דו"ח מסכם של פרויקט מחקר מס' 1823 – מרץ 2024

השפעת בצורת ושינויים בדפוסי פיזור גשם על דינמיקה ותפקוד חברות צומח טבעיות באקוסיסטמות ים תיכוניות: תחנת המחקר מטע LTER כמקרה בוחן.

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תקציר

דו"ח זה מציג לאחר שנה שלישית ואחרונה את סיכום התוצאות של הפרויקט במימון קק"ל, אך מייצג את השנה הרביעית מאז תחילת מניפולציות הגשם במסגרת מחקר על השפעות שינויי האקלים על חברות צומח טבעיות באקוסיסטמות ים תיכוניות באתר מטה LTER. לפיכך, הדוח כולל תוצאות מתקופות שהחלו לפני הפרויקט הנוכחי (2021-23).

מחקר זה בוחן ההשפעה של אירועי בצורת קיצוניים ושינוי בתפרוסת הגשם על מבנה ותפקוד של המערכת האקולוגית בשטחי בתה ים-תיכונית בישראל. המחקר מתבצע באמצעות ניסוי בתנאי שדה המדמה שינויים בתדירות ובכמות הגשם השנתית. המחקר מתבצע בתחנת המחקר מטע (LTER) בהרי יהודה. מטרת הפרויקט היא הבנה מעמיקה במונחי גיוון פונקציונלי, של יחסי הגומלין בין התגובות האביוטיות והתגובות הביוטיות בצומח והקרקע כתוצאה משינויי אקלים, והשלכות של יחסי הגומלין האלה על תפקוד המערכת האקולוגית.

טיפולי ההדמיה של תנאי בצורת במחקר זה, כוללים הפחתה של 66% מכמות הגשם השנתית הממוצעת בתחנה (9 אירועי גשם של 20 מ"מ, לעומת 3 ארועי גשם של 60 מ"מ). זאת באמצעות חסימת כלל הגשם על ידי סככות צל-גשם, והמטרת גשם לפי כמות קצובה במערכת ממטרות. במהלך השנה השלישית לפרויקט ובדומה לשנה הקודמת נדגמה הצמחייה בשיא עונת הפריחה (באפריל 2023).

בדומה לשנים הקודמות, התוצאות הראו שבטיפול בבצורת הקיצוני הובחנה הפחתה מובהקת של ייצור ביומסת חומר ייבש, בהשוואה לחלקות הביקורת (המצויות בתנאי גשם טבעיים). הפחתה דומה אובחנה בעושר המינים (species richness) ובמגוון המינים (species diversity) . לעומת תוצאות ברורות אלה, לא נצפו הבדלים מובהקים בין שני הדפוסים השונים של חלוקת הגשם בתנאי בצורת.

טיפולי הבצורת השפיעו באופן משמעותי על ניטרט הקרקע ועל תכולת הזרחן זמין. NO_3 היה נמוך משמעותית בחלקות בתנאי בצורת, דבר המעיד על תחלופה נמוכה יותר של חנקן בקרקע שנגרמה על ידי

פעילות מיקרוביאלית מוגבלת, בעוד ריכוז גבוה יותר של PO_4 התקבל בתנאי בצורת קיצוניים, כאשר נוכחות צמחייה נמוכה יותר הוציאה פחות כמות מזינים שהובילה לריכוז גבוה יותר בקרקעות.

התוצאות תואמות לאלה שהתקבלו בשנים הקודמות לתחילת הפרויקט הנוכחי. ככל הנראה מתקיימת עדיין בחלקות הבצורת השפעה של התנאים שמלפני הטיפולים, יתכן דרך בנק הזרעים בקרקע המשפיע לטווח ארוך על מיתון השפעות הבצורת. נראה כי יידרש פרק זמן נוסף בכדי לזהות הבדלים בין שני טיפולי הבצורת. מכל מקום, אנו מסיקים כי לבצורת קיצונית וממושכת יהיו השפעות שליליות וגדולות על תפקוד מערכת אקולוגית מסוג זה. הפחתה בייצור הראשוני ושינויים במגוון המינים יביאו בעקבותיהם לשינויים נגזרים בקרקע, ובנוכחות וארגון של כלל האורזניזמים באוקוסיסטמה.

Abstract

This report presents the results of the third and last year of the KKL funded project but represent the fourth year since the start of the climate change rainfall manipulations at the Matta LTER site. Therefore, the report includes results from periods that started before the current project (2021-2022).

In the framework of the present research we study the effects of extreme drought and changes in rainfall distribution on plant community structure and composition as well as changes in primary productivity on a Mediterranean *batha* ecosystem. The study was carried out under field conditions and simulate expected changes in rainfall distribution patterns. The investigation was carried out at the research station Matta LTER in the Judean Hill. Rainfall manipulations treatments included rainfall reduction of 66% and changes in rainfall distribution (9 rainfall events of 20 mm each vs. 3 rainfall events of 60 mm each) using rainout shelters and irrigation systems.

During the third year of the project the vegetation was sampled in April 2023, at the peak of the flowering season. Similar to the previous years, the results showed a significant decrease in biomass production under extreme drought treatment when comparing to the control plots (natural rainfall). Similar results were obtained when considering species richness and species diversity. However, no significant differences were observed in any of the parameters measured when comparing changes in rainfall distribution under drought conditions. The drought treatments significantly affected soil nitrate and available phosphorous content. NO_3 was significantly lower in plots under drought conditions indicating lower soil nitrogen turnover induced by constrained microbial activity, while higher PO4 concentration were obtained under extreme drought conditions as lower vegetation presence extracted less nutrient amount leading to higher concentrations in soils.

These results are consistent with those obtained in previous years before the onset of the present project. Apparently, some legacy effects from past conditions are still evident through the long-term soil seed bank. However, the significant differences between the drought treatments and controls can lead to significant changes in the functioning of this type of ecosystem. Despite some differences noted between the treatments with different

rainfall frequency distribution, further time may be needed to identify differences between these two treatments. We conclude that climate change will have major effects on the functioning of this type of ecosystem through a reduction in primary production and changes in species diversity.

Introduction

The Mediterranean region is anticipated to experience heightened impacts from climate change, which is likely to lead to more frequent and severe droughts, extended periods of dry weather, and more intense summer heat waves. Observations have already noted a decline in yearly rainfall and a reduction in the duration of the wet season, particularly in the eastern Mediterranean. Such extreme climatic events and shifts in rainfall patterns are known to significantly affect plant life, aboveground biomass production, soil nutrients, and overall ecosystem performance. The consequences of climate change could include shifts in species distribution, phenological alterations, changes in the variety of functions species perform within ecosystems, impacts on primary production and nutrient cycling, and reordering of the spatial distribution of species and ecosystem functions. Our research focuses on exploring the impact that changes in rainfall amount and distribution have on biodiversity and ecosystem functions within a Mediterranean shrubland environment.

The third rainfall season (2022-23) of the present project is the fifth year since the establishment of the research experimental infrastructures at the Matta LTER study site, formally funded by the Ministry of Science & Technology. This included the set-up of 10 new rainout shelters where 66% drought was simulated with changes in frequency of rainfall distribution. In total there three treatments as follows: 1) 66% Drought simulation with three rainfall events of 60 mm each during the growing season (Low Frequency – D66-LF; total rainfall applied 180 mm), 2) 66% Drought simulation with nine rainfall events of 20 mm each during the growing season (High Frequency – D66-HF; total rainfall applied 180 mm), and 3) Control (C) with no changes in natural rainfall conditions. The rainfall reduction amount (360 mm) was estimated based on the long-term mean of 540 mm that falls in the area. Each treatment is replicated five times in a split-block design.

Results

During the period of this study, rainfall stand close to the long-term mean (540 mm) or above average as the total precipitation was 536 mm, 616 mm and 708 mm for 2021, 2022 and 2023, respectively. The last rainfall season of the project was relative wet with 31% above the long-term mean. Figure 1 presents the precipitation distribution along the rainfall season jointly with soil moisture measurements obtained from the meteorological station present at the site, combined with soil moisture differences among the control and drought treatments (D66-HF and D66-LF, respectively).

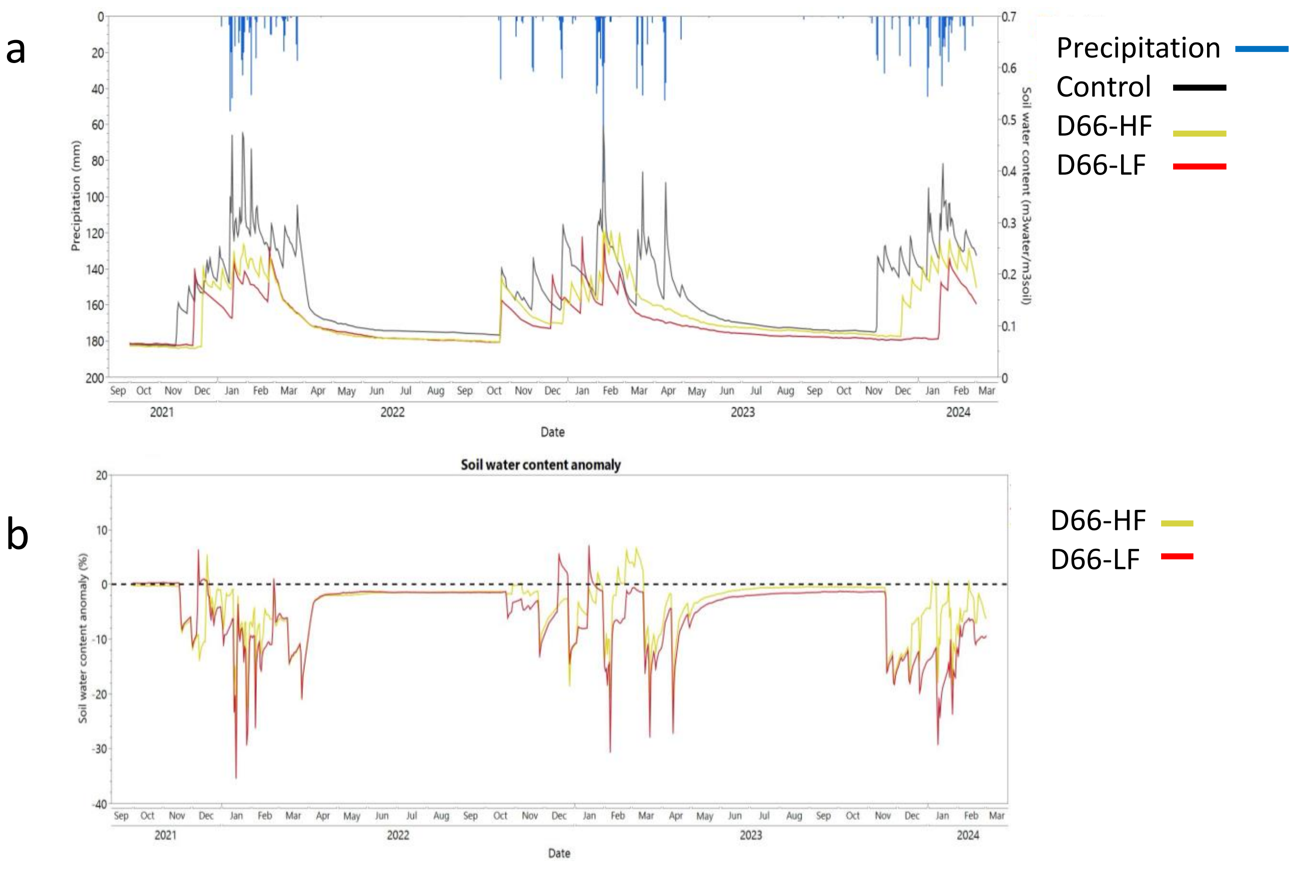

***Fig.1**. a) Representation of precipitation distribution for the rainfall seasons 2021-'22, 2022-'23 and 2023-'24; jointly with soil moisture measurements at the respective treatments; b) Soil water content anomaly (%) for the drought treatments compared to Control. Changes are relative to soil moisture differences from Control (Control was established as a zero baseline).*

Figure 1a illustrates the variation in rainfall patterns over different years. The rainfall season of 2021-2022 was characterized by a briefer duration of soil moisture in comparison to its subsequent year. The impact of individual precipitation and irrigation events is distinguishable, with increments in soil moisture corresponding to these occurrences. Significant difference in soil moisture were noted between the control treatment and the drought treatments (D66-HF and D66-LF). The contrast between the D66-HF (high frequency) and D66-LF (low frequency) treatments is apparent, as demonstrated by the varied peaks in soil moisture levels. The D66-LF showed lower soil moisture content in the soil compared to the higher frequency treatment indicating higher water stress in these plots. Figure 1b presents the heightened severity of drought conditions in the D66-LF treatment, as indicated by the consistently lower soil moisture throughout much of the growing season, a trend that was particularly noticeable during the dry summer period. Despite both treatments receiving an identical total rainfall of 180 mm, the distribution between smaller (20 mm) and larger rainfall events (60 mm) led to significant disparities in the availability of soil moisture, as evidenced by the data in the figure.

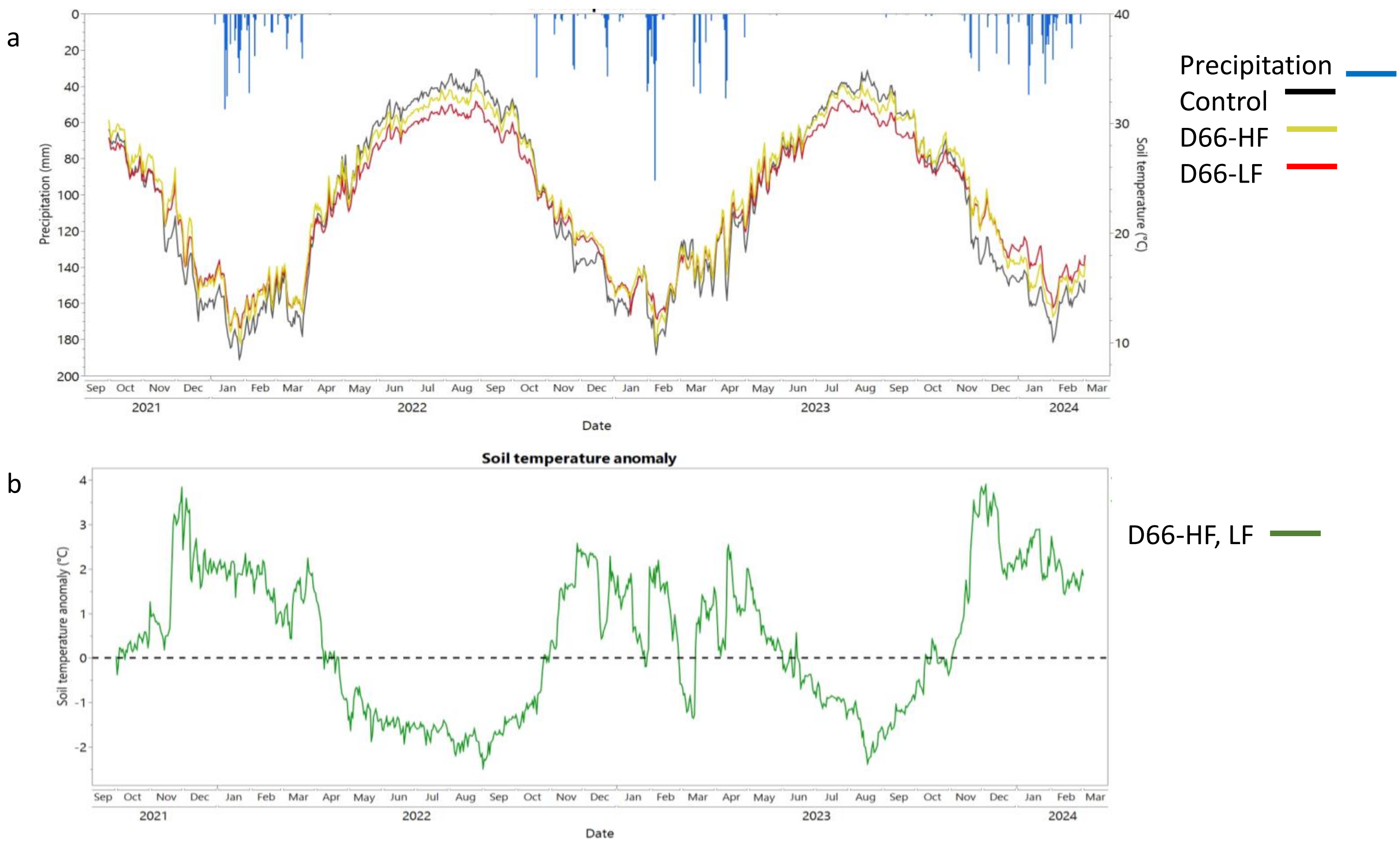

***Fig.2**. a) Representation of precipitation distribution for the rainfall seasons 2021-’22, 2022-’23 and 2023-’24; jointly with soil temperatures measurements at the respective treatments; b) Soil temperate anomaly (%) for the drought treatments compared to Control. Changes are relative to soil temperature differences from Control (Control was established as a zero baseline).*

Similar to the results presented in Figure 1, Figure 2a captures the fluctuations in rainfall across various years and overlays these with the corresponding seasonal temperature shifts, also taking into account the temperature variations observed across different drought treatment scenarios. Distinct seasonal contrasts are evident in the data. Notably, the rainout shelter infrastructure introduces secondary temperature effects, inducing an approximate warming of 2°C during the winter months and an equivalent cooling effect during the summer. These winter warming effects align with predicted future climate models forecasting increased winter temperatures, though the same cannot be said for summer predictions. Despite these artifacts, it's crucial to emphasize that the herbaceous vegetation, the primary focus of this study, remains dormant during summer and thus not photosynthetically active in this period. We believe that these experimental design effects do not compromise the validity of our results and the conclusions drawn therein.

In the spring of 2023, vegetation sampling was conducted during the peak of the flowering period. The data gathered revealed a notable decrease in the production of aboveground biomass on plots subjected to a 66% reduction in water availability, regardless of how the rainfall was distributed, as shown in Figure 3. Across all surveyed years, biomass production consistently declined under severe drought conditions. It is crucial to acknowledge that at the control site, biomass production did not exhibit a direct, positive relationship with the amount of rainfall. This is underscored by the significant variance in biomass production during years with high precipitation compared to those with average rainfall (notably, the 2020 and 2023 seasons as opposed to the 2021 season). This pattern was particularly pronounced in the 2023 season, where biomass production was unexpectedly lower, even in comparison to years that experienced less rainfall, such as 2021.

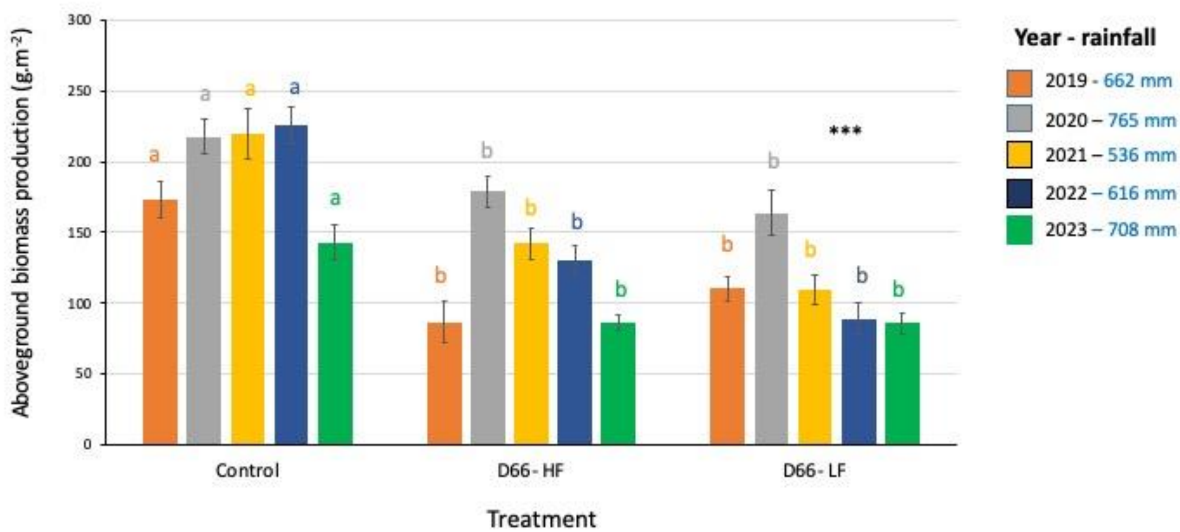

Fig. 3. *Effects of rainfall manipulations on aboveground biomass production. Comparison includes control and drought treatments with differences in rainfall distribution (HF- High Frequency vs LF Low Frequency). Significant differences between Control and D66-LF and D66-HF for the years 2019 to 2023 were noted. Letters indicate significant differences*

*between groups; Tukey HSD test. ***indicates significant difference between years at P < 0.001. Rainfall box indicate total amount of precipitation for that particular year.*

In an effort to broaden the context of this study, the findings discussed here include data from years prior to the initiation of the current project. When evaluating the average reduction in biomass production across all years since the project began, there is a discernible decrease in plots affected by drought with a higher frequency of rainfall (D66-HF), which exhibit a 30% reduction in biomass compared to control plots. However, plots experiencing drought with less frequent rainfall (D66-LF treatment) showed a more pronounced and significant biomass reduction of 37%. These figures are consistent with the lower soil moisture levels observed in the latter treatment, as shown in Figure 1.

Drought also affected species richness and species diversity as presented in Figure 4. Drought significantly reduced the number of species present at these plots, but no significant difference was observed between plots with high vs. low frequency of rainfall events. As noted in biomass production, no linear positive relation was found between rainfall and species diversity indices at the control plots (Fig. 4).

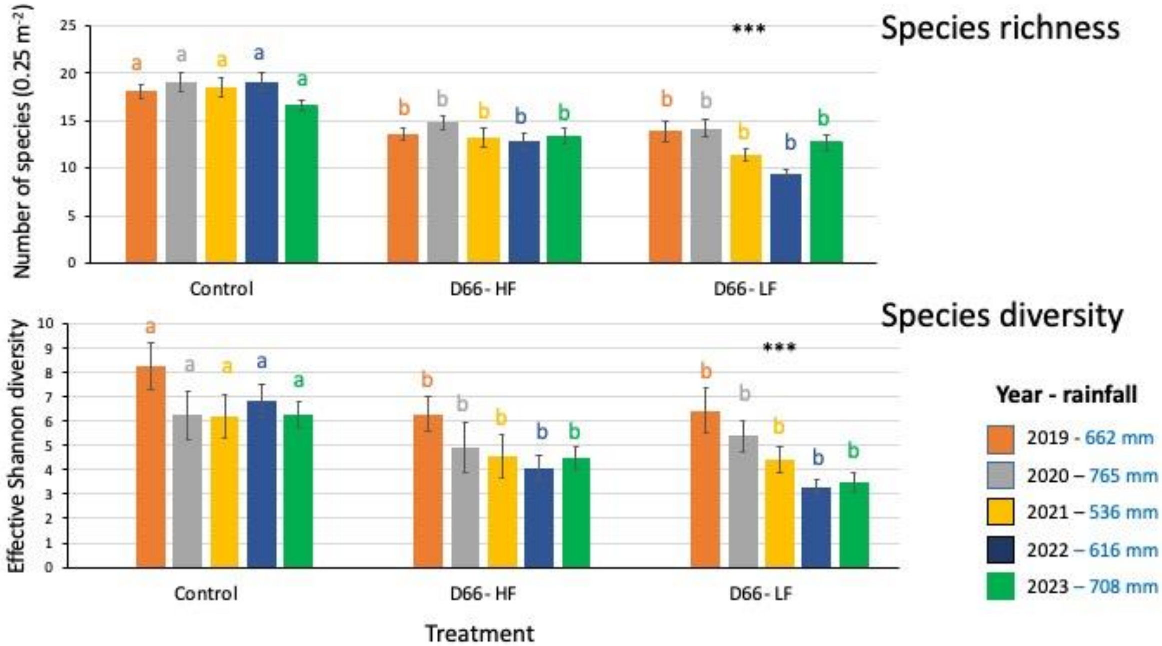

Fig. 4. *Effects of rainfall manipulations on species richness and species diversity. Significant differences between Control and D66-LF and D66-HF for the years 2019 to 2023 were noted. Letters indicate significant differences between groups; Tukey HSD test. ***indicates significant difference between years at P < 0.001. Rainfall box indicate total amount of precipitation for that particular year.*

While considering the mean species richness reduction by averaging all years since the start of the project, droughted plots that received high rainfall frequency (D66-HF) showed a decrease in species richness of 25% compared to controls, while plots under drought but with lower frequency of rainfall events (D66-LF), showed a significant reduction of 28% in species richness. Similar reduction patterns were noted when considering species diversity, although the strongest reduction was observed in the droughted plots with high frequency (D66-HF) with a mean decrease of 36% vs. a decrease of 31% in the low frequency (D66-LF) treatment plots. A reduction of around 30% in species diversity due to drought effects is considered a major change in any ecosystem.

The effects of drought treatments on soils nutrients were also analyzed. Soils were collected jointly with the vegetation in April 2022 and 2023. Five replicates of around 250 gr. of soils from the upper 10 cm were sampled. In total 100 soil samples were analyzed each year. Elements considered were: Organic carbon (%), total nitrogen (%), C/N, N-

NO_3 and PO_4 (Olsen P). No significant treatment effects were noted for soil organic carbon, total nitrogen and C/N ratios in any of the considered years. However, the results showed significant differences in N-NO3 and Olsen P (Fig. 5). The drought treatments significantly reduced the nitrate concentration in soils (Fig. 3a). No significant differences were noted between the drought treatments with changes in rainfall distribution (D66-HF vs. D66-LF). An oppositive effect of the drought treatment was observed when phosphorous (PO_4) concentration in soils. Significant lower phosphorous values were noted in soils at the Control plots.

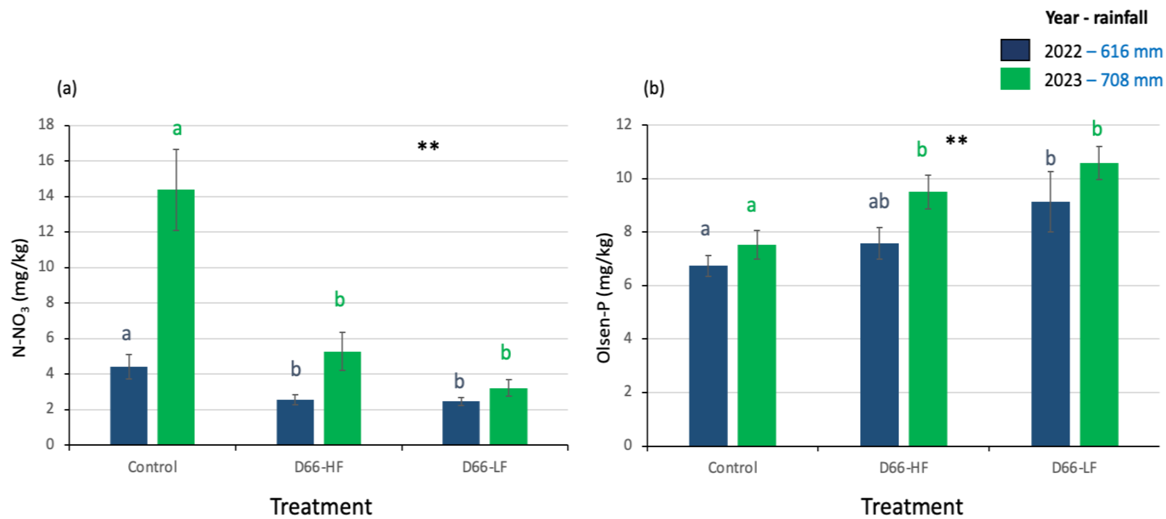

Fig. 5. *Effects of rainfall manipulations on soil nutrients. Significant differences in* NO_3 *between Control and D66-LF and D66-HF for the years 2022 and 2023 were noted (a); while significant differences in PO4 were observed between Control and D66-LF (b) in 2022, these differences were also significant with D66-HF in 2023. Letters indicate significant differences between groups with colors representing different yeas, Tukey HSD test. **indicates significant difference between treatments at P < 0.01,*

Discussion and Conclusions

The data from the meteorological station has shown the impact of rainfall manipulation on soil moisture and temperature. Throughout the years covered in this report, total rainfall was on par with or exceeded the long-term average. This detail is crucial when contrasting the conditions with those of drought treatments, which effectively underwent a 66%, 71%, and 75% reduction in rainfall for the years 2021, 2022, and 2023 respectively (comparing 566 mm to 180 mm, 616 mm to 180 mm, and 708 mm to 180 mm in the drought-affected plots). Despite these significant reduction in rainfall, a similar trend was not observed in the soil moisture profiles, as illustrated in Figure 1b. Here, the maximum soil moisture reduction was about 30%, with the average being around 20%. This kind of analysis is often overlooked in studies employing rainfall manipulations.

Moreover, Figure 1 highlights that the D6-LF treatment resulted in lower soil moisture levels, signifying drier conditions. This finding is pivotal as it suggests that more intense rainfall events, like those simulated by this treatment and predicted to increase due to climate change, could lead to reduced seasonal soil moisture, thereby affecting biomass production and species diversity.

Additionally, the presence of rainout shelters has been shown to affect soil temperature, as shown in Figure 2. Soil temperatures under the rainout shelters were approximately 2 degrees Celsius higher than the control plots during winter, while an inverse effect, a cooling impact, was observed during summer. The elevated winter temperatures are considered a positive secondary effect, aligning with predictions of warmer winters in the region's future climate scenarios. On the other side, the cooling effect in summer is considered insignificant for herbaceous vegetation, as during this time, their seeds lie dormant within the soil's seed bank.

Species richness and species diversity were consistently impacted by both drought treatments. As shown in Figure 4, these parameters were significantly reduced under drought conditions. Drought particularly affected legumes and crucifers, with a noticeable decline in their presence and relative abundance, resulting in decreased species richness and diversity. The more pronounced decline under the D66-LF treatment underscores the severity of this treatment and the potential negative effects on community structure in scenarios characterized by more concentrated rainfall events.

The observed minimal variation in response to drought treatments, despite differing rainfall distributions, might be attributed to the resilient characteristics of the ecosystem. The soil seed bank, pivotal for stability and resilience in such environments, may still be exerting an influence by supplying sufficient seedlings to mitigate the effects of the treatments. We anticipate that this mitigating impact will diminish over time as the seed bank is continually reducing. The notable decline in species diversity within the D6-LF treatment could be an early indication of this diminishing effect. Furthermore, significant changes in soil nitrate and available phosphorus linked to the drought treatments could be contributing to a negative feedback loop, adversely affecting vegetation biomass production through nutrient depletion.

These changes could substantially influence the community's structure and functionality, as other elements such as litter production—both above and below ground—are compromised, potentially destabilizing the community and disrupting nutrient cycles due to decreased organic input. The dry conditions in the drought-affected plots appear to significantly impact the microbial community responsible for nitrification, as evidenced by reduced nitrate levels (Fig. 5). The persistence of this trend may have profound effects on biomass production and could exacerbate the decline in species diversity.

Conversely, elevated phosphorus (P) levels in the drought plots may suggest alterations in the soil microbial community associated with the phosphorus cycle, and the reduced biomass production implies lower uptake by the vegetation. Particularly high P values in the most extreme drought treatment reveal that the vegetation did not absorb all the available soil phosphorus.

In summary, drought conditions are likely to have detrimental effects on the ecosystem's structure and services, such as forage production for grazing. From a management perspective, we advise a reduction in grazing intensity, especially during the growth season until seed production and dispersal have occurred. The reduction in biomass production could result in diminished seed output, a critical factor for the ecosystem's resilience and ability to cope with the severe drought and escalating soil water deficits anticipated due to climate change.

It is of high importance to continue this research to gather essential data for constructing models that predict the impact of climate change on these ecosystems' functions. This study stands out as the only research project in the Middle East that is actively manipulating both the quantity and distribution of rainfall in Mediterranean shrubland environments. Sustaining its financial support is critical to develop national forecasts of how natural ecosystems will respond to the changes induced by climate change.