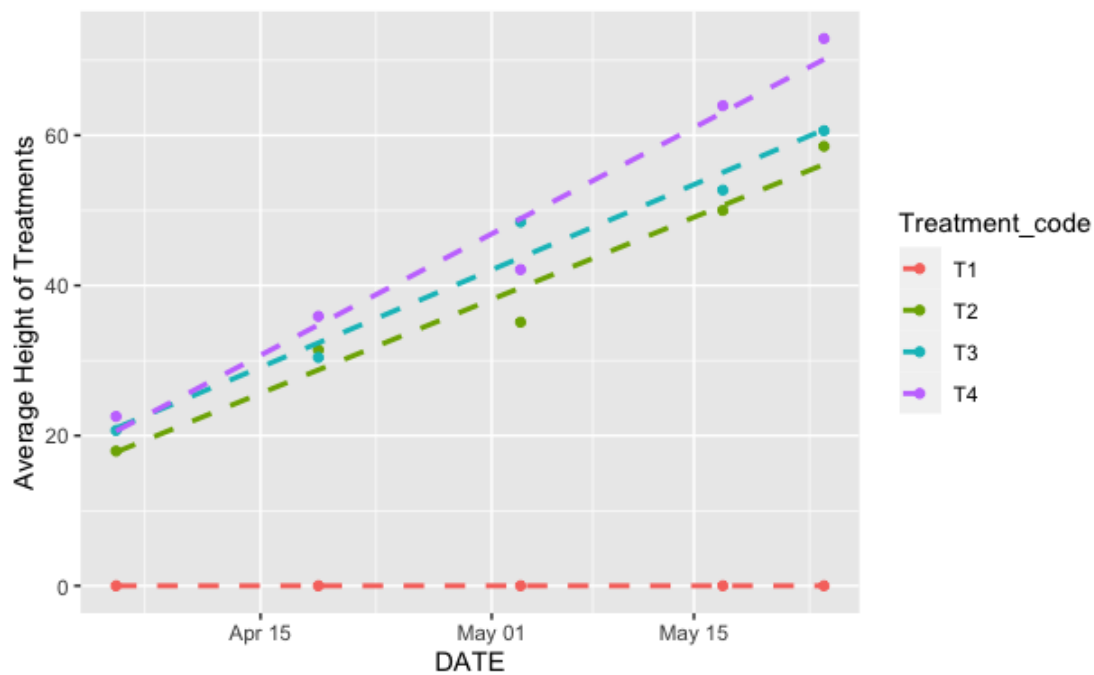
T4 NA

4 rows

```
``{r}
```

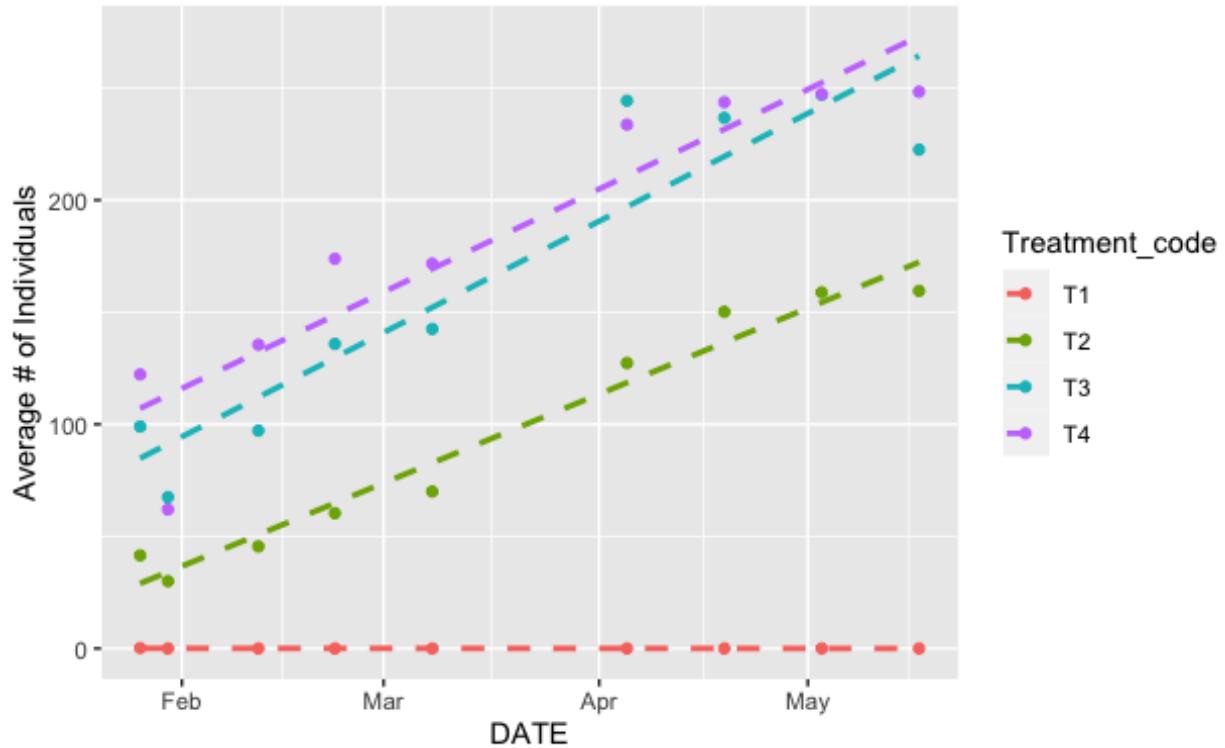
```
ggplot(data=Av_Heights, aes(x=DATE, y=Average_Height, colour = Treatment_code)) +
 geom_point(aes(color = factor(Treatment_code)))+
 labs(x="DATE", y = "Average Height of Treatments")+
 geom_smooth(method = "lm", se=FALSE, formula = y~x, linetype = "dashed")
```

```
``
```



```
``{r}
```

```
ggplot(data=Av_Data, aes(x=DATE, y=n_individuals, colour = Treatment_code)) +
 geom_point(aes(color = factor(Treatment_code)))+
 labs(x="DATE", y = "Average # of Individuals")+
 geom_smooth(method = "lm", se=FALSE, formula = y~x, linetype = "dashed")
````
```



```
````{r}
levels(EglaucusBIOMASS$TREATMENT_code)
```

```
EglaucusBIOMASS$TREATMENT_code <- ordered(EglaucusBIOMASS$TREATMENT_code,
 levels = c("T1", "T2", "T3", "T4"))
```

````

```
[1] "T1" "T2" "T3" "T4"
```

```

```{r}
group_by(EglaucusBIOMASS, TREATMENT_code) %>%
 summarise(
 count = n(),
 mean = mean(BIOMASS, na.rm = TRUE),
 sd = sd(BIOMASS, na.rm = TRUE)
)
```

```

A tibble: 4 × 4

TREATMENT_code

<ord>

count

<int>

mean

<dbl>

sd

<dbl>

| | | | |
|----|---|----------|----------|
| T1 | 6 | 0.00000 | 0.000000 |
| T2 | 6 | 30.02423 | 3.738522 |
| T3 | 6 | 33.00291 | 3.918275 |
| T4 | 6 | 31.40763 | 4.795019 |

4 rows

```
ggboxplot(EglaucusBIOMASS, x = "Treatment_code", y = "BIOMASS",
```

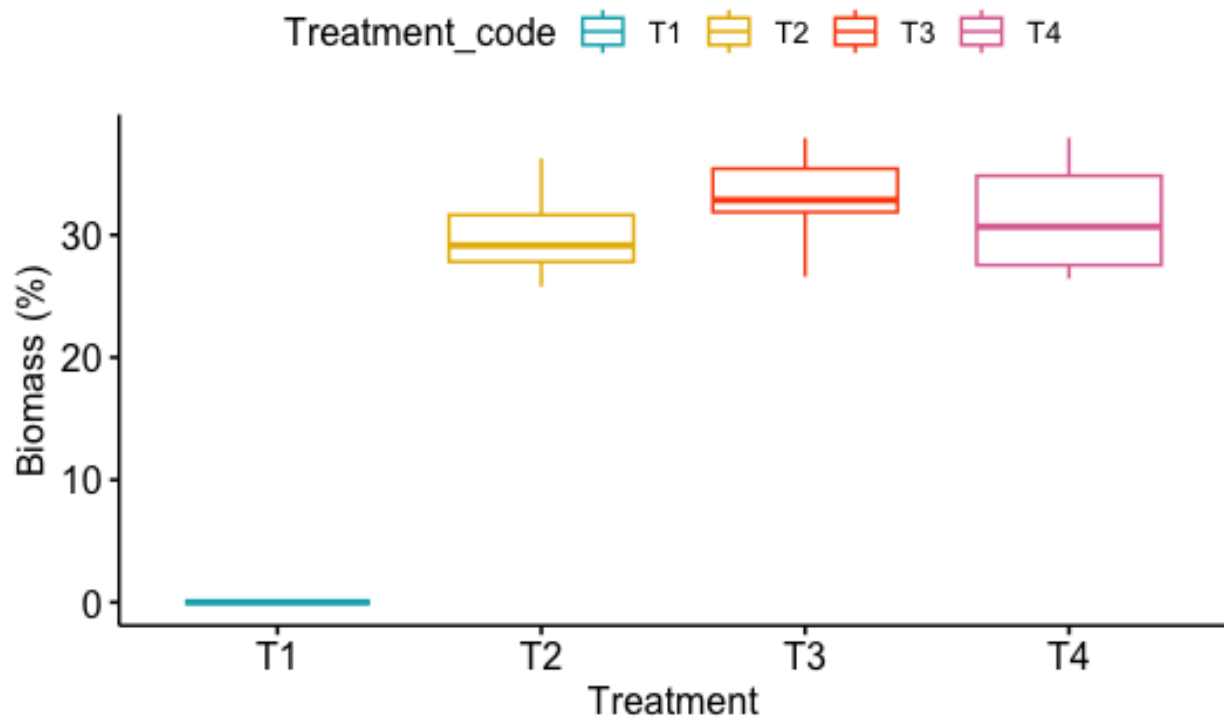
```

color = "Treatment_code", palette = c("#00AFBB", "#E7B800", "#FC4E07", "#de70a1"),
order = c("T1", "T2", "T3", "T4"),

```

```
ylab = "Biomass (%)", xlab = "Treatment")
```

```
add = c("mean_se", "jitter")
```



```
``{r}
```

```
ggplot(data=EglaucusBIOMASS, aes(x=Treatment_code, y=BIOMASS)) +  
  geom_jitter(position = position_jitter(width = .1)) +  
  stat_summary(fun.y = "mean", geom = "point", color = "red", size = 3) +  
  labs(x="Treatment", y = "Biomass (%)")
```


Tukey multiple comparisons of means

95% family-wise confidence level

Fit: aov(formula = BIOMASS ~ TREATMENT_code, data = EglaucusBIOMASS)

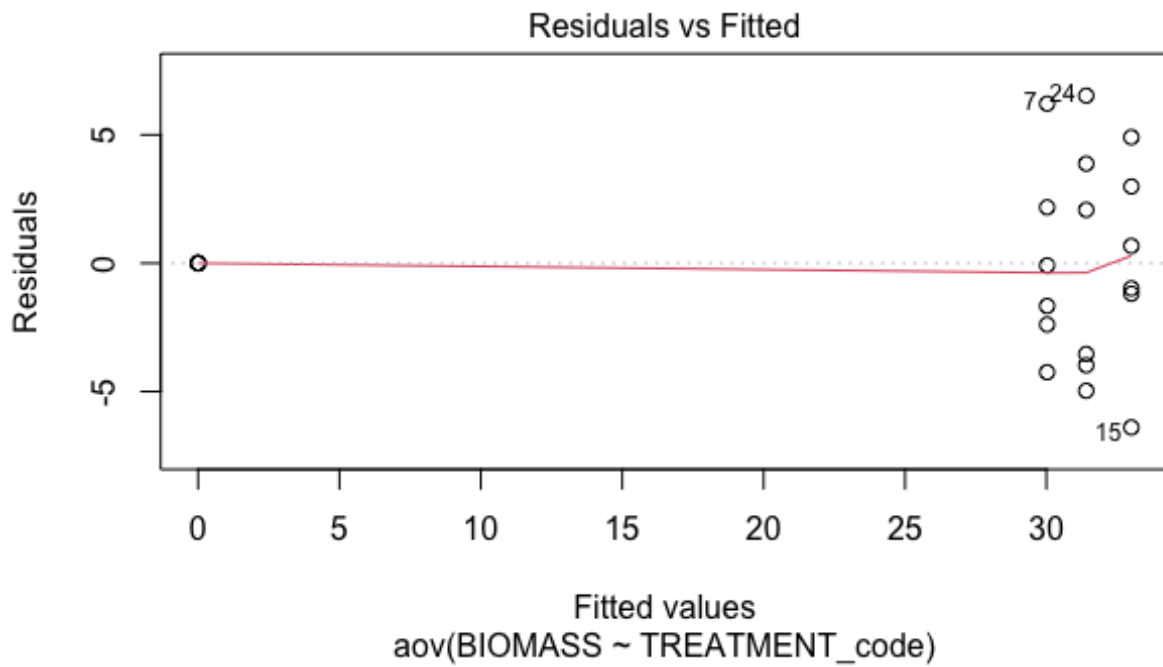
\$TREATMENT_code

| | diff | lwr | upr | p adj |
|-------|-----------|-----------|-----------|-----------|
| T2-T1 | 30.024232 | 24.179790 | 35.868673 | 0.0000000 |
| T3-T1 | 33.002910 | 27.158468 | 38.847351 | 0.0000000 |
| T4-T1 | 31.407625 | 25.563184 | 37.252067 | 0.0000000 |
| T3-T2 | 2.978678 | -2.865763 | 8.823119 | 0.4982461 |
| T4-T2 | 1.383393 | -4.461048 | 7.227835 | 0.9098682 |
| T4-T3 | -1.595285 | -7.439726 | 4.249157 | 0.8696011 |

``{r}

plot(res.aov, 1)

``



```
``{r}
```

```
library(car)
```

```
leveneTest(BIOMASS ~ TREATMENT_code, data = EglaucusBIOMASS)
```

```
``
```

Levene's Test for Homogeneity of Variance (center = median)

| group | Df | F value | Pr(>F) | Signif. codes |
|-------|--------|----------|--------|---------------|
| 3 | 5.1961 | 0.008123 | ** | |
| 20 | | | | |

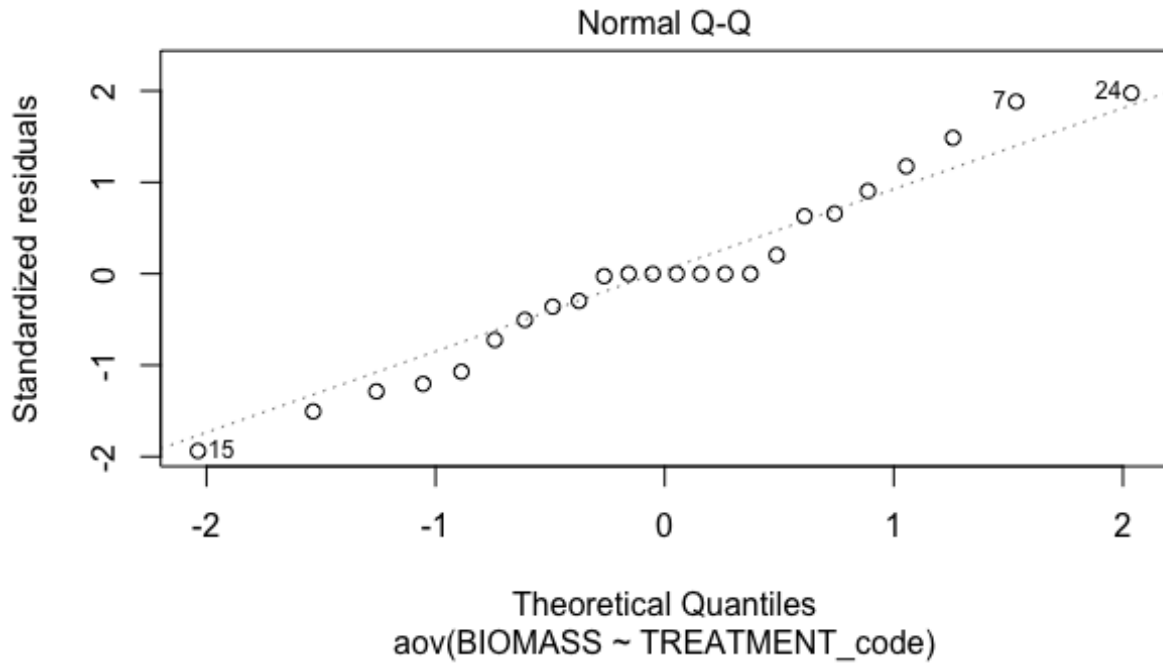
```
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```
``{r}
```

```
plot(res.aov, 2)
```

``



``{r}

```
aov_residuals <- residuals(object = res.aov )
```

```
shapiro.test(x = aov_residuals )
```

``

Shapiro-Wilk normality test

data: aov_residuals

W = 0.96659, p-value = 0.5839

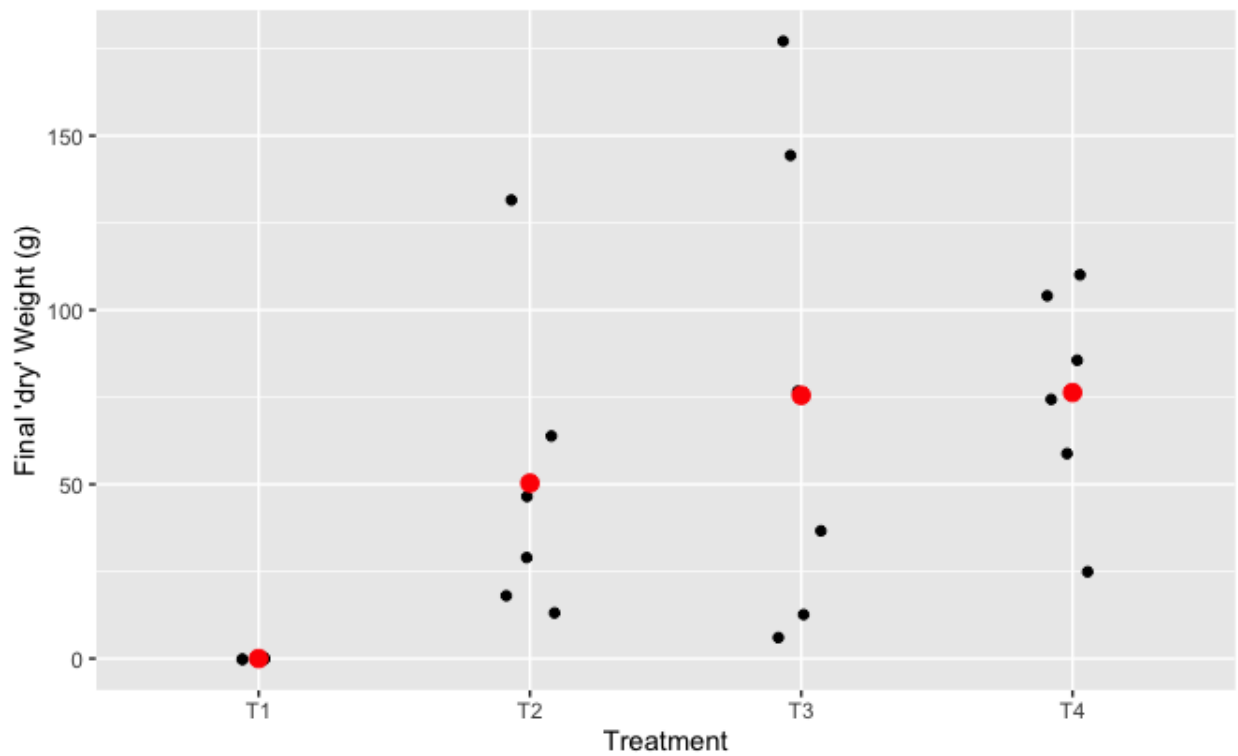
```
mean_by_treatment = EglacuasBIOMASS %>%
```

```
group_by(Treatment_code) %>%  
  summarise(meanmass=mean(`Dry_weight`))  
mean_by_treatment
```

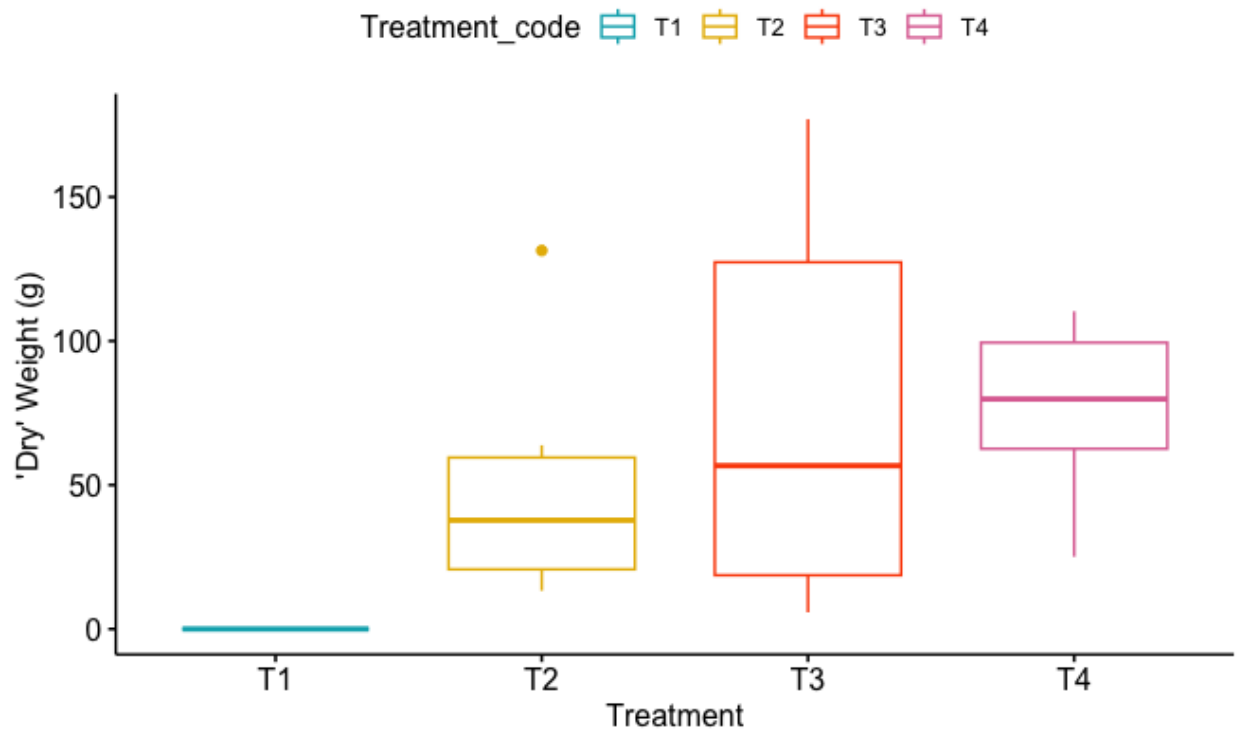
| Treatment_code | meanmass |
|-----------------------|-----------------|
| <chr> | <dbl> |
| T1 | 0.00000 |
| T2 | 50.33333 |
| T3 | 75.51667 |
| T4 | 76.31667 |

4 rows

```
ggplot(data=EglaucusDRY, aes(x=Treatment_code, y=Dry_weight)) +  
  geom_jitter(position = position_jitter(width = .1)) +  
  stat_summary(fun.y = "mean", geom = "point", color = "red", size = 3) +  
  labs(x="Treatment", y = "'Dry' Weight (g)")
```



```
ggboxplot(EglaucusDRY, x = "Treatment_code", y = "Dry_weight",  
color = "Treatment_code", palette = c("#00AFBB", "#E7B800", "#FC4E07", "#de70a1"),  
order = c("T1", "T2", "T3", "T4"),  
ylab = "'Dry' Weight (g)", xlab = "Treatment")  
add = c("mean_se", "jitter")
```



```
``{r}
```

```
res.aov <- aov(Dry_weight ~ Treatment_code, data = EglaucusDRY)
```

```
summary(res.aov)
```

```
``
```

```

Df Sum Sq Mean Sq F value Pr(>F)
Treatment_code 3 23056 7685 3.849 0.0252 *
Residuals 20 39935 1997
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

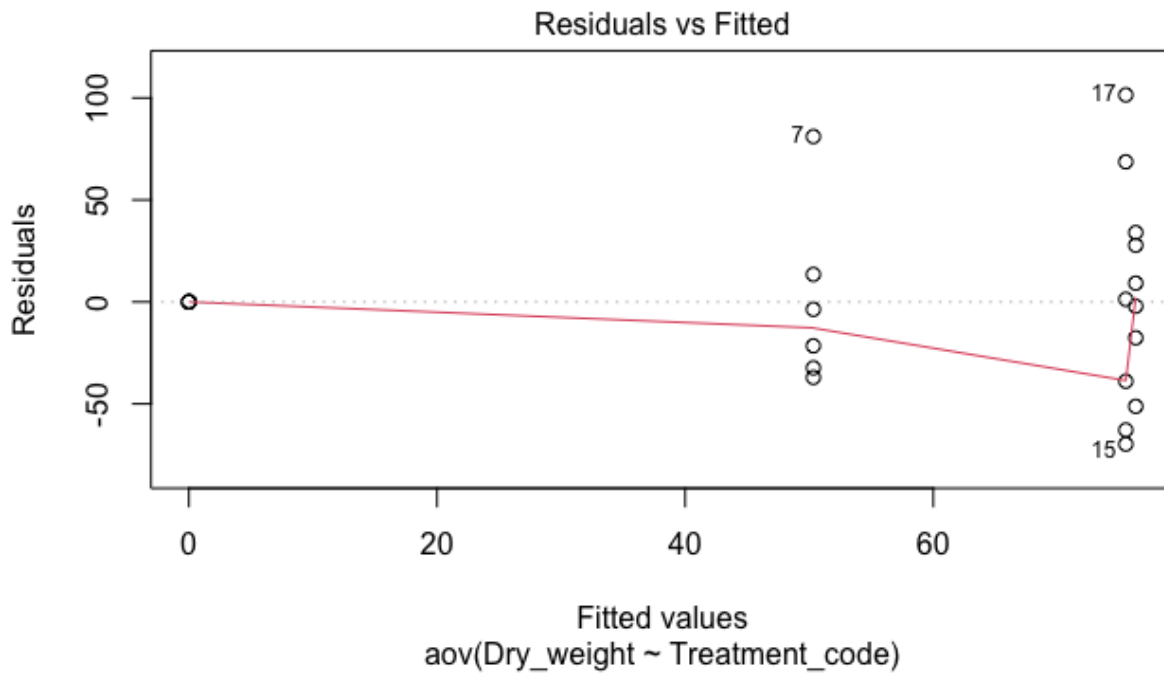
```
TukeyHSD(res.aov)
```

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = Dry_weight ~ Treatment_code, data = EglaucusDRY)

```
$Treatment_code
  diff   lwr   upr  p adj
T2-T1 50.33333 -21.87597 122.54264 0.2394273
T3-T1 75.51667  3.30736 147.72597 0.0383697
T4-T1 76.31667  4.10736 148.52597 0.0359607
T3-T2 25.18333 -47.02597  97.39264 0.7643545
T4-T2 25.98333 -46.22597  98.19264 0.7471154
T4-T3  0.80000 -71.40931  73.00931 0.9999889
```

plot(res.aov, 1)



```
``{r}
```

```
leveneTest(Dry_weight~ Treatment_code, data = EglaucusDRY)
```

```
````
```

levene's Test for Homogeneity of Variance (center = median)

```
 Df F value Pr(>F)
group 3 4.5346 0.01396 *
```

20

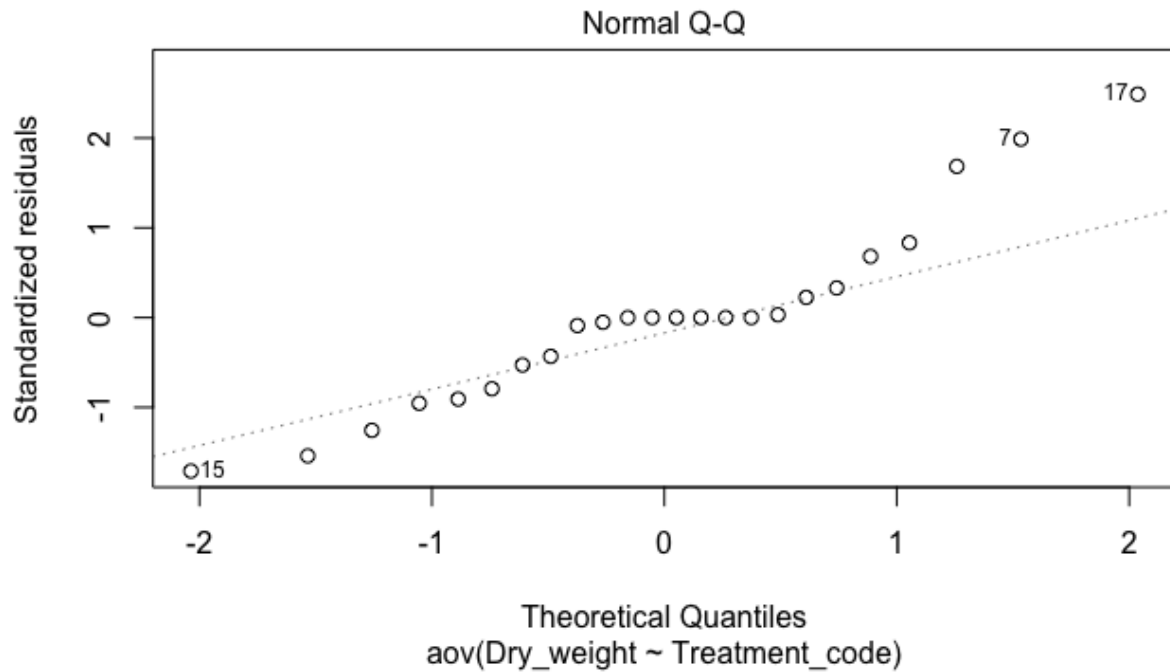
---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

```
``{r}
```

```
plot(res.aov, 2)
```

---



```
``{r}
```

```
aov_residuals <- residuals(object = res.aov)
```

```
shapiro.test(x = aov_residuals)
```

---

Shapiro-Wilk normality test

data: aov\_residuals  
W = 0.9287, p-value = 0.0912

```
``{r}
```

```

mean_by_treatment = Drydata %>%
 group_by(Treatment_code) %>%
 summarise(meanmass=mean(`Dry_Individuals`))

```

```
mean_by_treatment
```

```
```
```

| Treatment_code | meanmass |
|-----------------------|-----------------|
| <chr> | <dbl> |
| T1 | 0.0000000 |
| T2 | 0.2871336 |
| T3 | 0.2902302 |
| T4 | 0.3032315 |

```
4 rows
```

```
```{r}
```

```
levels(Drydata$Treatment_code)
```

```

Drydata$Treatment_code <- ordered(Drydata$Treatment_code,
 levels = c("T1", "T2", "T3", "T4"))

```

```
```
```

```
```{r}
```

```

group_by(Drydata, Treatment_code) %>%
 summarise(
 count = n(),
 mean = mean(Dry_Individuals, na.rm = TRUE),
 sd = sd(Dry_Individuals, na.rm = TRUE)
)

```

```

```

| Treatment_code | count | mean      | sd         |
|----------------|-------|-----------|------------|
| <ord>          | <int> | <dbl>     | <dbl>      |
| T1             | 6     | 0.0000000 | 0.00000000 |
| T2             | 6     | 0.2871336 | 0.14058185 |
| T3             | 6     | 0.2902302 | 0.19887152 |
| T4             | 6     | 0.3032315 | 0.04519254 |

```
4 rows
```

```
``{r}
```

```
res.aov <- aov(Dry_Individuals ~ Treatment_code, data = Drydata)
```

```
summary(res.aov)
```

```

```

```
Df Sum Sq Mean Sq F value Pr(>F)
Treatment_code 3 0.3886 0.12953 8.445 0.000799 ***
Residuals 20 0.3068 0.01534

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
``{r}
```

```
TukeyHSD(res.aov)
```

```
Tukey multiple comparisons of means
```

```
95% family-wise confidence level
```

```
Fit: aov(formula = Dry_Individuals ~ Treatment_code, data = Drydata)
```

```
$Treatment_code
```

```
diff lwr upr p adj
```

```
T2-T1 0.287133643 0.08699584 0.4872714 0.0034897
T3-T1 0.290230159 0.09009236 0.4903680 0.0031625
T4-T1 0.303231481 0.10309368 0.5033693 0.0020898
T3-T2 0.003096516 -0.19704128 0.2032343 0.9999698
T4-T2 0.016097839 -0.18403996 0.2162356 0.9958418
T4-T3 0.013001323 -0.18713648 0.2131391 0.9977928
```

```

```

```
leveneTest(Dry_Individuals~ Treatment_code, data = Drydata)
```

```
Levene's Test for Homogeneity of Variance (center = median)
```

```
 Df F value Pr(>F)
group 3 3.7702 0.02704 *
 20
```

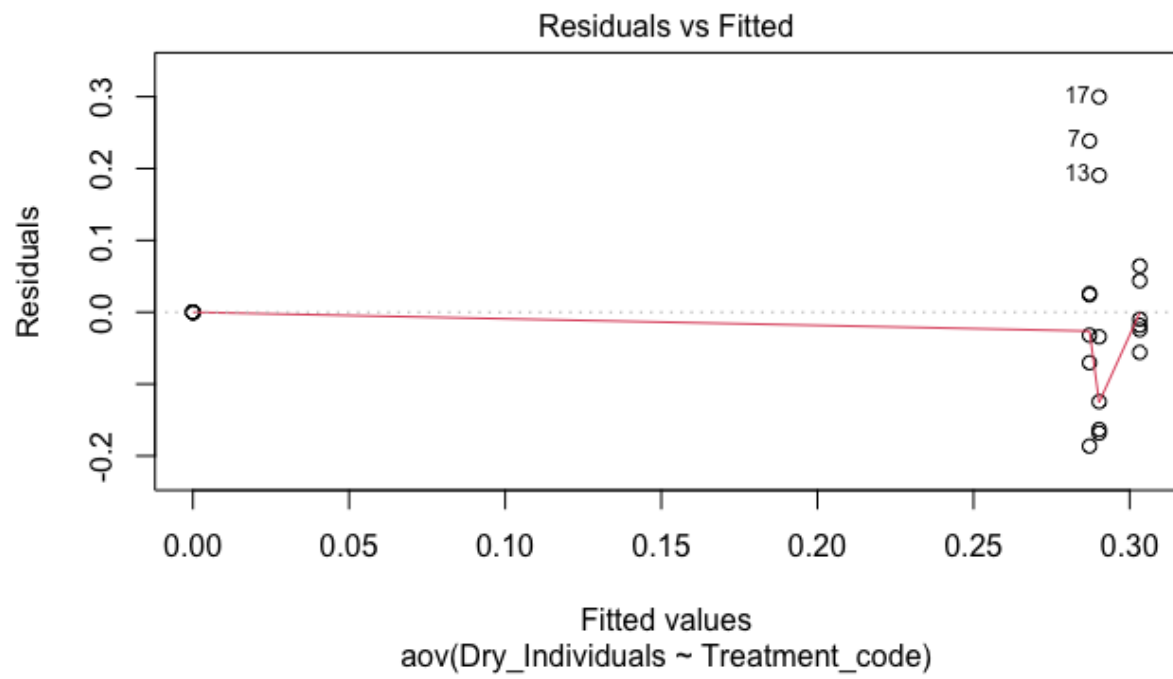
```

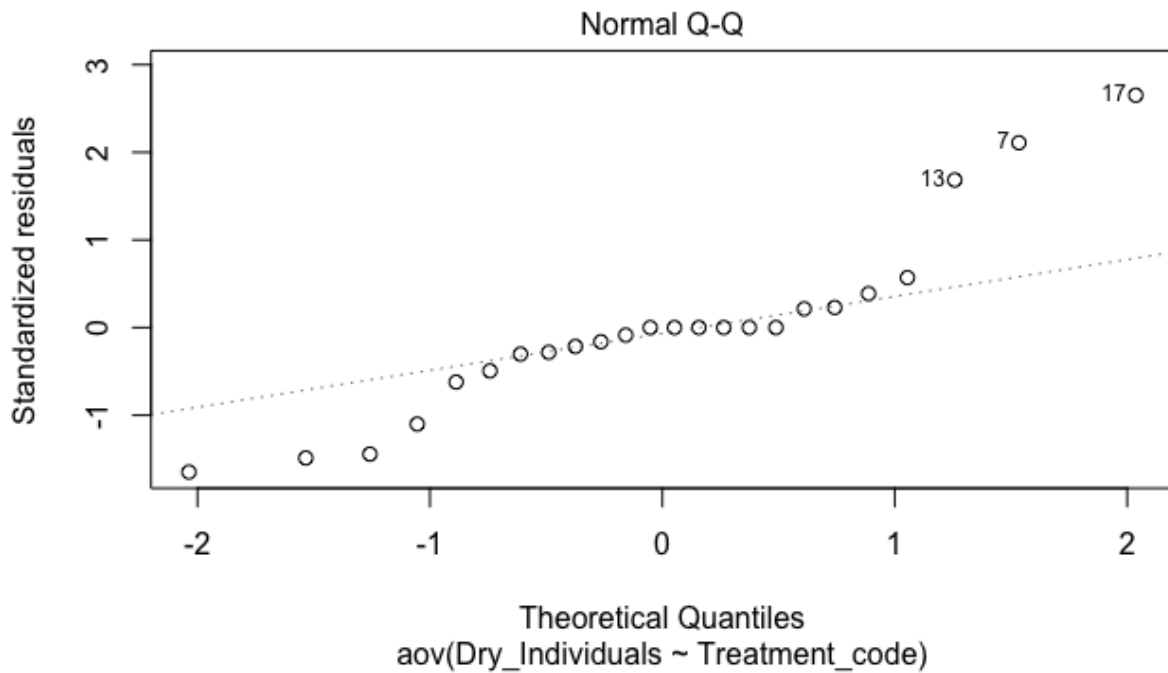
```

```
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
``{r}
```

```
plot(res.aov, 1)
```





```
``{r}
```

```
aov_residuals <- residuals(object = res.aov)
```

```
shapiro.test(x = aov_residuals)
```

```
...
```

```
Shapiro-Wilk normality test
```

```
data: aov_residuals
```

```
W = 0.88863, p-value = 0.01245
```

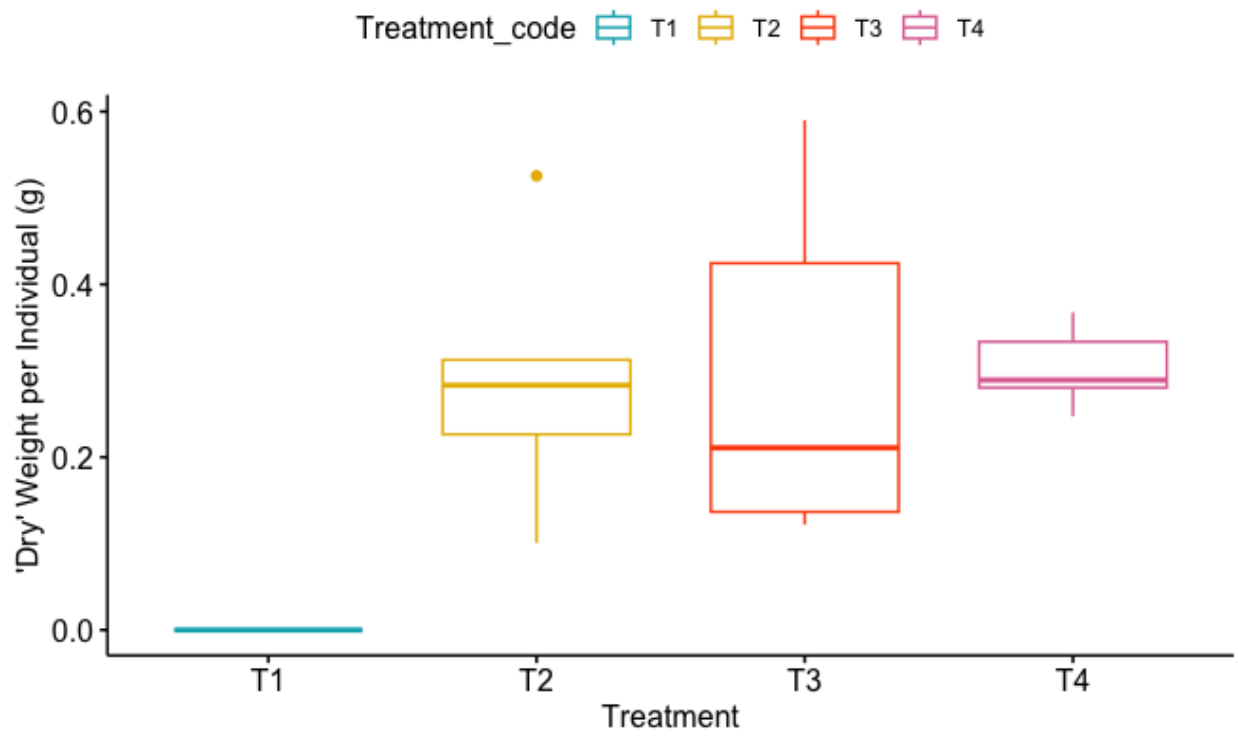
```
ggboxplot(Drydata, x = "Treatment_code", y = "Dry_Individuals",
```

```
color = "Treatment_code", palette = c("#00AFBB", "#E7B800", "#FC4E07", "#de70a1"),
order = c("T1", "T2", "T3", "T4"),
```

```
ylab = "'Dry' Weight per Individual (g)", xlab = "Treatment")
```

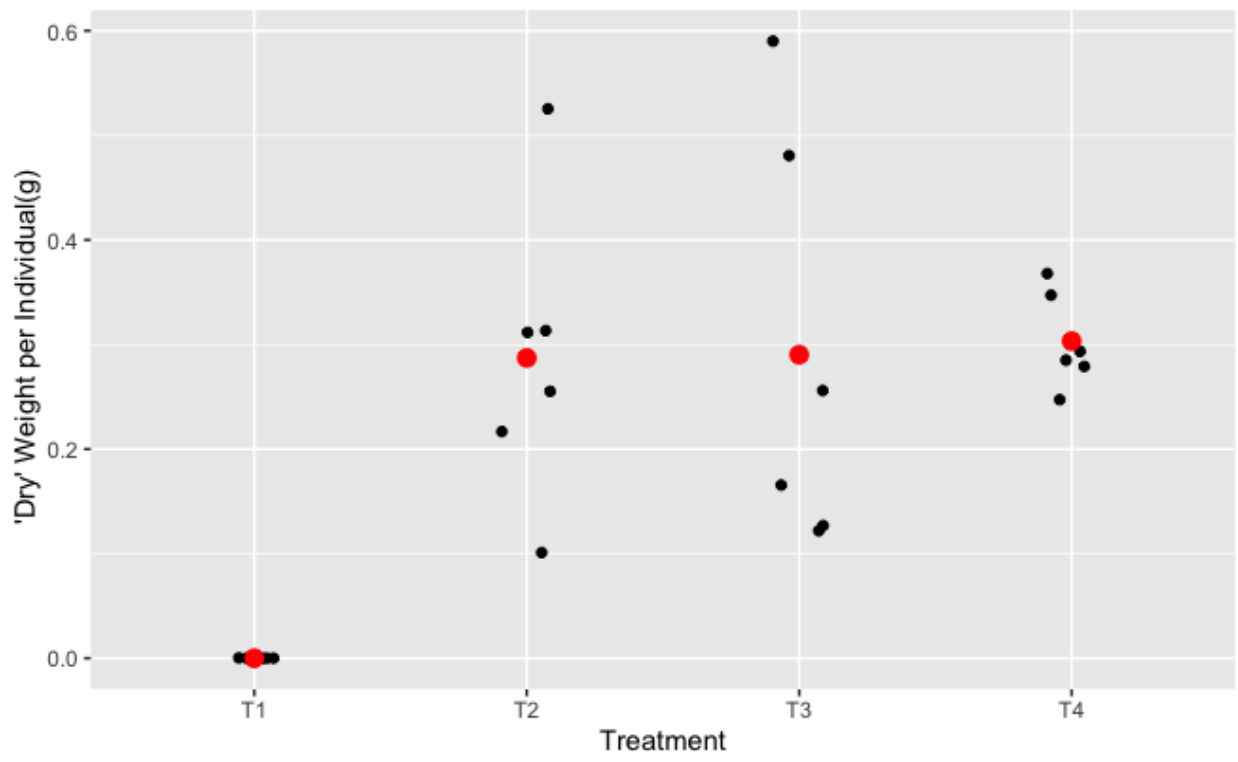
```
add = c("mean_se", "jitter")
```

```
...
```



```
ggplot(data=Drydata, aes(x=Treatment_code, y=Dry_Individuals)) +
 geom_jitter(position = position_jitter(width = .1)) +
 stat_summary(fun.y = "mean", geom = "point", color = "red", size = 3) +
 labs(x="Treatment", y = "'Dry' Weight per Individual(g)")
```

```
...
```



## APPENDIX D

The weather data for November 2023.

Climatological Data for DE SABLE, CA - November 2023

| Date               | Max Temperature | Min Temperature | Avg Temperature | GDD Base 40 | GDD Base 50 | Precipitation | Snowfall   | Snow Depth |
|--------------------|-----------------|-----------------|-----------------|-------------|-------------|---------------|------------|------------|
| 2023-11-01         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-11-02         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-11-03         | 69              | 59              | 64.0            | 24          | 14          | 0.00          | 0.0        | 0          |
| 2023-11-04         | M               | M               | M               | M           | M           | 0.10          | 0.0        | 0          |
| 2023-11-05         | M               | M               | M               | M           | M           | 0.10          | 0.0        | 0          |
| 2023-11-06         | M               | M               | M               | M           | M           | 0.10          | 0.0        | 0          |
| 2023-11-07         | 58              | 45              | 51.5            | 12          | 2           | 0.10          | 0.0        | 0          |
| 2023-11-08         | 63              | 43              | 53.0            | 13          | 3           | 0.00          | 0.0        | 0          |
| 2023-11-09         | 60              | 46              | 53.0            | 13          | 3           | 0.00          | 0.0        | 0          |
| 2023-11-10         | 63              | 47              | 55.0            | 15          | 5           | 0.00          | 0.0        | 0          |
| 2023-11-11         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-11-12         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-11-13         | 59              | 48              | 53.5            | 14          | 4           | 0.00          | 0.0        | 0          |
| 2023-11-14         | 62              | 45              | 53.5            | 14          | 4           | 0.00          | 0.0        | 0          |
| 2023-11-15         | 65              | 47              | 56.0            | 16          | 6           | 0.00          | 0.0        | 0          |
| 2023-11-16         | 62              | 50              | 56.0            | 16          | 6           | 0.25          | 0.0        | 0          |
| 2023-11-17         | 65              | 48              | 56.5            | 17          | 7           | 0.00          | 0.0        | 0          |
| 2023-11-18         | M               | M               | M               | M           | M           | 1.23          | 0.0        | 0          |
| 2023-11-19         | M               | M               | M               | M           | M           | 1.23          | 0.0        | 0          |
| 2023-11-20         | 59              | 45              | 52.0            | 12          | 2           | 1.24          | 0.0        | 0          |
| 2023-11-21         | 59              | 42              | 50.5            | 11          | 1           | 0.00          | 0.0        | 0          |
| 2023-11-22         | 61              | 48              | 54.5            | 15          | 5           | 0.00          | 0.0        | 0          |
| 2023-11-23         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-11-24         | 66              | 30              | 48.0            | 8           | 0           | 0.00          | 0.0        | 0          |
| 2023-11-25         | 55              | 31              | 43.0            | 3           | 0           | 0.00          | 0.0        | 0          |
| 2023-11-26         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-11-27         | 56              | 30              | 43.0            | 3           | 0           | 0.00          | 0.0        | 0          |
| 2023-11-28         | 56              | 38              | 47.0            | 7           | 0           | 0.00          | 0.0        | 0          |
| 2023-11-29         | 58              | 44              | 51.0            | 11          | 1           | 0.00          | 0.0        | 0          |
| 2023-11-30         | 54              | 38              | 46.0            | 6           | 0           | 0.00          | 0.0        | 0          |
| <b>Average/Sum</b> | <b>60.5</b>     | <b>43.4</b>     | <b>51.9</b>     | <b>230</b>  | <b>63</b>   | <b>4.35</b>   | <b>0.0</b> | <b>0.0</b> |

Weather data pulled from <https://agacis.rcc-acis.org/>. Degrees are in Fahrenheit, precipitation is measured in inches, and 'M' is missing data.

## The weather data from December 202

Climatological Data for DE SABLA, CA - December 2023

| Date               | Max Temperature | Min Temperature | Avg Temperature | GDD Base 40 | GDD Base 50 | Precipitation | Snowfall   | Snow Depth |
|--------------------|-----------------|-----------------|-----------------|-------------|-------------|---------------|------------|------------|
| 2023-12-01         | 58              | 29              | 43.5            | 4           | 0           | 0.09          | 0.0        | 0          |
| 2023-12-02         | M               | M               | M               | M           | M           | 0.19          | 0.0        | 0          |
| 2023-12-03         | M               | M               | M               | M           | M           | 0.19          | 0.0        | 0          |
| 2023-12-04         | 64              | 49              | 56.5            | 17          | 7           | 0.20          | 0.0        | 0          |
| 2023-12-05         | 61              | 39              | 50.0            | 10          | 0           | 0.01          | 0.0        | 0          |
| 2023-12-06         | 59              | 41              | 50.0            | 10          | 0           | 0.08          | 0.0        | 0          |
| 2023-12-07         | 47              | 34              | 40.5            | 1           | 0           | 0.76          | 0.0        | 0          |
| 2023-12-08         | 61              | 30              | 45.5            | 6           | 0           | 0.17          | 0.0        | 0          |
| 2023-12-09         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-12-10         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-12-11         | 59              | 39              | 49.0            | 9           | 0           | 0.00          | 0.0        | 0          |
| 2023-12-12         | 62              | 44              | 53.0            | 13          | 3           | 0.03          | 0.0        | 0          |
| 2023-12-13         | 59              | 44              | 51.5            | 12          | 2           | 0.00          | 0.0        | 0          |
| 2023-12-14         | 56              | 40              | 48.0            | 8           | 0           | 0.00          | 0.0        | 0          |
| 2023-12-15         | 65              | 48              | 56.5            | 17          | 7           | 0.00          | 0.0        | 0          |
| 2023-12-16         | M               | M               | M               | M           | M           | 0.27          | 0.0        | 0          |
| 2023-12-17         | M               | M               | M               | M           | M           | 0.27          | 0.0        | 0          |
| 2023-12-18         | 49              | 48              | 48.5            | 9           | 0           | 0.28          | 0.0        | 0          |
| 2023-12-19         | 53              | 48              | 50.5            | 11          | 1           | 3.83          | 0.0        | 0          |
| 2023-12-20         | 60              | 42              | 51.0            | 11          | 1           | 1.18          | 0.0        | 0          |
| 2023-12-21         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| 2023-12-22         | 63              | 43              | 53.0            | 13          | 3           | 0.00          | 0.0        | 0          |
| 2023-12-23         | M               | M               | M               | M           | M           | 0.09          | 0.0        | 0          |
| 2023-12-24         | M               | M               | M               | M           | M           | 0.09          | 0.0        | 0          |
| 2023-12-25         | M               | M               | M               | M           | M           | 0.09          | 0.0        | 0          |
| 2023-12-26         | M               | M               | M               | M           | M           | 0.10          | 0.0        | 0          |
| 2023-12-27         | 56              | 34              | 45.0            | 5           | 0           | 0.10          | 0.0        | 0          |
| 2023-12-28         | 53              | 43              | 48.0            | 8           | 0           | 0.46          | 0.0        | 0          |
| 2023-12-29         | 53              | 45              | 49.0            | 9           | 0           | 0.00          | 0.0        | 0          |
| 2023-12-30         | 55              | 43              | 49.0            | 9           | 0           | 1.10          | 0.0        | 0          |
| 2023-12-31         | M               | M               | M               | M           | M           | 0.00          | 0.0        | 0          |
| <b>Average Sum</b> | <b>57.5</b>     | <b>41.2</b>     | <b>49.4</b>     | <b>182</b>  | <b>24</b>   | <b>9.58</b>   | <b>0.0</b> | <b>0.0</b> |

Weather data pulled from <https://agacis.rcc-acis.org/>. Degrees are in Fahrenheit, precipitation is measured in inches, and 'M' is missing data.

