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Changes in the Water Deficit Characteristics of Rangeland Dominant Species at Different Grazing Intensities in Gypseous and Sandy Soil Conditions

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ABSTRACT

The semi-desert rangeland of Uzbekistan, characterized by gypseous and sandy soils, undergo significant changes due to grazing of different intensities. This study examines the water deficit characteristics of key plant species in these rangelands and focuses on how different grazing pressures affect plant water stress and overall ecosystem health. Field experiments were conducted to evaluate plant water potential parameters in fields with initial, low, medium and high grazing intensity. Our findings suggest that increased grazing intensity exacerbates plant water deficits, particularly in areas with sandy soils where water retention is inherently low. In contrast, gypseous soils showed higher resistance to grazing-induced water stress, but significant degradation was still observed under high grazing. These results highlight the critical need for sustainable grazing practices to mitigate adverse effects on plant water dynamics and ensure the long-term viability of these semi-desert ecosystems.

Keywords: semi-desert rangeland, grazing intensities, gypseous soil, sandy soils, rangeland species, rangeland management, sustainable grazing practices.

INTRODUCTION

Rangelands are one of the world's major terrestrial ecosystems, occupying approximately 40% of the earth's surface [1]. These ecosystems, with their high biodiversity, are essential for providing a wide range of ecosystem services throughout the world [2]. Rangelands make a significant contribution to food security through providing part of the feed requirements of ruminants used for meat and milk production [3]. Including food production, carbon (C) balance and climate change mitigation, pollination, water regulation and a range of cultural services [4].

Despite the importance of rangelands, degradation processes in rangelands are increasing [5]. Especially due to the influence of anthropogenic factors, rangelands in many parts of the world are at risk of becoming a crisis at a rapid pace [6].

Degradation of rangelands under the influence of various anthropogenic factors is also a concern in Uzbekistan [7]. 21.1 million of the total land area in Uzbekistan are rangelands [8].

Historically, the vegetation cover of this area has been important not only as the main source of food for wild herbivores, but also as a natural forage reserve for grazing livestock in the area [9]. Rangeland animal husbandry began with the domestication of wild animals by humans 10–15 thousand years ago, that is, in the Neolithic period [10]. Its main centers are Southwest Asia and the Mediterranean Sea. Humans gradually

focused on the quality and quantity of animals, and began to breed from them and produce breeds according to product lines [11].

Animal husbandry led to a nomadic way of life. Along with the development of society, the need for use of rangelands increased with the development of animal husbandry. As a result, rangeland ecosystems were subjected to anthropogenic changes [12].

In the 1930s, the policy of gross collectivization of agriculture implemented by the former Soviet government destroyed the ancient nomadic cattle breeding system and its centuries-old traditions in the rangelands of Uzbekistan [13]. In recent years, 50–70% of existing rangelands have been in degradation due to overgrazing of livestock [14]. As a result, it led to the plant composition change in the rangelands and the acceleration of the desertification process [15].

One of the most serious anthropogenic factors in rangelands is irregular livestock management, and this problem is considered to be of global importance [16]. This can be explained by the degradation of rangelands as a result of irregular and continuous grazing of livestock in many countries of the world [17]. In this case, the types of plants, depending on the soil conditions, show different characteristics of adaptation [18].

Overgrazing of livestock in pastures leads to reduce the soil organic matter and CO2 exchange [19]. As a result, water shortage stress occurs in rangeland plants [20]. Water use efficiency is an important indicator of drought resistance of plants [21, 22]. The lack of water in plants causes negative changes, especially in plants growing in arid environments. Lack of water for plants can occur as a result of low rainfall and various environmental factors [22]. However, the influence of livestock on the characteristics of the water deficit of plants is also of special importance [23, 24]. From the few studies conducted on the relationship between the water use efficiency of rangeland plants at the dominant species, and functional group level to grazing intensity, it is known that at moderate grazing intensities, water use efficiency can be significantly increased [25]. However, at high grazing intensities, evapotranspiration negatively affects soil water content, soil organic carbon, and soil mass density [26]. As a result, water shortage stress processes increase in rangeland dominant species at high grazing intensities [27]. Through this research, we seek to contribute to the development of sustainable rangeland management practices that enhance ecosystem resilience, conserve biodiversity, and support livelihoods in arid and semi-arid regions characterized by gypseous and sandy soils. By integrating ecological knowledge with practical management approaches, we can strive towards achieving a balance between livestock production and environmental conservation in rangeland ecosystems facing increasing challenges from climate change and human activities.

Research questions

1. How do different grazing intensities affect the water deficit characteristics of semi-desert rangelands plants on gypseous and sandy soils in Uzbekistan?
2. What are the threshold levels of grazing intensity that lead to significant changes in water deficit characteristics of rangeland plants?
3. How do gypseous and sandy soils influence water retention and availability in semi-desert rangelands?
4. What sustainable grazing practices can improve water retention and reduce water stress in plants?

MATERIALS AND METHODS

Description of the study areas

The Karnabchul semi-desert is located at the foot of the Zyrubulok mountains according to its natural-geographical location of Uzbekistan, characterized by arid and semi-arid climatic conditions typical of Central Asian rangelands (Figure 1).

This region experiences extreme continental climate with hot, dry summers and cold winters. The annual precipitation is low, averaging between 100 mm, and is unevenly distributed throughout the year, with the majority falling in late winter and early spring (Figure 2).

In the south of Karnabchul, the Karshi steppes border the Bukhara oasis from the west and the Jom hills from the east, with a total area of 500,000 ha [28, 29]. In the part of the Karnabchul semi-desert located in the Samarkand region, there are large settlements such as Sepki, Tim, Agron, Sakhoba, Tutli, and Gobdin [30]. The climate of the Karnabchul semi-desert differs from the dry continental climate of all the deserts of Central Asia [30]. The average annual temperature is +17.1 °C.

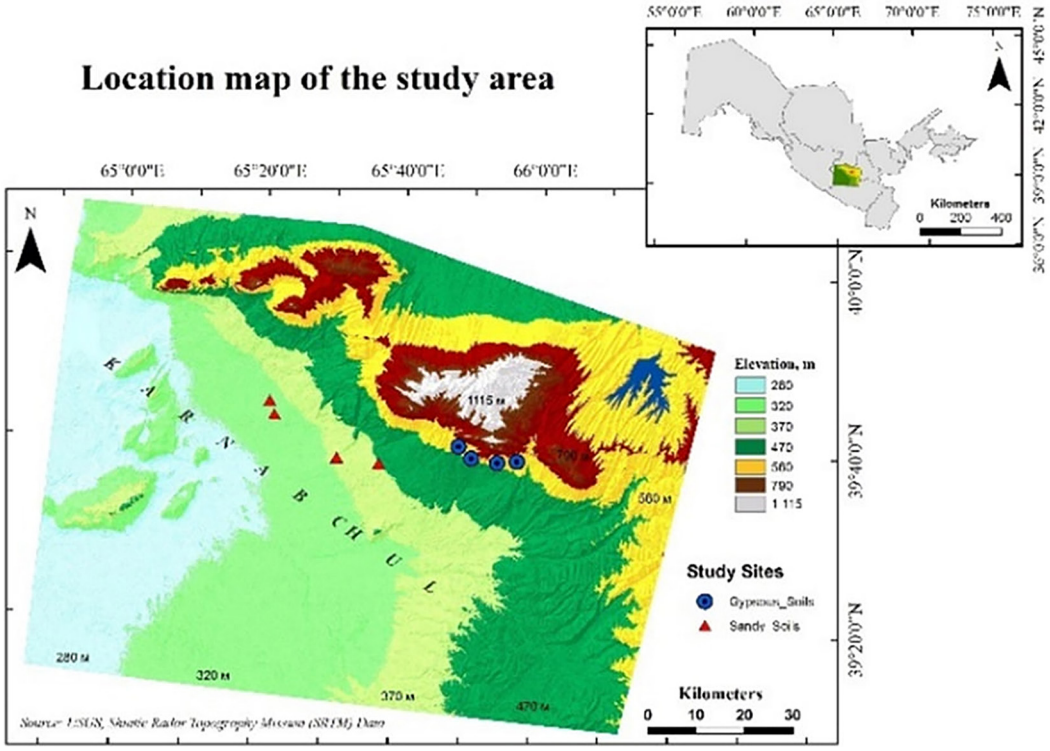

Figure 1. Location and elevation indicators of study sites of Karnabchul semi-desert of Uzbekistan

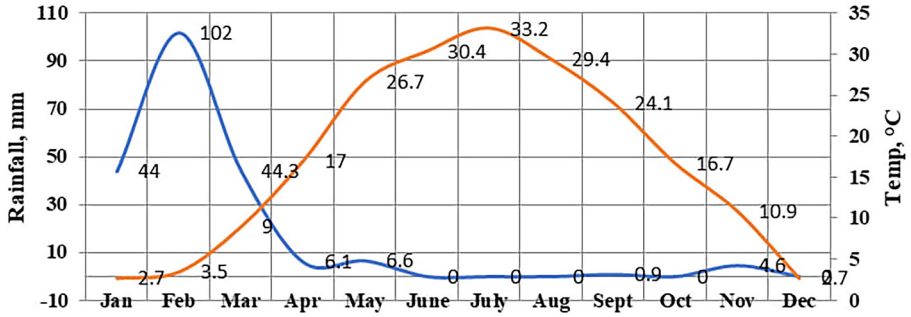

Figure 2. Rainfall and temperature of the studied area, the blue line is rainfall, and the orange line is the temperature

The average temperature in June-July is 29–35 °C, the lowest temperature is observed in December and February, sometimes it drops to minus 10–20 °C, and the average annual amount of precipitation is 140 mm [31]. According to the modern Köppen-Geiger classification, the natural climate of the Karnabchul semi-desert belongs to the cold arid desert climate region [32].

Data collection and analysis

In the spring season of 2021–2022, studies were conducted aimed at determining the characteristics of water deficit changes in dominant plant communities under the influence of different grazing intensities and under two different soil conditions. Based on the levels of degradation caused by the intensity of livestock grazing, four rangeland areas were selected. Water deficit indicators in green leaves and one-year vegetative branches of dominant (*A.diffusa, P.harmala, I.songarica*) plants were determined by comparing 4 different grazing intensities: initial, low, medium, and high.. A total of 108 samples from each dominant species were collected and remeasured three times at 2-hour intervals. The initial weight of leaves and one-year assimilion branches of dominant plants was measured and the weight was measured again after being kept immersed in water for two hours. The obtained samples were

dried in dryers at 105 °C and the total amount of water was determined by deducting the initial weight of pure organic matter [33].

The obtained results were examined separately for each grazing intensity and soil condition using ANOVA analysis [34]. The ANOVA test shows that the mean difference exceeds the least significant difference [$p < 0.05$] across all treatment levels [35]. Significant interactions indicate that there are also significant responses between treatment levels [eg, different grazing intensities or soil types].

RESULTS AND DISCUSSION

Gypseouse soil

When the level of water deficit of *A.diffusa* was compared according to different grazing intensities, the level of water deficit increased with increasing grazing intensity in the grasslands with gypseous soil. In particular, it was observed that the four grazing intensities selected in our experiments differed with the increase in temperature during the day, but the highest index was evident in the rangelands with [HG] intensities (Table 1). 1 g of green mass of *A.diffusa* spread in the rangelands at the levels of livestock (IG) intensities showed a water deficit of 8% in the first part of the day of the experiment, while in the middle of the day at 12^{00} and until 14^{00} 11.3% and 10.2% respectively (Figure 3).

It was observed that the water deficit was up to 9.4% at the determined times of the day of the experiment. *A.diffusa* spread in the rangeland at (LW) levels of livestock grazing intensities was found to be close to the results obtained at the initial levels of livestock grazing intensities, and there was no significant difference (Table 2). In our results obtained in the early hours of the day, a 14.8% water deficit level was shown in *A.diffusa* in rangelands with livestock [MG] intensities. It was found that

Table 2. Comparison of mean values of water deficit levels of dominant plants by four treatments, grazing intensity, soil type, time, plant species and combined effects ANOVA test ($p < 0.05$)

ANOVA	F-value	P-value
Grazing intensities	97.4	< 0.001
Soil type	48.1	0.03
Time	45.7	< 0.001
Plant species	179.3	0.48
Grazing intensities × Soil type	0.88	0.16
Grazing intensities × Time	128.6	< 0.001
Grazing intensities × Plant species	0.93	0.45
Grazing intensities × Soil type × Time	3.8	0.36

Table 1. Temperature and humidity on the day of the experiment

Experience time	10^{00}	12^{00}	14^{00}	16^{00}
Temperature, °C	29.1	37.6	36.3	35.4
Air humidity, %	37.3	20.6	17.8	15.6

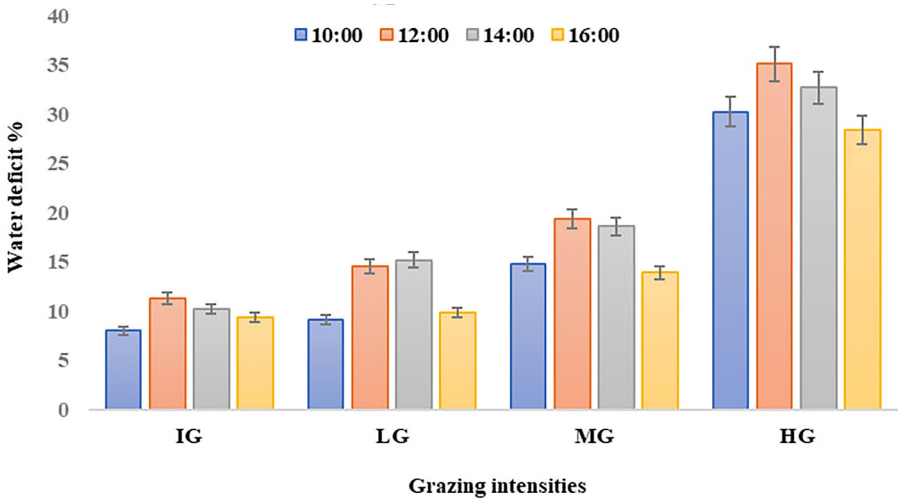

Figure 3. Water deficit levels of *A.diffusa* in gypseous soils at different grazing intensities and at different times of the day

the level of significant deficiency increased from 19.3% to 18.6% during the experiment in the middle of the day of the experiment. It was found that the results of the last part of the day of the research were also slightly increased to 13.9%. The temperature also had a significant effect on the daily changes of the water deficit level of the dominant plants. The biggest significant differences between different grazing intensities were observed in the middle of the research day, and it was found that the water deficit was from 35.1% to 32.1%. In observations at the end of the study day, wather deficits were significantly higher in HG intensities than in other different grazing intensities. The following results were obtained for grasslands with gypseous soil when comparing the water deficit levels of the pasqual species *P.harmala* and *I.songarica*, which are increasing as a result of grazing, with *A.diffusa*. The level of water deficit of 1 g of green mass of *A.diffusa* was 30.2% at 10^{00} hours of the first day of the experiment, while it was observed that it reached 21.3% in *P.harmala* at this time (Figure 4).

It was found that in *P.harmala*, compared to the other two species, the water deficit is 22.7%. It was found that the level of water shortage in *I.songarica* at 16^{00} hours of the day is up to 23.4%.

Among the dominant species in the grassland with gypseous soil, the highest level of water deficit was observed in *A.diffusa*. The lowest level was shown by the results obtained from *P.harmala*.

Sandy soil

Significant differences were observed in the water deficit level of dominant plants in rangelands with sandy soils compared to pastures with gypsum soils with different grazing intensities and increasing temperatures. *A.diffusa* and *P.harmala* are common among the dominant species in sandy soil rangelands.

Mainly due to the influence of livestock grazing intensities, *A.diffusa* experienced various changes in water deficit levels. In particular, it was revealed that these changes had a significant effect on rangelands with sandy soil compared to rangelands with gypseous soil ($F = 48.1$, $p = 0.03$).

It was observed that the level of water deficit in rangelands at the (IG) intensities of livestock grazing is the lowest. It showed that *A.diffusa* was not significantly affected in rangelands with a (LG) level of grazing intensities. In the results of the determined times during the day during which the research was conducted, the water deficit level of *A.diffusa* also varied with the increase in air temperature. The green mass of 1 g of *A.diffusa* was 12.2% at the first 10^{00} hours of the day of the study, while at the same time it was slightly increased to 14.6% at (LG) intensities (Figure 5). In the results of the first 10^{00} hours of the research day at (MG) and (HG) intensities, the level of significant water deficit increased and reached 20.8% in *A.diffusa* rangelands of (MG) intensities showed 27.87% at the (HG) intensities.

In the middle of the research day at 12^{00} hours, due to the increase in temperature in the rangelands at the level of livestock [IG] intensities, the water deficit was slightly increased from the results obtained at the beginning of the day, from 15.7% to 15.3%. it was observed to be from 18.9% to 18.2% at levels of [LG] intensities. It was observed that the level of water deficit of *A.diffusa* increased from 26.7% to 28.7% in the

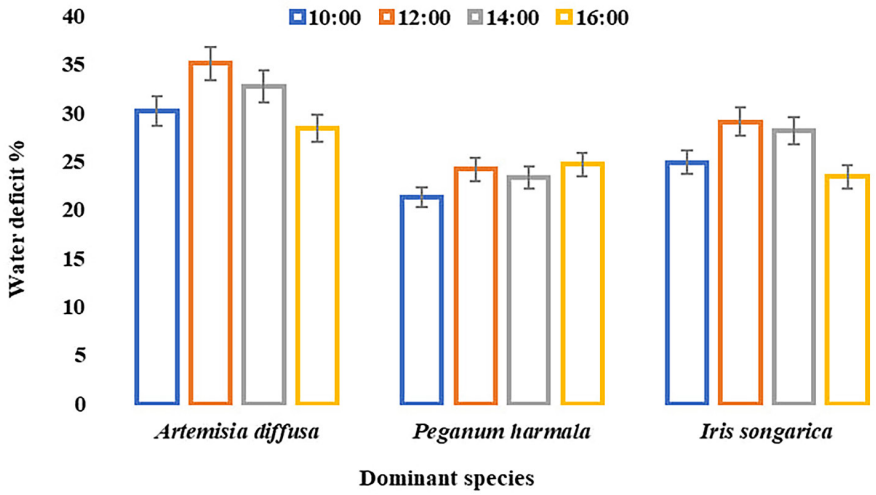

Figure 4. Water deficit level of *A.diffusa* and *P.harmala*, *I.sangarica* in gypseous soils

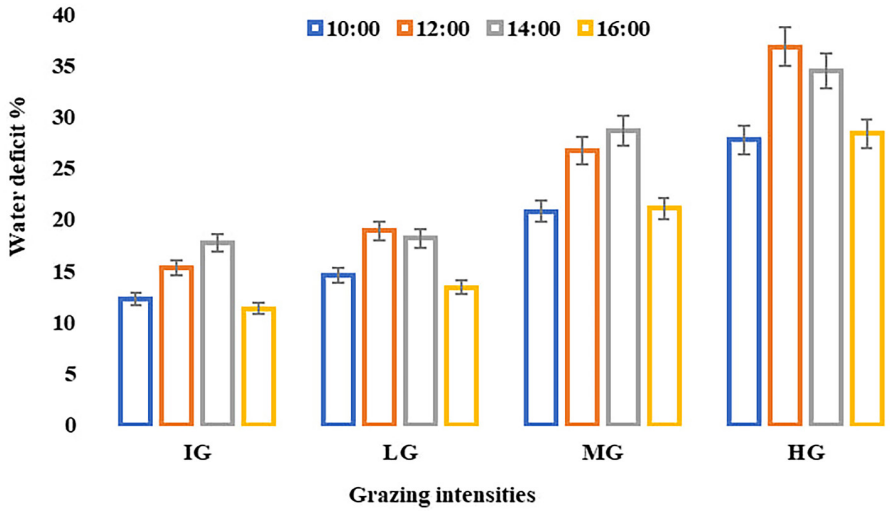

Figure 5. Water deficit levels of *A.diffusa* in sandy soils at different grazing intensities and at different times of the day

rangelands of the level of [MG] intensities, and it was found that the of grazing intensities has a significant effect.

In the results obtained from the measurements at 16^{00} at the end of the research day, the level of water deficit decreased from the results at 12^{00} and 14^{00} in the middle of the day, but the effect of grazing intensities remained unchanged. In the first 10^{00} hours of our results obtained during the day in sandy soil rangelands, the level of water deficit in *A.diffusa* was 13.1%, while in *P.harmala* it was significantly higher and equal to 21.6% in the results obtained at the same time. was observed (Figure 6). By 12^{00} on the day of the research, the level of water deficit in both species increased, and it was found to be 29.8% in *A.diffusa* and 23.3% in *P.harmala*.

In *P.harmala*, it was known that the characteristics of water deficit levels in the first 10^{00} hours of the research day were not significantly different from the results in the middle of the day, while in *A.diffusa* it was the opposite, and in the early hours of the day it was observed that the level of water scarcity is significantly different from the level of water scarcity in the middle part of the day ($p < 0.001$). Taking into account the fact that the temperature dropped slightly in the observations at 16^{00} hours of the last day of the research, it was found that there was a decrease in the level of water deficit in both dominant species, but it was significantly different from each other. *A.diffusa* had a water deficit of 28.4%, while *P.harmala* had a water deficit of 15.2%. As can be seen from these results, it can be concluded that *P.harmala* is less water-deficient than *A.diffusa*.

In rangelands with gypseous soil at different levels of grazing intensities, the greatest water

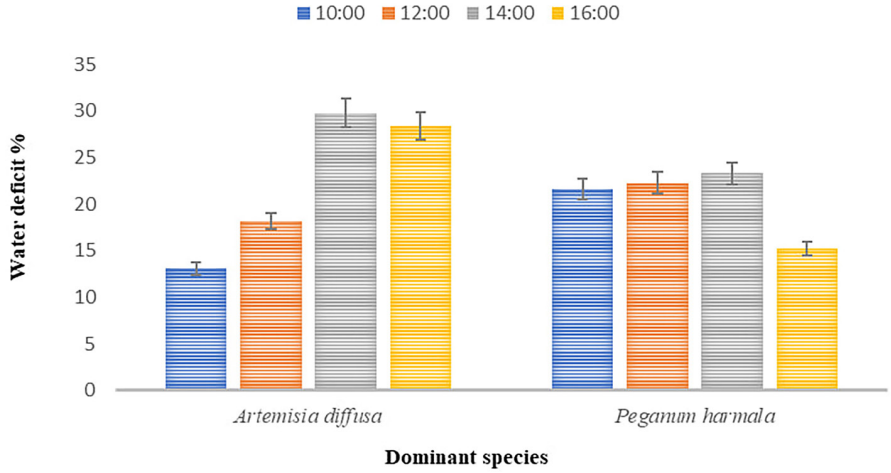

Figure 6. Water deficit level of *A.diffusa* and *P.harmala*, in sandy soils

deficit occurred in rangelands with high grazing intensities in all studied plants. It was found that the smallest indicators of water scarcity characteristics are observed at the IG and LG intensities.

It can be seen that the different intensities of livestock grazing have a significant impact on the water deficit characteristics of the dominant plants of Karnabchul desert rangelands ($p < 0.001$).

To determine whether the water balance is affected by plant growth and development, and the extent of the actual water deficit, it is necessary to compare water deficit levels and seasonal variations in different dominant plant species. Plant water deficit is an indicator of plant water stress level [35]. We found it in the assimilation organs of dominant plants. The level of water supply in Karnabchul plant communities is one of the possibilities for assessing the grazing factor in different conditions of their use. According to many physiologists 15–20% water deficit is a standard indicator for most species [7]. During the growing season, the water deficit changes significantly, which is associated with a decrease in soil moisture reserves due to strong physical evaporation from the surface of the soil cover and greater consumption in the second half of the growing season [37]. In conditions of high intensity of grazing, a decrease in soil moisture is observed, which leads to an increase in water deficit for plant species [38, 39].

Furthermore, our study highlights the importance of considering soil characteristics in understanding the water deficit responses of rangeland species. We found that species growing in gypseous soils exhibited different water deficit characteristics compared to those in sandy soils. Gypseous soils typically have higher clay content and better water retention capacity compared to sandy soils [40]. As a result, plant species in gypseous soils may be more resilient to water deficits induced by grazing compared to those in sandy soils [41].

CONCLUSIONS

The study demonstrates that grazing intensity significantly affects water deficit characteristics of dominant rangeland species. While both soil types experienced increased water deficits with higher grazing intensities, the magnitude of this effect varied. Sandy soils exhibited greater changes to grazing pressure. In both soil conditions, it was found that the water deficit increased of *A.diffusa* with increasing grazing intensities compared to the invasive species *P.harmala* and *I.songarica*. It was observed that *I.songarica* is a species resistant to high grazing intensities in gypseous soils, while *P.harmala* was shown to be a resistant species with adaptation to water deficit under the influence of grazing intensities in sandy soil conditions. The obtained results show that the control of grazing intensity in rangeland and a complete understanding of the water deficit characteristics of rangeland plants will help to improve sustainable management skills. Further research is required to fully understand the physiological mechanisms underlying plant water deficit under different grazing intensities and soil conditions. Long-term monitoring studies can provide valuable insights into the dynamics of rangeland ecosystems and help refine management strategies to enhance their resilience in the face of changing environmental conditions

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