ECOLOGICAL RESTORATION OF DEGRADED MOUNTAIN GRASSLANDS THROUGH MULCHING AND OVERSEEDING IN THE CINDREL MOUNTAINS (ROMANIA)

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Abstract

Degradation of semi-natural mountain grasslands represents a major threat to biodiversity and forage quality in Central and Eastern Europe. Ecological restoration practices such as mulching and overseeding are increasingly applied to counteract grassland degradation, yet their floristic effects under mountain conditions remain insufficiently documented. The present study evaluated the impact of different restoration measures on the floristic composition of a degraded grassland at the Păltiniş Experimental Station (Cindrel Mountains, Romania). The experiment was established in a randomized block design with five treatments: abandoned grassland (control), mulching, mulching combined with organic fertilization, mulching with overseeding using Dactylis glomerata and Lolium perenne, and mulching with overseeding using Phleum pratense. Vegetation surveys were conducted in 2023, two years after the installation of the experiment, and data were processed using PC-ORD software. The control variant was characterized by a Festuca rubra grassland type, representative for the study area. Mulching alone promoted a shift toward a Festuca rubra – Agrostis capillaris grassland, while the combination of mulching and organic fertilization resulted in the installation of an Agrostis capillaris grassland with Festuca rubra. Overseeding treatments significantly increased the proportion of Poaceae and led to the establishment of mixed grassland types dominated by Dactylis glomerata or Phleum pratense, respectively. The results demonstrate that mulching and overseeding are effective restoration techniques for degraded mountain grasslands, contributing to improved floristic structure and enhanced forage potential under high-altitude conditions.

Keywords: mountain grasslands, ecological restoration, mulching, overseeding, floristic composition, Cindrel Mountains

INTRODUCTION

Semi-natural mountain grasslands are among the most valuable agroecosystems in Europe, due to their exceptional floristic diversity, high ecological stability and long-term co-evolution with traditional agricultural practices. In the Carpathian region, these grasslands represent biodiversity hotspots, hosting a large proportion of endemic and subendemic plant species and maintaining complex ecological networks shaped by extensive land use (Reif et al., 2005; Reif et al., 2008; Păcurar & Rotar, 2011; Gliga et al., 2013). Numerous studies conducted in Romanian mountain areas emphasize that the conservation value of these grasslands is directly linked to their management history and ecological continuity (Păcurar et al., 2008;

Ruşdea et al., 2011; Păcurar et al., 2018).

In Romania, mountain grasslands play a crucial role not only in biodiversity conservation but also in sustaining rural livelihoods, providing forage resources, maintaining soil stability and preserving cultural landscapes (Plăias, 1994; Reif et al., 2008; Păcurar et al., 2014). Semi-natural grasslands with High Nature Value (HNV) status are particularly important, as they combine low-input management with high species richness and ecological resilience (Păcurar et al., 2018; Păcurar & Reif, 2023; Vaida et al., 2021). However, these ecosystems are highly sensitive to changes in land use and management intensity (Rotar et al., 2010; Vaida et al., 2016). During recent decades, socio-economic transformations in Central and Eastern Europe have led to significant pressures on mountain grasslands, resulting in processes such as agricultural intensification, overgrazing, nutrient imbalance and, most critically, land abandonment (Rotar et al., 2013; Păcurar et al., 2015; Vaida et al., 2016; Moş & Brînzan, 2024). Abandonment disrupts the traditional disturbance regime, accelerates secondary succession and favors the expansion of competitive or unpalatable species, leading to a decline in species richness and forage quality (Brinkmann et al., 2009; Reif et al., 2008; Păcurar et al., 2014).

Numerous studies conducted in the Apuseni Mountains and other Romanian mountain regions have demonstrated that changes in management strongly affect the floristic composition and functional structure of Festuca rubra and Agrostis capillaris grasslands (Păcurar & Rotar, 2006; Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2014). Long-term abandonment or inadequate management leads to a reduction in Fabaceae species, an increase in stress-tolerant grasses and a simplification of vegetation structure (Păcurar et al., 2007; Rotar et al., 2016; Vaida et al., 2017).

In this context, ecological restoration has become a key strategy for maintaining and recovering the ecological and agronomic value of degraded mountain grasslands. Restoration approaches aim to re-establish favorable environmental conditions and promote the reinstallation of characteristic species assemblages (Török et al., 2011; Blakesley & Buckley, 2016). In Romanian grasslands, restoration measures are often adapted to local ecological conditions and traditional management practices, as highlighted by multiple experimental studies coordinated by Păcurar and collaborators (Păcurar et al., 2009; Păcurar et al., 2012; Păcurar et al., 2014). Mulching represents one of the most frequently applied low-impact restoration techniques in abandoned grasslands, being used to control excess biomass, reduce litter accumulation and stimulate natural regeneration processes (Hopkins, 1954; Rotar et al., 2014; Wu et al., 2024). Previous research has shown that mulching can significantly influence species composition, light availability and soil microclimate, leading to measurable changes in floristic structure (Brinkmann et al., 2009; Păcurar et al., 2018; Rotar et al., 2020).

In addition to mulching, overseeding is widely applied as an active restoration method, particularly in grasslands with limited natural regeneration capacity. Overseeding with well-adapted forage species can enhance sward density, increase the proportion of Poaceae and Fabaceae and improve overall forage value (Rotar et al., 2014; Scotton, 2019; Rotar et al., 2016). However, the success of overseeding depends on site-specific conditions, species selection and interactions with existing vegetation, especially in mountain environments characterized by acidic soils and harsh climatic conditions (Păcurar et al., 2012; Rotar et al., 2014).

Several long-term experiments conducted in Romanian mountain grasslands have demonstrated that combined management approaches, including mulching, fertilization and overseeding, lead to distinct floristic trajectories and functional changes in vegetation (Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2010; Gheţe et al., 2025). Nevertheless, despite the extensive body of research on Festuca rubra grasslands in the Apuseni Mountains, data from other mountain regions, such as the Cindrel Mountains, remain comparatively scarce.

Therefore, the present study aims to assess the floristic response of degraded mountain grasslands at the Păltiniş Experimental Station (Cindrel Mountains, Romania) to different restoration measures, including mulching, mulching combined with organic fertilization and mulching associated with overseeding. The specific objectives were to characterize the initial floristic composition of the abandoned grassland, to evaluate vegetation changes induced by mulching-based management and to determine the effectiveness of overseeding in restoring grassland structure and forage potential. The results contribute to the broader understanding of sustainable restoration strategies for mountain grasslands under high-altitude conditions.

MATERIAL AND METHOD

The research was conducted at the Păltiniş Experimental Station, located on the north-eastern ridge of the Cindrel Mountains, near the Păltiniş resort, Romania, at an altitude of 1,348 m a.s.l. The study area belongs to the upper montane belt and is characterized by specific climatic conditions, including low annual average temperatures, a persistent snow cover during winter and a relatively high annual precipitation regime.

The soils are classified as submesotrophic brown acidic soils, typical for mountain grasslands developed on siliceous parent material, with moderate fertility and acidic reaction. The Cindrel Mountains cover an area of approximately 900 km², with a maximum altitude of 2,244 m (Cindrel Peak). From a geomorphological perspective, the mountain range is bordered by the Sadu River to the east and south, separating it from the Lotru Mountains, and by the Frumoasa and Sebeș rivers to the west, separating it from the Șureanu Mountains (Anghel & Doniță, 1980).

Experimental design

To achieve the objectives of the study, an ecological restoration experiment was established in 2021 on degraded mountain grasslands within the Păltiniș Experimental Station. The experiment was designed according to a randomized block layout, including five experimental treatments with four replications each. The surface area of each experimental plot was 20 m², allowing for adequate control of spatial variability and reliable interpretation of results.

Floristic assessments presented in this study are based on vegetation surveys conducted in 2023, two years after the establishment of the experimental treatments, a period considered sufficient to evaluate the initial floristic responses to the applied restoration measures.

Experimental treatments

The five experimental variants included in the study were as follows:

- **V1 – Control (abandoned grassland):**
  No management interventions were applied. This variant was used as a reference for assessing the degree of grassland degradation and the natural dynamics of vegetation.

V2 – Mulching: The grassland was managed exclusively through mulching, aimed at fragmenting accumulated plant biomass and stimulating natural regeneration processes.

V3 – Mulching combined with organic fertilization: In addition to mechanical management, organic fertilization was applied to improve soil properties and stimulate vegetation recovery.

V4 – Mulching combined with overseeding using *Dactylis glomerata* (60%) and *Lolium perenne* (40%): Overseeding was applied to accelerate grassland restoration by introducing productive forage species adapted to mountain conditions.

V5 – Mulching combined with overseeding using *Phleum pratense*: A forage species well adapted to cool climatic conditions and acidic soils was used, characterized by good establishment capacity and persistence under mountain environments.

Data processing and analysis

Floristic data were processed using PC-ORD software, version 7. Vegetation data were organized into two matrices: one containing species abundance values and another coding the experimental variants. The software was used for vegetation classification, ordination and graphical representation of results. The methodological details and analytical procedures implemented in PC-ORD have been described extensively in the literature (McCune, 2002; Peck, 2010).

RESULTS AND DISCUSSIONS

Results regarding the establishment capacity of plant species after overseeding

In the control variant, represented by the abandoned grassland, the vegetation was classified as a *Festuca rubra* grassland type, which is characteristic for oligotrophic mountain grasslands in Romania. This grassland type is widely distributed in the Carpathian region and has been repeatedly described as a reference phytocenosis for semi-natural mountain grasslands maintained under low-input or abandoned conditions (Păcurar & Rotar, 2006; Păcurar et al., 2012; Rotar et al., 2014).

The floristic composition of the *Festuca rubra* grassland was dominated by Poaceae, which accounted for 33.8% of the total plant cover. The dominance of grasses, particularly *Festuca rubra*, together with the relatively low proportion of Fabaceae (4.0%), indicates a simplified trophic structure and a reduced contribution of nitrogen-fixing species. Similar patterns have been reported in abandoned or extensively managed *Festuca rubra* grasslands from the Apuseni Mountains and other Romanian mountain regions (Păcurar et al., 2007; Morea et al., 2008; Vaida et al., 2016).

The reduced share of Fabaceae and the presence of stress-tolerant species such as *Nardus stricta* and *Deschampsia flexuosa* suggest nutrient-poor soil conditions and limited regenerative capacity of the vegetation. According to previous studies, these features are typical for oligotrophic mountain grasslands subjected to long-term abandonment, where litter accumulation and reduced disturbance negatively affect species richness and forage quality (Reif et al., 2005; Brinkmann et al., 2009; Rotar et al., 2016).

Plants from other botanical families (41.0%) contributed substantially to species richness, reflecting the semi-natural character of the grassland. However, many of these species have low forage value, which further confirms the reduced agronomic potential of the abandoned variant. Similar floristic structures have been described in Festuca-dominated grasslands with high nature value (HNV), where biodiversity is preserved, but productivity remains low in the absence of appropriate management (Păcurar et al., 2014; Vaida et al., 2021). Overall, the control variant represents a degraded but ecologically stable reference state, suitable for assessing the effectiveness of restoration measures applied in the experimental variants.

Table 1

Floristic composition of the *Festuca rubra* grassland type and species sensitivity to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	5.1
-	-	-	-	-	-	-	-	-	-	-	-	*Briza media*	0.5
-	-	-	-	-	-	-	-	-	-	-	-	*Danthonia decumbens*	0.5
HT	x	x	2	3	3	4	4	n	4	2 - 3	2	*Deschampsia flexuosa*	4.4
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	17.55
HT	x	x	2	2	3	5	5	n	3	2 - 4	1	*Nardus stricta*	5.8
POACEAE													**33.83**
HT	x	5	3	3	6	4	4	n	4	2 - 3	1	*Luzula multiflora*	1.5
CYPERACEAE AND JUNCACEAE													**1.5**
H	5	4	4	2	4	8	7	n	3	2 - 3	1	*Genistella sagittalis*	3.1
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	0.5
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	0.5
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	0.5
FABACEAE													**4.0**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	0.50
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula serata*	0.50
H	X	4	X	2	3	8	7	n	3	2 - 3	1	*Carlina acaulis*	0.50
												Cerastium glomeratum	0.50
TT	X	5	X	7	3	7	2	n	3	2 - 3	1	*Cuscuta trifolii*	0.50
HS	3	5	4	2	5	6	6	n	4	3 - 4	2	*Hieracium pilosella*	3.1
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	2.6
HR	x	5	x	5	7	7	7	n	5	3 - 4	3	*Leontodon autumnale*	4.4
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	0.50
HR	x	4	8	3	4	8	8	n	5	2 - 4	2	*Plantago media*	1.00
HT	x	x	x	2	3	4	5	n	5	2 - 3	1	*Potentilla erecta*	0.5
HS	x	x	4	x	9	8	8	n	4	3 - 4	2	*Prunella vulgaris*	0.50
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	5.1
HRs	x	x	x	x	6	4	2	n	4	3 - 4	2	*Rumex acetosa*	2.6
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	2.0
ChLT	x	4	5	6	4	4	4	n	3	2 - 3	2	*Thymus pullegioides*	4.4
ChLS	x	x	2	3	1	8	9	n	3	2 - 3	2	*Vaccinium myrtillus*	4.4
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	0.50
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	1.5
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.50
OFB													**41.0**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

In variant V2, where the grassland was managed exclusively through mulching, the floristic composition shifted toward a *Festuca rubra – Agrostis capillaris* grassland type. This transition indicates an early stage of vegetation recovery, characterized by increased species dynamism and improved structural heterogeneity. Similar vegetation shifts following mulching have been reported in mountain grasslands across Romania and Central Europe (Hopkins, 1954; Brinkmann et al., 2009; Rotar et al., 2014).

Mulching resulted in an increase of Poaceae cover to 38.8%, reflecting enhanced competitiveness of grasses under improved light and microclimatic conditions. The increased presence of *Agrostis capillaris* suggests that mulching reduced litter accumulation and facilitated the germination and establishment of species adapted to moderate disturbance regimes. This response is consistent with findings reported by Păcurar et al. (2012) and Rotar et al. (2014), who highlighted the positive role of mulching in restoring grassland structure without inducing excessive intensification. The proportion of Fabaceae increased to 7.1%, compared to the control variant, indicating a gradual improvement in nitrogen availability and ecological functionality. According to Păcurar et al. (2007) and Vaida et al. (2017), the recovery of Fabaceae species is a key indicator of successful restoration in oligotrophic grasslands, as these species contribute to soil fertility and forage quality. The absence of Cyperaceae and Juncaceae species in this variant suggests improved soil aeration and reduced moisture stress, which are favorable conditions for mesophilous grassland species. Similar trends were observed in mulched grasslands from the Apuseni Mountains, where mechanical management reduced the dominance of hygrophilous species and promoted a more balanced floristic composition (Morea et al., 2008; Păcurar et al., 2014). Overall, mulching alone proved to be an effective low-impact restoration measure, leading to measurable improvements in floristic composition and ecological balance, while maintaining the semi-natural character of the grassland. These results confirm previous findings that mulching can serve as an intermediate management strategy between abandonment and more intensive restoration measures (Rotar et al., 2014; Wu et al., 2024) (Table 2).

In variant V3, where mulching was combined with organic fertilization, the floristic composition evolved toward an *Agrostis capillaris* grassland with *Festuca rubra*. This vegetation type reflects a more advanced stage of grassland recovery compared to mulching alone, indicating that the addition of organic nutrients enhanced both structural complexity and species dynamics. Similar successional trajectories have been documented in mountain grasslands subjected to combined mechanical management and fertilization in the Apuseni Mountains (Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2010).

The share of Poaceae increased to 42.2%, confirming the stimulatory effect of organic fertilization on grass growth and competitiveness. *Agrostis capillaris* became the dominant species, benefiting from improved nutrient availability and reduced litter cover.

Table 2

Floristic composition of the *Festuca rubra – Agrostis capillaris* grassland type and species sensitivity to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	16.3
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	0.5
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	0.5
												Poa pratensis	0.5
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	21.1
POACEAE													**38.8**
H	5	4	4	2	4	8	7	n	3	2 - 3	1	*Genistella sagittalis*	1.0
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	1.5
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	3.1
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	1.5
FABACEAE													**7.1**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	3.1
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	1.0
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula abietina*	0.50
												Cerastium glomeratum	0.50
TT	X	5	X	7	3	7	2	n	3	2 - 3	1	*Cuscuta trifolii*	2.0
HS	3	5	4	2	5	6	6	n	4	3 - 4	2	*Hieracium pilosella*	3.1
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	3.8
HR	x	5	x	5	7	7	7	n	5	3 - 4	3	*Leontodon autumnale*	3.8
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	3.1
HT	x	x	x	2	3	4	5	n	5	2 - 3	1	*Potentilla erecta*	0.5
HS	x	x	4	x	9	8	8	n	4	3 - 4	2	*Prunella vulgaris*	0.50
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	4.4
HRs	x	x	x	x	6	4	2	n	4	3 - 4	2	*Rumex acetosa*	2.6
												Ranunculus acris	0.5
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	4.4
ChLT	x	4	5	6	4	4	4	n	3	2 - 3	2	*Thymus pullegioides*	4.4
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	2.6
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	2.0
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.50
												Taraxacum officinale	1.0
OFB													**35.1**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

According to Păcurar and Rotar (2006) and Rotar et al. (2014), *Agrostis capillaris* responds positively to moderate nutrient inputs, especially under mountain conditions where soil fertility is naturally limited.

Fabaceae species reached a coverage of 8.8%, representing a substantial increase compared to both the control variant and the mulched-only treatment. This increase is ecologically significant, as Fabaceae contribute to nitrogen enrichment and enhance forage quality. Similar responses of Fabaceae to organic fertilization have been reported in long-term experiments on *Festuca rubra* grasslands in the Apuseni Mountains (Păcurar et al., 2007; Păcurar et al., 2012; Vaida et al., 2017). The presence of species such as *Trifolium pratense*, *Trifolium repens* and *Lotus corniculatus* indicates an improvement in both trophic status and agronomic value of the grassland. Plants from other botanical families accounted for 46.4% of total cover, reflecting a high level of floristic diversity. This increase suggests that organic fertilization, when applied in moderate doses, does not necessarily reduce biodiversity, but can support a more heterogeneous vegetation structure. Similar conclusions were drawn by Brinkmann et al. (2009) and Păcurar et al. (2014), who showed that low to moderate organic inputs can maintain species richness while improving grassland productivity. The absence of Cyperaceae and Juncaceae species in this variant further indicates improved soil aeration and reduced excess moisture, conditions that favor mesophilous grassland species. According to Rotar et al. (2016) and Păcurar et al. (2018), such changes are typical responses to improved management in previously abandoned mountain grasslands. Overall, the combined application of mulching and organic fertilization proved to be a more effective restoration strategy than mulching alone, leading to increased grass dominance, enhanced presence of Fabaceae and a more balanced floristic composition. These results are consistent with previous studies conducted in Romanian mountain grasslands, which emphasize that moderate organic fertilization can accelerate grassland recovery without compromising biodiversity (Morea et al., 2008; Păcurar et al., 2012; Rotar et al., 2014) (Table 3).

In variant V4, where mulching was combined with overseeding using a mixture of *Dactylis glomerata* (60%) and *Lolium perenne* (40%), the floristic composition evolved toward a mixed grassland type dominated by *Dactylis glomerata* with *Agrostis capillaris* and *Lolium perenne*. This vegetation structure reflects a strong response to active restoration measures and indicates a shift toward a more productive grassland system, characterized by high grass dominance and improved sward density.

Table 3

Floristic composition of the *Agrostis capillaris – Festuca rubra* grassland type and species requirements in relation to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	21.1
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	0.5
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	0.5
												Poa pratensis	4.4
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	13.8
POACEAE													**42.2**
H	5	4	4	2	4	8	7	n	3	2 - 3	1	*Genistella sagittalis*	0.5
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	3.8
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	2.0
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	2.5
FABACEAE													**8.8**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	4.4
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula patula*	0.5
												Cerastium glomeratum	0.5
TT	X	5	X	7	3	7	2	n	3	2 - 3	1	*Cuscuta trifolii*	0.5
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	7.3
HR	x	5	x	5	7	7	7	n	5	3 - 4	3	*Leontodon autumnale*	4.4
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	5.8
HS	x	x	4	x	9	8	8	n	4	3 - 4	2	*Prunella vulgaris*	0.5
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	5.1
												Ranunculus acris	0.5
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	3.1
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	7.3
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	2.5
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.5
												Taraxacum officinale	3.1
OFB													**46.4**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

Similar outcomes following overseeding interventions have been reported in mountain and submontane grasslands in Romania and other European regions (Rotar et al., 2014; Török et al., 2011; Scotton, 2019).

The proportion of Poaceae increased markedly to 58.8%, confirming the high establishment capacity and competitive ability of the introduced species. *Dactylis glomerata* became the dominant species, reaching a substantial cover, while *Lolium perenne* also successfully established within the sward. According to Rotar et al. (2014) and Rotar et al. (2016), *Dactylis glomerata* exhibits strong adaptability to mountain environments, particularly when combined with mechanical management, due to its deep root system and high tolerance to low temperatures. The successful integration of *Lolium perenne* further contributed to sward densification and increased forage potential, as previously observed in experimental forage mixtures under

Romanian conditions (Rotar et al., 2014; Rotar et al., 2016).

Despite the strong dominance of Poaceae, Fabaceae species accounted for 4.5% of total cover, a value comparable to that of the control variant. This relatively low proportion of Fabaceae suggests that the aggressive growth of the introduced grasses limited the establishment and expansion of nitrogen-fixing species. Similar competitive interactions between sown grasses and Fabaceae have been reported in overseeded grasslands, where high grass density can suppress less competitive functional groups (Păcurar et al., 2012; Rotar et al., 2014; Scotton, 2019).

Plants from other botanical families represented 29.4% of the vegetation cover, indicating a reduction in overall floristic diversity compared to the previous variants. This decrease is a common consequence of overseeding with highly competitive forage species and reflects a trade-off between biodiversity conservation and forage productivity. According to Păcurar et al. (2014), Rotar et al. (2016) and Vaida et al. (2021), such shifts are typical for grasslands subjected to active improvement measures and must be carefully managed in high nature value (HNV) systems to avoid excessive biodiversity loss.

The absence of Cyperaceae and Juncaceae species in this variant indicates improved drainage conditions and reduced soil moisture, which favor productive grassland species. Similar ecological responses have been documented in grasslands improved through mechanical treatments and overseeding in the Apuseni Mountains (Morea et al., 2008; Păcurar et al., 2014).

Overall, the combined application of mulching and overseeding with *Dactylis glomerata* and *Lolium perenne* proved to be an effective strategy for rapidly increasing grass cover and forage potential. However, the observed reduction in floristic diversity highlights the need for careful consideration of management objectives, particularly in mountain grasslands with conservation value. These findings are consistent with previous studies emphasizing that overseeding enhances productivity but may alter species composition and ecological balance if not properly regulated (Păcurar et al., 2012; Rotar et al., 2014; Török et al., 2011) (Table 4).

In variant V5, where mulching was combined with overseeding using *Phleum pratense*, the floristic composition evolved toward a *Phleum pratense* grassland with *Agrostis capillaris*. This vegetation type reflects a successful establishment of the introduced species and represents an alternative restoration trajectory compared to the grassland dominated by *Dactylis glomerata*. Similar responses to overseeding with *Phleum pratense* have been reported in mountain grasslands characterized by cool climatic conditions and acidic soils, where this species shows good adaptability and persistence (Rotar et al., 2014; Samuil et al., 2025).

Table 4

Floristic composition of the *Dactylis glomerata* grassland with *Agrostis capillaris* and *Lolium perenne* and species sensitivity to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	13.8
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	29.0
												Lolium perenne	8.0
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	1.0
												Poa pratensis	0.5
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	6.5
POACEAE													**58.8**
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	1.0
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	2.0
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	1.5
FABACEAE													**4.5**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	3.1
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
												Alchemila vulgaris	3.1
-	-	-	-	-	-	-	-	-	-	-	-	*Campanula abietina*	0.5
												Cerastium glomeratum	0.5
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	2.0
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	2.0
TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	3.3
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	3.1
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	5.1
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	4.6
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.5
												Taraxacum officinale	1.0
OFB													**29.4**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

The proportion of Poaceae reached 58.8%, confirming the strong competitive ability of *Phleum pratense* under improved management conditions. The dominance of this species indicates favorable establishment conditions created by mulching, which reduced litter accumulation and enhanced seed–soil contact. According to Rotar et al. (2014) and Păcurar et al. (2012), *Phleum pratense* performs well in mountain environments when disturbance intensity is moderate and soil fertility is slightly improved.

Fabaceae species accounted for 6.8% of total cover, a higher value compared to variant V4, suggesting that *Phleum* *pratense* exerted a lower competitive pressure on nitrogen-fixing species than *Dactylis glomerata*. This observation is ecologically relevant, as the persistence of Fabaceae contributes to nutrient cycling and forage quality. Similar patterns were reported in grasslands overseeded with *Phleum pratense*, where a more balanced coexistence between grasses and legumes was observed (Păcurar et al., 2012; Rotar et al., 2016; Vaida et al., 2017).

Plants from other botanical families represented 27.8% of the vegetation cover, indicating a moderate reduction in floristic diversity compared to the control and mulched variants, but a level comparable to that observed in V4. According to Păcurar et al. (2014) and Vaida et al. (2021), such reductions are expected following active improvement measures and reflect a shift toward more productive grassland types. Nevertheless, the presence of a relatively diverse assemblage of accompanying species suggests that overseeding with *Phleum pratense* did not lead to excessive floristic simplification. The absence of Cyperaceae and Juncaceae species in this variant further supports the interpretation of improved soil aeration and reduced moisture excess, conditions favorable for productive mountain grasslands. Similar ecological responses were observed in grasslands improved through overseeding and fertilization in the Apuseni Mountains (Morea et al., 2008; Păcurar et al., 2014). Overall, mulching combined with overseeding using *Phleum pratense* proved to be an effective restoration measure, leading to high grass cover, a balanced presence of Fabaceae and a moderate reduction in species richness. Compared to overseeding with *Dactylis glomerata* and *Lolium perenne*, this variant appears more suitable for mountain grasslands where both forage productivity and biodiversity conservation are desired. These findings align with previous studies emphasizing the suitability of *Phleum pratense* for grassland restoration under cool and humid mountain conditions (Rotar et al., 2014; Păcurar et al., 2012; Samuil et al., 2025) (Table 5).

Table 5

Floristic composition of the *Phleum pratense* grassland with *Agrostis capillaris* and species sensitivity to ecological, agronomic and anthropogenic factors

B	**T**	**U**	**R**	**N**	**C**	**P**	**S**	**SO**	**VF**	**H**	**UR**	SPECIES	ADM %
HT	x	x	x	4	6	5	5	n	6	2 - 4	3	*Agrostis capillaris*	21.1
HT	x	5	x	6	8	4	6	n	9	3 – 4	3	*Dactylis glomerata*	0.5
HT	x	5	x	6	8	6	6	n	9	-	-	*Phleum pratense*	29.0
												Poa pratensis	1.0
HT	x	5	x	x	9	7	6	n	7	5	3	*Festuca rubra*	7.3
POACEAE													**58.8**
HT	7	2	8	6	3	4	3	n	6	2 - 3	3	*Trifolium pratense*	0.5
HT	x	4	7	4	6	4	4	n	7	2 - 4	3	*Lotus corniculatus*	5.8
ChRs	x	x	x	6	8	8	8	n	8	3 - 5	3	*Trifolium repens*	0.5
FABACEAE													**6.8**
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea millefolium*	4.4
												Cuscuta trifolii	0.5
ChRs	x	4	x	5	7	4	5	n	6	2 - 4	3	*Achillea distans*	0.5
												Cerastium glomeratum	0.5
HRs	x	6	3	2	3	3	3	n	4	2 - 3	1	*Hypericum maculatum*	1.5
HR	x	x	x	x	7	6	6	n	6	2 - 4	3	*Plantago lanceolata*	2.0

TRs	x	x	x	3	5	8	3	n	3	2 - 3	1	*Rhinanthus minor*	4.4
HS	x	4	4	x	4	5	5	n	1	2 - 4	2	*Stellaria graminea*	3.1
ChRs	x	4	x	6	7	6	6	n	4	2 - 4	2	*Veronica chamaedrys*	5.8
HT	5	x	x	6	4	2	2	n	4	2 - 3	1	*Viola canina*	2.5
HT	5	x	x	6	5	4	4	n	4	3 - 5	2	*Viola declinata*	0.5
												Taraxacum officinale	2.1
OFB													**27.8**

(ADM – average dominant abundance; B – life form; T – temperature; U – moisture; R – soil reaction; N – trophicity; C – mowing tolerance; P – grazing tolerance; S – trampling tolerance; VF – forage value; H – hemeroby; UR – urbanophily; SO – sozological category)

Overall, the applied restoration measures induced distinct floristic trajectories across the experimental variants. Mulching alone promoted gradual vegetation recovery while maintaining a relatively high level of floristic diversity. The combination of mulching and organic fertilization accelerated grassland recovery and enhanced forage potential without a marked loss of biodiversity. In contrast, active restoration through overseeding strongly increased grass dominance and productivity, with *Phleum pratense* showing a more balanced response between forage improvement and species conservation compared to *Dactylis glomerata*–based mixtures.

CONCLUSIONS

The abandoned grassland from the Păltiniș Experimental Station was characterized by a *Festuca rubra* grassland type, representative for oligotrophic mountain grasslands in Romania. The dominance of Poaceae and the low proportion of Fabaceae reflected reduced trophicity, limited forage value and the effects of long-term abandonment, confirming its suitability as a reference state for evaluating restoration measures.

Mulching applied as a single management intervention promoted favorable floristic changes, leading to the transition toward a *Festuca rubra – Agrostis capillaris* grassland type. This management practice reduced litter accumulation, improved light availability and supported a gradual increase in Fabaceae, demonstrating its effectiveness as a low-impact restoration measure for abandoned mountain grasslands.

The combination of mulching and organic fertilization resulted in a more advanced stage of grassland recovery, characterized by the establishment of an *Agrostis capillaris* grassland with *Festuca rubra*. This treatment enhanced grass dominance, increased the contribution of Fabaceae and maintained a high proportion of species from other botanical families, indicating an improvement in both ecological functionality and forage potential without a pronounced loss of biodiversity.

Active restoration through overseeding significantly altered floristic composition and grassland structure. Overseeding with *Dactylis glomerata* and *Lolium perenne* led to the rapid establishment of a highly productive grassland dominated by Poaceae, but was accompanied by a reduction in floristic diversity, highlighting a trade-off between forage productivity and biodiversity conservation.

In contrast, overseeding with *Phleum pratense* resulted in a grassland type characterized by high grass cover, a more balanced presence of Fabaceae and a moderate reduction in species richness. This variant appears more suitable for mountain grasslands where restoration objectives include both productivity improvement and the preservation of ecological value.

Overall, the results demonstrate that mulching, organic fertilization and overseeding are effective tools for the ecological restoration of degraded mountain grasslands, but their outcomes differ substantially depending on the intensity of intervention and species used. Low-impact measures favor gradual ecological recovery, while active overseeding accelerates productivity at the potential cost of reduced biodiversity. These findings provide valuable guidance for selecting restoration strategies adapted to the ecological conditions and management objectives of mountain grasslands in Romania.

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