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Microscale Assessment of Brush Packing Mulch as a Method for Enhancing Soil Moisture Content and Promoting Delayed Grass Seedling Mortality of Subtropical Grasses

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ABSTRACT

Recurring droughts in South Africa's dryland rangelands have profound effects on ecosystem health. Consequently, identifying sustainable soil moisture content techniques is critical for enhancing plant growth to support ecosystem function. Soil moisture content was measured daily for five weeks using the field capacity as a reference and compared within the two mulching densities, high and low versus bare soil. The effect thereof was evaluated on growth parameters: emergence, relative growth, and survival rate of three subtropical grasses (*Cenchrus ciliaris, Chloris gayan*, and *Panicum maximum*) in seedling trays under a greenhouse. Soil moisture content significantly differed in all the treatments ($p < 0.05$); the mulching treatments retained half their moisture compared to the no cover treatment, which lost more than 77% moisture. The evapotranspiration was cumulatively lowest in the high-density mulching. Overall, *Chloris gayana* and *Panicum maximum* had the highest emergence (> 40%) and relative growth in the mulching treatments, while *Cenchrus ciliaris emerged better* (56%) and had relative growth in the no cover. By Week 6, many seedlings did not survive; however, *Panicum maximum* persisted in the high-density mulching with almost 17% seedlings survival. The mulching effect improved soil moisture content, thus providing more conducive conditions for germination and survival, especially of understorey grasses. While this approach is effective for certain grass species, it has demonstrated ecologically significant enhancement for soil moisture content and reducing evaporation, potentially promoting good soil structure and health.

1 | Introduction

Droughts frequently occur in South Africa's arid and semiarid rangelands and have severe ecological and economic consequences (Vetter 2009). In arid and semiarid areas, droughts can trigger substantial and often irreversible ecological changes, including reduced perennial vegetation cover, increased bare ground, soil erosion, and diminished rain use efficiency (Abdelhak 2022). Soil moisture content in arid and semiarid regions is critical, as it serves as a key environmental variable that mediates the interactions between soil characteristics, vegetation dynamics, and climate within water-limited ecosystems (D'Odorico et al. 2007; Yin et al. 2019). The interaction of these factors considerably influences ecological stability and productivity, making the management of soil moisture an important concern in such environments.

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The establishment and growth of grasses in drylands depend on soil moisture. However, since water is a limiting factor in arid and semiarid regions, low rainfall, and inherently dry soils often hinder the effective establishment and accumulation of plant life (Osman 2018). As soil moisture decreases, soil surface temperatures increase, which results in reduced plant survival and thus diminished herbaceous vegetation cover (Smit and Rethman 2000). This can ultimately lead to an irreversible shift toward a drier climate state, where rainfall is no longer sufficient to allow for vegetation recovery (Lejeune et al. 2002). Several studies have examined the effect of tree canopy and vegetation cover on soil moisture content for plant growth (Nicholson 2000; D'Odorico et al. 2007; Lozano-Parra et al. 2018). Although the canopy density was not quantified, soils beneath the trees were found to be wetter, implying that tree canopy and vegetation assist in preserving soil moisture (D'Odorico et al. 2007; Lozano-Parra et al. 2018).

Most parts of South Africa are classified as semiarid, with some parts being arid (Zifan 2016). An increase in aridity can result in increased concern for soil physical factors that promote land degradation, such as eolian and alluvial erosion, which is reported to contribute to 87% of degraded lands (McAuliffe et al. 2018). Additionally, grazing pressure and the lack of good soil conservation practices contribute to soils in arid and semiarid regions being more susceptible to erosion (Vetter 2009). Although the role of changing vegetation cover on soil in land degradation is well recognized, the understanding of interactions among brush packing as a mulch, vegetation growth, and evapotranspiration are generally still uncertain. Brush packing is a veld restoration method where woody species are cleared and the branches used as mulch to keep grazers away from establishing vegetation, but also reported to prevent soil surface water runoff (Visser et al. 2007; Kellner et al. 2021; Mangani et al. 2022).

Soil moisture and vegetation cover are two of the most critical factors in dryland ecosystems, making it essential to maintain favorable soil water conditions at the microclimate level (Ravi et al. 2010). While both factors play interdependent roles in ecosystem stability, the depletion of soil moisture severely limits the ability of vegetation to survive and reestablish. Therefore, it is imperative to identify and implement sustainable and cost-effective methods aimed at minimizing moisture loss, particularly in these vulnerable arid and semiarid areas (Coetzee and Wallie-Stroebel 2011). The development of such methods will not only support ecosystem health but also enhance resilience against the adverse effects of climate variability. There is a lack of empirical evidence evaluating the microscale effects of brush packing as a mulch particularly in relation to its impact on soil moisture content and the growth parameters of common veld grass mixture in arid and semiarid grasslands. Moreover, given the inherent irregularity and variability in the density of brush packing when applied as mulch, quantifying its cover density was deemed essential to assess whether variations in density influence its impact. Therefore, the study objectives were to evaluate soil moisture content under two different mulching densities (high and low) compared to bare soil (no cover) and to assess the effect of the microclimates on grass (i.e., *Cenchrus ciliaris, Chloris gayana*, and *Panicum maximum*) emergence, relative growth, and survival rates. In our perception, we believe that this study is significant as this method is used by many researchers in restoration of woody encroached rangelands. Investigating the microscale effects of brush packing mulch on soil moisture content and its influence on grass growth provides improved understanding and more accurate estimates of soil water dynamics.

2 | Materials and Methods

2.1 | Study Location

The experiment was carried out in a plastic-covered greenhouse structure with side ventilation panels at the Hatfield Experimental Farm, located in Pretoria, South Africa (25°45′S, 28°16′E; 1308 m). The structure was designed to minimize external rainfall and maintain consistent internal conditions. Temperature inside the greenhouse was monitored using digital data sensors. During the experiment, daytime temperatures were between 24°C–28°C, while nighttime temperatures ranged between 17°C and 19°C. No artificial heating or cooling was used, and the air temperature inside the greenhouse remained mostly between 26.5°C–27°C during the day and 18°C–20°C during the night. All treatments experienced identical microclimatic conditions. Soil was collected from the upper soil horizon at a depth of 0–30 cm (which represents the biologically active layer relevant for seedling germination and early root development). Sampling was conducted using a hand auger, and five subsamples were collected across the experimental farm, where many of the pasture trials occur, and composited to minimize variability. After collection, the soil was air-dried at room temperature in the greenhouse to a constant weight. Plant residues, stones, and other debris were removed manually, after which the soil was gently crushed and sieved through a 2 mm mesh to ensure homogeneity. The processed soil was thoroughly mixed before being used in the glasshouse experiment. Before planting, the soil was placed into trays and equilibrated under glasshouse conditions to allow moisture stabilization before seed sowing. This preparation ensured uniformity in soil physical conditions among treatments and reduced potential for unwanted seedling germination and early growth. The soil collected was a red Shorrock series of the Hutton form (Soil Classification A Natural and Anthropogenic System for South Africa. by the Soil Classification Working Group 2018). Based on the soil particle size distribution, 72% sand, 22% clay, and 6% silt, soil texture was classified as sandy-clay-loam using the USDA soil texture triangle. The soil analysis before planting indicated a P and K concentration of 9.47 $mg.L^{-1}$ and 18.76 $mg.L^{-1}$, respectively, using a Bray1 test. The soil pH, measured using KCl test, was 5.4. The average recorded evaporation rate during the study was 8.3 mm (Hatfield automatic weather station). The average surface soil temperature measured by Thermochron iButtons sensors on the seedling trays ranged between 26°C and 20°C during the day and night.

2.2 | Greenhouse Experimental Setup

The study was arranged in a randomized complete block design which consisted of three mulching treatments (high, low, and bare) as main treatments and three grass species, *Cenchrus*

ciliaris (Blue buffalo grass), *Chloris gayana* (Rhodes grass), and *Panicum maximum* (Guinea grass) as sub-treatments.

Mulching consisted of thin tree branches of *Dichrostachys cinerea* simulating brush packing, a method commonly used in rangeland management for creating microclimate for seed establishment, (Kellner et al. 2021). This approach would give detailed grass growth parameters from a smaller controlled scale. To quantify the mulching, we build a 25-cm-high fence cages around the trays to represent high-density mulch, and 15 cm to represent the low-density (LD). The height was designed for operational practicality so that the fence can easily balance and for ease of access to the plants. The average density of the mulching treatments were 963 g for 25 cm height and 485 g for 15 cm height which represented the high density and low density respectively.

Three tables that served as blocks were set in the greenhouse from east to west direction, and nine seedling trays were laid in each table. In each table, the three mulching treatments and the grass species were randomly allocated within nine trays and replicated three times randomly across the three blocks. This resulted in a total of twenty-seven (27) plots with equal spacing between the trays (see Figure S1). To avoid the seepage of soil and rapid water drainage, a mesh material (0.001 mm) was placed at the bottom of the seedling trays. Each of the trays was filled with sterilized soil (oven heated at 107°C for 24 h, then cooled at room temperature) and weighed using a Columbic, August Sauter balance, capacity 30 kg maximum in 10 g divisions. We also measured the average weight of the soil and tray to make sure there were not competing factors, and each tray weighed approximately 12.25 kg. One hundred (100) seeds of each grass species were planted in each seedling tray before the mulching treatments were applied. At the end, the net weight of the seedling trays with the high-density mulching treatment was 13.21 kg, 12.74 kg for the seedling trays with the low-density treatments and 12.25 kg for the no cover treatment.

2.3 | Measurements

2.3.1 | Soil Moisture Content

The soil moisture content was monitored using field capacity as a reference point (Nel et al. 2014). Field capacity was determined in the laboratory using a standard gravimetric method. The soil was saturated, allowed to drain freely for 48 h, and weighed to determine water content at field capacity. Based on particle size distribution (72% sand, 22% clay, and 6% silt), the soil was classified as sandy-clay-loam, and the measured field capacity was in line with reported values for this soil textural class. Each of the trays that contained 12.25 kg soil required an average capacity of 3.1 L of water to fill them to field capacity. The soil in the seedling trays was irrigated weekly to field capacity; subsequently, soil moisture content was assessed by weighing the trays daily at 14:00 throughout the study to determine which treatment retained more water. This assessment also considered the evaporation rate in the greenhouse. A kg of mass measured was equivalent to a liter of water and then converted to ml (1 L × 1000 mL). The amount of water recorded in mL was converted to mm at the end. At the end of each week (Day 6), we irrigated to field capacity again.

2.3.2 | Growth Parameters

2.3.2.1 | Grass Emergence for the Three Selected Grass Species. A quick seed viability test was prepared to test how each of the seeds from the grass species germinated. Fifty seeds of each species were neatly laid on a damp paper towel, then folded; thereafter, put in a transparent plastic bag. The seeds were left at room temperature of 22°C for about 10 days. On the tenth day, the number of germinated seeds was recorded to determine their viability. The seeds germinated between 70% and 83% in all the species; this was taken as acceptable. One hundred (100) seeds per species (*Cenchrus ciliaris, Chloris gayana*, and *Panicum maximum*) were sown in each tray (per each replicated treatment [high- and low-density mulching], and no cover). A total of one hundred seeds represented 100% (100%) per tray. The seeds were sown on the surface of the soil and slightly compacted using the hand to ensure good contact with the soil. Emergence (Equation 1) was recorded after 6 days of sowing in accordance with the (ISTA (International Seed Testing Association) 2007) guidelines. At the end of the seventh day, an assumption was made that all viable seeds would have germinated and emerged. Seedlings were not thinned because the aim of the experiment was to evaluate germination, emergence, and early establishment in conditions that closely resembled natural recruitment. Competition effects were minimized because the experiment focused only on the early developmental stages (first few weeks), during which nutrient demand is relatively low and seedlings primarily rely on seed reserve.

$$Emergence\,(\%) = \frac{Number\ of\ seedlings\ emerged}{Total\ number\ of\ seeds\ sown}\ x\ 100 \tag{1}$$

where number of seedlings emerged = count of seedlings that have visibly broken the soil surface; total number of seeds sown = initial number of viable seeds planted.

2.3.2.2 | Relative Growth Rate and Survival Time. The relative growth rate (RGR) (Equation 2) was measured weekly to quantify the rate of plant growth per week (Hoffmann and Poorter 2002). The duration of the seedling growth period in the greenhouse lasted between six to seven weeks; this was because most of the grasses did not survive. The mass (mg) of the grass seedlings was measured from Week 3 to Week 6. Three (three out of 100 sown) seedlings, excluding the roots, for each grass species were removed per treatment for assessment. The seedlings' average dry mass (after 72 h at 85°C) was measured in milligrams (mg). This was done to determine how grasses responded to the mulching treatments compared to no cover soil.

$$RGR = (lnW2 - lnW1)\,/\,(t2 - t1) \tag{2}$$

where ln = natural logarithm; t_1 = time one (in days); t_2 = time two (in days); W_1 = dry weight of plant at time one (in grams); W_2 = dry weight of plant at time two (in grams).

The plants were intentionally not fertilized throughout the duration of the experiment; this approach was adopted to simulate veld conditions where there are no external nutrient inputs and to allow seedlings establishment to reflect treatment effect rather than fertilizer-induced response. The live seedlings

(survival rate) were determined by seedlings that still had green or straight leaves. The survival rate was recorded weekly to determine how the different grasses persist under the different treatments. Each week we recorded the 100 sown seeds per each grass species and converted the number as a percentage representing the 100 seeds sown per plant. Grass survival rate was recorded from the emergence. It was also taken into consideration that some seedlings were removed for the relative growth assessment. The trial was terminated after seven weeks.

2.3.3 | Data Analysis

Soil moisture content and grass growth parameters (emergence rate, relative growth, and survival rate) were assessed in plots under mulching vs. those with no cover. A repeated analysis of variance (ANOVA) was performed to evaluate the differences in amounts of the variables between mulching treatments and uncovered soil treatments. This analysis was done for each week separately. The ANOVA assessed the effect of treatments on each species individually using RCBD: 3 treatments x 3 species x 3 blocks per week. All assumptions of ANOVA were satisfied. Means were compared using Fisher's protected least significant difference test and the Studentized range at the 5% level. Data were analyzed using the statistical program GenStat (GenStat Introduction to GenStat for Windows and Payne 2014).

3 | Results

3.1 | Soil Moisture Content

The moisture (mm) loss per day for the three different treatments is illustrated in Table 1. Moisture content was recorded up to Week five as the trend was similar to that observed during the preceding two weeks. There was a significant difference ($p < 0.05$) in soil moisture content between the three treatments (high- and low-density mulching [HD and LD] and bare soil [NC]) over the weeks. Week 1 was the first exposure of soil to water and resulted in soil moisture at field capacity (FC) for all treatments. On Day 2, the HD treatment retained 4.7 mm more moisture than the LD treatment and 9.8 mm more moisture than the NC treatment. On Days 3 and 4, the HD treatment retained > 14.0 mm of moisture more than the NC treatment and just below 11.8 mm of moisture more than the LD treatment. On Day 5, both the LD and NC treatments lost almost 70% (> 125 mm) of their moisture. However, the HD treatment lost just less than half (116 mm) of its moisture. Weeks 2 and 3 showed similar trends in moisture loss. The results of Weeks 2 and 3 were as follows: on Day 2, moisture loss was less than that on Day 2 in Week 1 among the three treatments. The HD treatment had 49.2 mm of moisture more than that of the LD treatment and 56.8 mm more than that of the NC treatment. On Days 3 and 4, all the treatments had lost almost half of their moisture as compared to day 2. The HD treatment retained almost 56.9 mm more moisture than the LD and NC treatments. On Day 5, the LD and NC treatments lost approximately 66% (> 126 mm) of moisture as compared to 52% (116.9 mm) from the HD treatment. Weeks 4 and 5 showed that moisture content started dropping from Day 2; this was true for all the treatments. In these weeks, the results showed that the HD and LD treatments managed to retain half of their moisture (< 114.4 mm) on Day 5 compared to the NC treatment, which lost more than 77% (133 mm) moisture on Day 5. Generally, the HD treatment had higher moisture content followed by the LD and lastly the NC treatments.

TABLE 1 | Average moisture (mm) loss per day, high-density (HD), low-density (LD) mulching and no cover soil (NC).

		Moisture difference ($mm.day^{-1}$)		
		Average per day		
	Day	HD	LD	NC
Week 1	1	**FC**	**FC**	**FC**
	2	82.4	87.1	97.8
	3	105.1	111.5	116.1
	4	104.2	120.5	123.9
	5	116.7	128.5	130.6
	LSD (0.05)		**14.0**	
Week 2	1	**FC**	**FC**	**FC**
	2	81.3	86.9	89.7
	3	106.9	110.2	111.3
	4	109.1	119.1	120.0
	5	117.9	127.7	128.6
	LSD (0.05)		**14.6**	
Week 3	1	**FC**	**FC**	**FC**
	2	79.4	85.4	89.4
	3	103.8	108.9	110.2
	4	105.9	114.7	118.9
	5	115.7	128.1	130.5
	LSD (0.05)		**14.5**	
Week 4	1	**FC**	**FC**	**FC**
	2	86.4	91.7	93.0
	3	103.8	107.4	113.9
	4	108.9	111.1	122.4
	5	112.4	114.9	130.6
	LSD (0.05)		**14.5**	
Week 5	1	**FC**	**FC**	**FC**
	2	87.5	92.3	93.6
	3	103.3	106.9	111.3
	4	106.6	111.1	122.9
	5	117.3	119.3	133.4
	LSD (0.05)		**16.1**	

The average evaporation rate after five weeks is illustrated in Figure 1. The evaporation rates between the high- and low-density

mulching (HD and LD) treatments were not significantly different ($p > 0.05$) from each other. However, there was a significant difference ($p < 0.05$) between the mulching and the no cover treatment. The HD treatment resulted in the lowest evaporation rate (2.47 mm), followed by the LD treatment (2.72 mm) and the NC treatment with the highest evaporation rate (3.87 mm).

3.2 | Grass Emergence of the Three Grass Species Seven Days After Sowing

The seed emergence of the three grass species, seven days after sowing is illustrated in Figure 2. At Day 7, *Chloris gayana* (S2) resulted in the earliest and highest emergence (41%) in the HD treatment, compared to *C. ciliaris* (31%) and *Panicum maximum* (38%) (Table S1). The was no significant difference ($p > 0.05$) in percentage emergence for *C. gayana* on the high- and low-density mulching treatments. *Cenchrus ciliaris* showed the highest emergence (56%) in the NC treatment compared with the other two grasses and compared to the high- and low-density mulching. Although *Panicum maximum* emerged better (38%) in the high-density mulching treatment, overall, it had the least emergence as compared to the other species and even lower (16%) in the no cover treatment.

3.3 | Relative Growth Rate of Each Grass Species Under the Different Environments

Figure 3 illustrates the growth rate per week for the three grass species, *C. ciliaris* (S1), *C. gayana*, and *P. maximum*. At week two and three, there was no significant difference ($p > 0.05$) in the mass (mg) of the grass seedlings among all the treatments. By Week 3, all the grass species weighed less than 0.1 mg against all treatments. At Week 4, *P. maximum* had the highest growth (0.32 mg) in the high-density mulching treatment, followed by *C. gayana* (0.204 mg) and lastly *C. ciliaris* (0.139 mg). In Week 4, all grasses grew by approximately 66% more in weight than in Week 3. The trends were similar; *P. maximum* had the highest weight (0.948 mg) in the high-density mulching treatment, followed by *C. gayana* with 0.772 mg and *C. ciliaris* having the least weight of 0.691 mg. The low-density mulching treatment also produced higher growth rates between *P. maximum* and *C. gayana* (0.832 and 0.721 mg), respectively. By Week 6, *P. maximum* and *C. gayana* had almost doubled in weight, 1.94 and 1.64 mg, respectively, under the mulching treatments; however, they remained with low growth, 0.981 mg for *P. maximum* and 1.09 mg for *C. gayana*, in the no cover treatment. At Week 6, *C. ciliaris* growth was better favored in the no cover treatment (1.87 mg) and least favored in the high-density mulching with

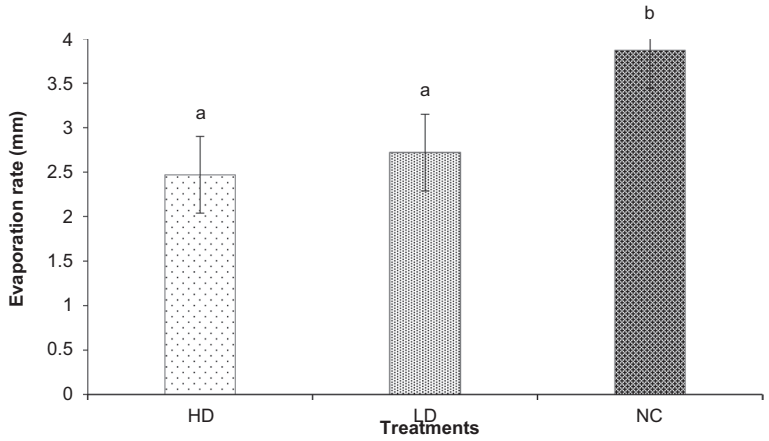


FIGURE 1 | Average evaporation rate (mm) under high- and low-density mulching (HD and LD respectively), and no cover soil (NC). Means with different superscript letters differed significantly.

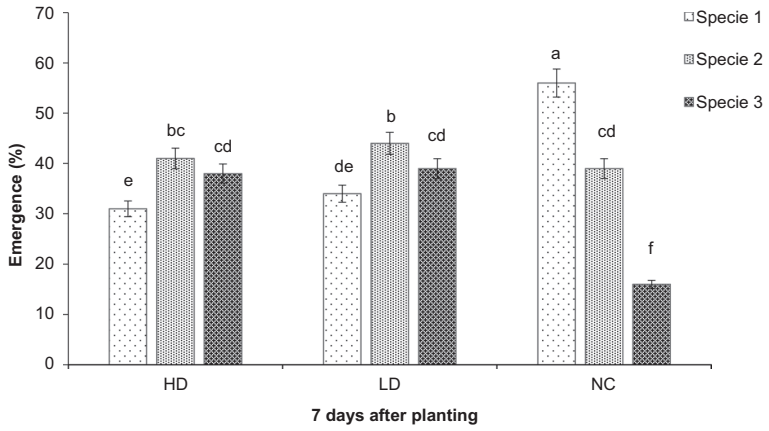


FIGURE 2 | Seed emergence (%) 7 days after sowing of *Cenchrus ciliaris, Chloris gayana*, and *Panicum maximum*. Means with different superscript letters differed significantly.

the lowest growth of 1.21 mg in the high-density mulching treatment and 1.32 mg in the low-density treatment.

3.4 | Survival Rate for Each Grass Species

The results for the seedling's survival from Week 2 to 6 weeks is shown in Figure 4 for *C. ciliaris*, Figure 5 for *C. gayana*, and Figure 6 for *P. maximum*. The highest live seedlings were recorded between Weeks 2 and 3 among all the grasses, with over 50% live seedlings for *C. ciliaris* and *Chloris gayana* and more than 40% for *P. maximum*. While expectedly, Weeks 5 and 6 recorded the lowest live seedlings among all grasses.

C. ciliaris had the greatest survival of seedlings over the six weeks period in the no cover treatment compared to the mulching treatments and other grasses (Figure 5). A significant drop was recorded in Week 4 where *C. ciliaris* had 31% live seedlings in the no cover treatment and less than 17% in the mulching treatments. Although most seedlings did not survive in Weeks 5 and 6, *C. ciliaris*, however, had 25% of the seedlings survived compared to the 6% in the high-density and 4% in the low-density mulching treatments (see Table S2).

Chloris gayana had greatest live seedlings in the no cover treatment over time at $p < 0.05$ (Figure 5). The percentage survival fluctuated over the weeks between the mulching treatments. In

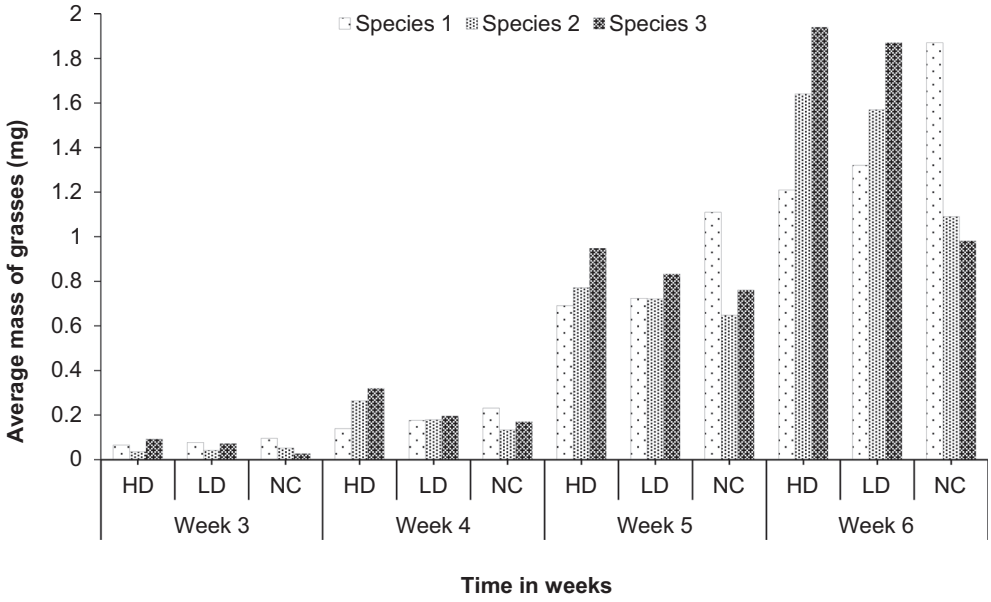


FIGURE 3 | Relative growth rate for *Cenchrus ciliaris*, *Chloris gayana*, and *Panicum maximum* under high- and low-density mulching (HD and LD, respectively), and no cover soil (NC).

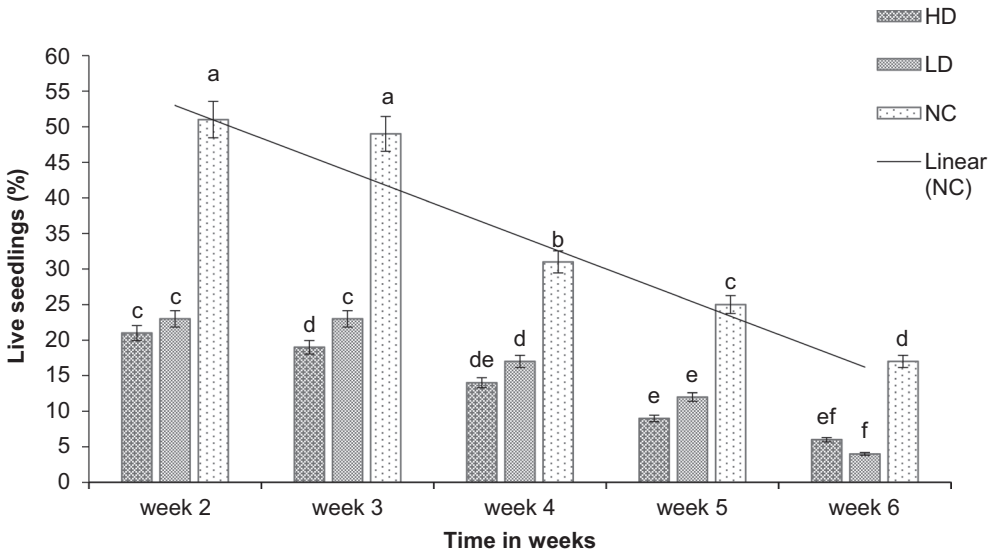


FIGURE 4 | Survival rate over 6 weeks under high- and low-density mulching (HD and LD) and no cover (ND) treatments for *Cenchrus ciliaris*. Means with different superscript letters differed significantly.

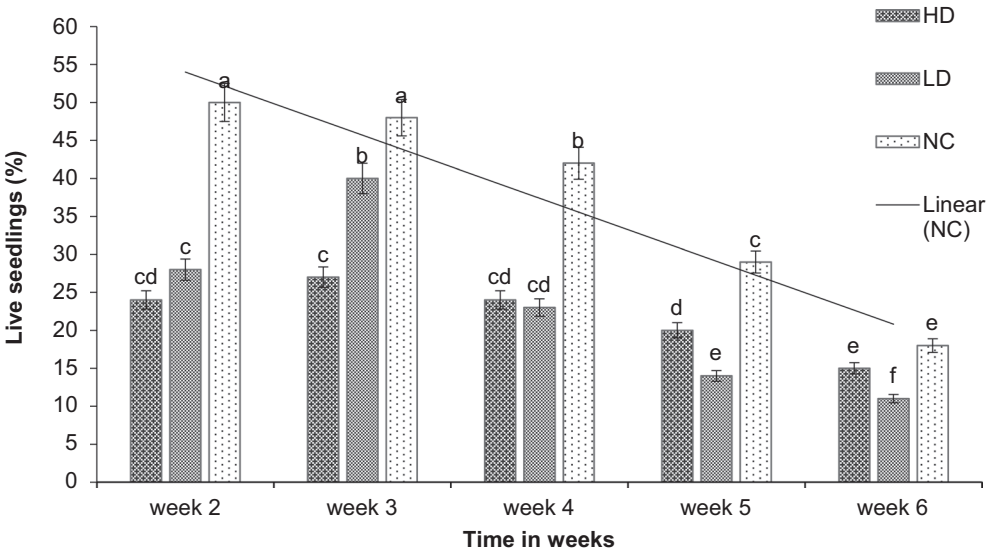


FIGURE 5 | Survival rate over 6 weeks under high- and low-density mulching (HD and LD) and no cover (ND) treatments for *Chloris gayana*. Means with different superscript letters differed significantly.

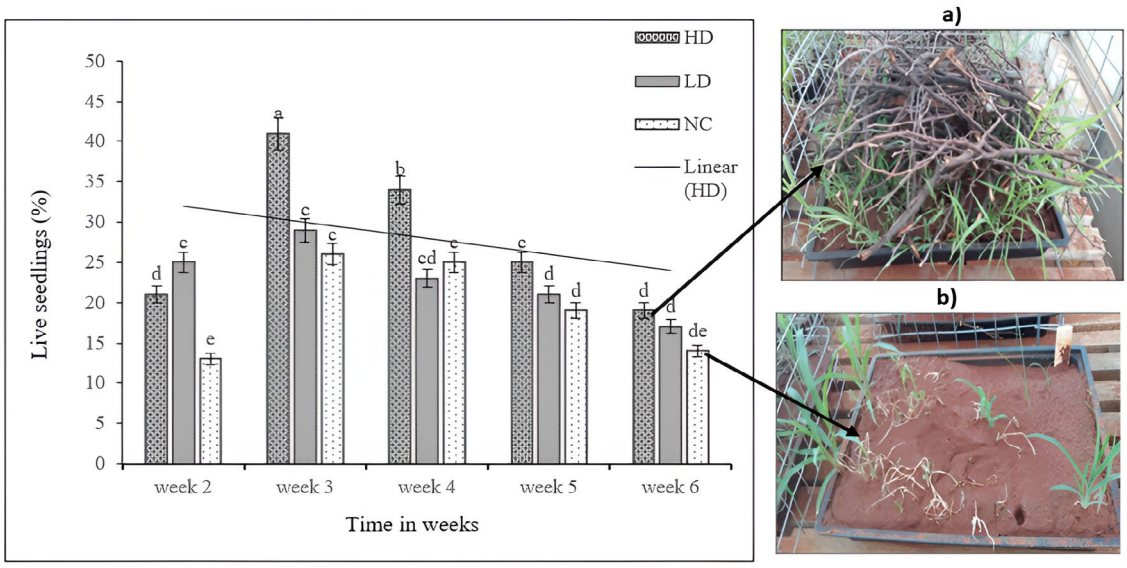


FIGURE 6 | Survival rate over 6 weeks and live seedling representation at Week 5 (a) for high-density mulching, (b) no cover for *Panicum maximum* under high- and low-density (HD and LD) mulching and no cover (NC) treatments. Means with different superscript letters differed significantly.

the early stages, Weeks 2 and 3, *t*he low-density mulching recorded higher survival (> 40%) than the high-density mulching (< 30%) ($p < 0.04$); however, by Weeks 5 and 6, the high-density superseded the low-density mulching, > 20% compared to 11% (see Table S3).

Panicum maximum had the lowest live seedlings in the no cover treatment (< 15%) in Week 2 (Figure 6). However, Week 3 had a sharp increase with the live seedlings almost doubling in percentage for all treatments, and the high-density mulching recording the highest (> 40%) compared to the other treatments ($p < 0.005$). Overall, seedling survival in the low-density mulching treatment did not mostly differ significantly ($p > 0.05$) from that of the no cover treatment. At the end of the six weeks, the no cover treatment still recorded the lowest survival as compared to the mulching treatments, while more than 20% seedlings survived in the high-density mulching.

Generally, there was a consistent difference in the grass species survival rates among the treatments. *Cenchrus ciliaris* and *Chloris gayana* showed better survival in the no cover treatment; however, toward Week 6, the low-density mulching and no cover treatments started to show no significant differences ($p > 0.05$). *Panicum maximum* was the slowest to establish; however, it had the best survival rate in the high-density treatment overall (see Table S4).

4 | Discussion

The application of mulch contributed to the development of a microclimate that increased soil moisture content and thus promoted plant emergence and overall plant growth of selected species. The experiment primarily focused on assessing the factors limiting early stages of plant development, particularly seedling emergence and resistance to soil moisture stress over time. The extent to which a microclimate influences plant germination and establishment is critical for informing effective land management strategies in arid and semiarid ecosystems.

The soil water status within microclimatic zones is a crucial determinant of vegetation performance particularly in semiarid and arid ecosystems (Costantini et al. 2016). Variations in soil water content influence surface emissivity, and consequently soil surface temperature, parameters closely linked to evapotranspiration rates and plant stress responses (Zhang et al. 2010). In this study, the brush packing mulching treatments contributed to the microenvironment that significantly enhanced soil moisture content compared to bare soil treatments. The recorded soil moisture levels were higher than the standard value in the mulching treatments when compared to the uncovered soil. This may be attributed to the limited surface area of the seedling trays, which likely influenced runoff and water seepage during irrigation. Similar outcomes were reported by Marais (2006), who found comparable water use of perennial summer grasses. The shading effect of the mulching reduced evapotranspiration rates; this is because moisture was trapped beneath the cover. The findings align with those of Zhang et al. (2010) who demonstrated that mulching, particularly with organic material, effectively reduced soil temperatures and enhanced water content by minimizing evaporative losses. In contrast, the uncovered soil treatments exhibited lower moisture content; this is attributed to the absence of a protective cover resulting in higher soil surface temperatures and elevated evaporation rates. Such conditions are known to create hostile environments for seedling emergence and growth (du Toit 2012; Abdu et al. 2023). Interestingly, soil moisture content improved progressively over the experimental period, except during the final week. This anomaly may be justified by increased water uptake by the developing plants which corresponds to higher transpiration demands. Another reason could be in the initial week, loose soil structure may have allowed more water infiltration, while in the later weeks the soil structure stabilized.

The moisture content under the brush packing treatments resulted in higher relative growth for *C. gayana* and *P. maximum*. This also corresponds with the results by Marais (2006) who demonstrated that *P. maximum* produces optimal growth under high moisture levels and establishes better in shady environments (Van Oudtshoorn 2012). *Cenchrus ciliaris* exhibited higher relative growth in the bare soil treatment; however, the brush packing treatments—although the latter still supported moderate yields. The species is known to be shade-intolerant, which may explain its reduced growth performance under the brush packing conditions that limit light availability (Van Oudtshoorn 2012).

4.1 | Seed Emergence Response to Mulching Verse No Cover

Previous studies have indicated that mulching can enhance seed germination and early emergence (Gebremeskel and Pieterse 2008; Abdu et al. 2023; Demo and Girma 2024). However, the results of this study reveal a more subtle response; germination and emergence in mulching is influenced by both species-specific traits and environmental conditions. Not all grass species demonstrated improved germination under mulch; in instances of *C. ciliaris*, shady environments and prolonged moisture levels beneath the mulch layer may have created unfavorable conditions, such as seed rot prior to germination—a phenomenon also reported in studies on seed viability under excessive humidity (Snyman 2009). Secondly, the germination study was conducted under a greenhouse environment, which differs considerably from field conditions where complex interactions between soil and seed influence germination. Light availability also emerged as a critical factor influencing germination. Brush packing mulch reduces light penetration to the soil surface, which can inhibit the germination of photoblastic seeds—those requiring light to initiate germination (Van Oudtshoorn 2012). In this study, *C. ciliaris* and *C. gayana* exhibited higher emergence and seedling survival rates under the no cover treatment, likely due to their preference for full sunlight and reduced tolerance to shaded conditions. Conversely, *P. maximum* showed improved emergence and survival under shade, also supported by subsequent field observations in South African grasslands (Snyman 2009).

5 | Conclusion

These findings support the conclusion that brush packing as a mulching technique offers a viable and ecologically relevant intervention to enhance soil moisture and improve early plant establishment in degraded South African arid and semiarid rangelands. Brush packing enhances grass establishment and growth primarily by improving soil moisture dynamics and creating a favorable microenvironment for seedlings. Its shading effect, combined with the physical barrier formed by the branches, promoted greater water infiltration and minimized runoff, thereby reducing evapotranspiration rates observed under the brush packing treatments, irrespective of the density. This microenvironment contributed particularly to the performance of *P. maximum*, which showed improved emergence and survival under the modified microenvironment. However, the results also highlight the species-specific responses to mulching, as *C. ciliaris* performed the least in these treatments, indicating that brush packing does not uniformly benefit all grass species during restoration interventions. Consequently, the selection of species for land restoration should consider both the ecological requirements of the species and the expected microenvironmental conditions created by restoration treatments such as brush packing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that supports the findings of this study are available in the supporting information of this article (Figure S1).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Experimental layout in a greenhouse. **Table S1:** Grass emergence out of a 100 seeds. **Table S2:** Survival rate over six weeks of Cenchrus ciliaris (S1). **Table S3:** Survival rate over six weeks of Chloris gayana (S2). **Table S4:** Survival rate over six weeks of Panicum maximum (S3).